Radio Broadcasting Technology

75 Years of Development in Australia

1923 – 1998

John F Ross AM

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1923 - 1998

John F Ross AM
Fellow The Institution of Engineers Australia.
Fellow The Institution of Radio and Electronics Engineers Australia.

History records no greater contribution to humanity than the discovery of radio.
The Radio Educator 1924.

Radio Broadcasting Technology
75 Years of Development In Australia 1923–1998

Also by the Author:
* Handbook for Radio Engineering Managers.
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PREFACE

This is not a book about disc jockeys, radio stars, talkback celebrities, quiz masters, long running serials or the social impact of broadcasting on society. Rather, it is about broadcasting technology and the people associated with its development and application in bringing the voices behind the microphone, recorded music and concerts into the homes of an entertainment starved nation.

When Harry Kauper, a well-known radio experimenter who later became Chief Engineer of 5CL and Technical Consultant for 3DB, returned to Australia after studying the introduction of broadcasting in Great Britain and the USA, before it started in Australia, he said, 'People there are badly bitten by the bug. Radio grips you. Once you become an experimenter or a listener-in, you cannot let it alone. The prospects of development are so great that the whole business is a long way past the nine days wonder stage. Wireless is part of people's lives. London suburbs are a forest of aerials, while in America, the shops are eight deep with people scrambling to buy radio sets.'

When broadcasting commenced in Australia following Government approval in July 1923, it had enormous impact. Life has not been the same since.

Broadcasting was sheer magic. People could vaguely understand how long distance communication by the telegraph or the telephone was possible — after all, the electric current travelled along a wire — but wireless, that was different. There was no visible interconnecting medium. A length of wire flung up into a tree or tied to a chimney or a rickety sapling and connected to a black box with valves which lit up like Aladdin's lamp, or a crystal set with a piece of thin wire like a cat's whisker and a lump of crystal could pluck out of the air, a voice or music from a nearby station or far away Perth, Sydney, Melbourne, Perth, Hobart, or Brisbane. Oh! the magic of it all.

The first person to construct a wireless set was the most popular person in the neighbourhood. People would flock to the house without invitation to 'listen-in' while the lady of the house kept the kettle boiling on the wood fired stove to satisfy the thirst of those who jammed into the lounge room to hear the program.

Sometimes the owner would do the right thing and turn up the volume enabling the whole neighbourhood to hear the program comprising a cacophony of voice, music, static, squeals and howls, all shockingly distorted.

Overnight, the nation became a land of budding scientists. Anyone who could construct or fix a wireless set was considered a genius and the thirst for knowledge was unquenchable. It is difficult for the present generation to imagine the passionate interest of people in those early days. In 1924, a magazine 'The South Australian Wireless and Radio Monthly' was launched. The demand for copies exceeded the wildest expectations. The publisher changed printing schedule to a weekly basis and halved the price to further increase demand.

Radio Clubs sprang up like mushrooms in a cow paddock after summer rains. Most Clubs met one night a month but many met on a weekly basis. They catered for the expert, the novice, the curious and even Dad who came along at the insistence of Junior. Hundreds of Clubs were established throughout the nation.

Radio Shops were established to supply complete receivers, parts and accessories and to advise on tuning-in procedures. In Adelaide alone, in mid 1925 there were some 150 Registered Dealers selling radio parts and fully assembled receivers.

It is now nearly 70 years since the start of the decade of the 1930's described by many as 'The Golden Age of Radio'. Although broadcasting had commenced in 1923, progress in the technology was slow for the first few years. It was the start of the 1930s which ushered in a period of phenomenal growth in the production and provision of broadcasting equipment and the development of the technology. Even though the nation was reeling from the effects of the Depression, radio was one of the few growth industries and only the outbreak of the Second World War put a halt to the expansion.

Today, Engineers and Technicians can call upon sophisticated high speed computers to handle complex radio design problems, provide transmitters and receivers of very high efficiency and reliability at levels undreamed of in the formative days of broadcasting and take advantage of all the benefits which have flowed on from space age technology. Some cynics may compare the work of early radio pioneers as being not far removed from stone age technology, but the debt we owe to those people who struggled with the immense technical problems of the day in bringing Broadcast Engineering to its present high stage of development and public acceptance is incalculable.

This book only scratches the surface of a complete recording of the history of 75 years of radio broadcasting technology in Australia, but it is hoped that it will entice others to follow on and cover in much more detail many of the exciting phases of the technology not detailed in this work.

John F Ross.

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A work of this nature would be impossible without the cooperation and assistance of a great many individuals and organisations. I am indebted to many colleagues, friends, businesses and those people in charge of public and private collections of historical material including photographs related to the technical aspects of broadcasting who so kindly provided material, help and encouragement and research.

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The material contained in this book has been based mainly on information and data supplied by a great many individuals, organisations, and recorded in technical publications, station records, reports, handbooks, and from my own involvement in broadcasting extending over many years from the 1930s. As Editor of 'The Broadcaster', I have relied heavily on material published in the magazine over a period of some 10 years, particularly in relation to the National Broadcasting Service facilities.

In some cases, in the absence of written records, I have had to rely on the memories of people who at various times had been involved in broadcasting technology including planning, design, consultancy, maintenance of studios and transmitters, the manufacturing industry, operation of radio servicing businesses, teaching, etc. I have endeavoured to check facts where possible, but some alert readers may find errors, particularly in relation to dates, equipment models, valve types and the like. If so, I seek your pardon.

Unfortunately, many of the technical details of early broadcasting equipment and components, and photographs are difficult to obtain today, as it was practice to dump handbooks, technical literature, brochures, circuit diagrams, photographs, logs etc on disposal of the equipment concerned. Also, some reports, instructions and lecture notes which have been located, have been shown to be at variance with documentation prepared by others, especially in the technical press by journalists. Under such circumstances, it is not easy to determine the true facts of the matter after so many years.

The inclusion or omission of any person or manufacturer or product should not be taken as recognition or otherwise of the relative importance in this history of broadcasting technology in Australia. Information on key people who played a significant role in the technology, and many businesses, is limited, and sadly, in the majority of cases, unavailable or non-existent.

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Chapter One

Planning the Broadcasting Service

The Concept of Broadcasting

Although Nikola Tesla, pioneer experimenter in high voltage, high frequency technology visualised a public broadcasting service, as early as 1904, it was David Sarnoff, a fellow American, who is credited with the concept of radio broadcasting as we know it today.

Sarnoff was an employee of the Marconi Wireless Company of America and became famous when he broke the news in 1912 of the sinking of the Titanic which sank on its maiden voyage, resulting in the loss of 1517 lives. He was a Wireless Operator with a local wireless station and for three days and nights without sleep, he remained on duty while a horrified world waited for him to decode the lists of survivors.

In the late autumn of 1915, while occupying the position of Traffic Manager with the company, he wrote a memorandum to his Vice-President concerning a plan which he called a Radio Music Box. In his plan, he projected an extraordinarily accurate preview of the domestic radio receiver as it was to emerge in the early 1920s.

The following extract from his submission is of interest:

'I have in mind a plan of development which would make radio a "household utility" in the same sense as the piano or phonograph. The idea is to bring music into the home by wireless.

While this has been tried in the past by wires, it has been a failure because wires do not lend themselves to this scheme. With radio, however, it would be entirely feasible.

For example, a radio telephone transmitter having a range of say 25 to 50 miles can be installed at a fixed point where the instrumental or vocal music or both are produced. The problem of transmitting music has already been solved in principle and therefore all receivers attuned to the transmitting wavelength should be capable of receiving such music. The receiver can be designed in the form of a simple "Radio Music Box" and arranged for several different wavelengths, which should be changeable with the throwing of a single switch or pressing of a single button.

The "Radio Music Box" can be supplied with amplifying tubes and a loudspeaking telephone, all of which can be neatly mounted in one box. The box can be placed on a table in the parlor or living room, the switch set accordingly and the music received. There should be no difficulty in receiving music perfectly when transmitted within a radius of 25 to 50 miles.

Within such a radius, there reside hundreds of thousands of families and as all can simultaneously receive from a single transmitter, there should be no question of obtaining sufficiently loud signals to make the performance enjoyable. The power of the transmitter can be made 5 kW if necessary, to cover even a short radius of 25 to 50 miles; thereby giving extra loud signals in the home if desired. The use of headphones would be obviated by this method. The development of a small loop antenna to go with the "Radio Music Box" would likewise solve the antenna problem.

The same principle can be extended to numerous other fields as, for example receiving lectures at home which can be made perfectly audible; also, events of national importance can be simultaneously announced and received. Baseball scores can be transmitted in the air by the use of one set installed at the Polo Grounds. The same would be true of other cities. This proposition would be especially interesting to farmers and others in outlying districts removed from cities. By the purchase of a "Radio Music Box" they could enjoy concerts, lectures, recitals, etc., which may be going on in the nearest city within their radius.'

To the Vice-President and others, the plan was incredulous and hairbrained. They promptly filed it away, and dealt with more pressing problems of the day.

However, Sarnoff raised the matter at every opportunity with his company and also outside, whenever he had the opportunity.

Experimenters were broadcasting music and speech and the public was becoming aware of a new form of entertainment which many considered might rival the entrenched phonograph.

One active experimenter was Frank Conrad of Pittsburgh, and a local Department store advertised wireless sets which could receive Conrad's broadcasts. The demand was beyond expectations. One of the major electrical firms in the USA, Westinghouse, saw that there were encouraging signs that broadcasting could become an important public service, so they applied for a licence to establish a transmitting station. They were allocated callsign KDKA. It broadcast bulletins about the Presidential election which was taking place at the time in November 1920, and started a craze which swept the country to become a new and major industry called broadcasting. Manufacturers who had made tentative steps towards the manufacture of home radio receivers were caught short. The demand was tremendous, and far exceeded the capacity of factories to meet it. Building simple crystal sets and one valve receivers became a national pastime.

The 'Radio Music Box' plan of David Sarnoff became a reality but unfortunately his own firm was left behind at the starting gate to supply the public demand because they failed to act sufficiently early to lead the field. Sarnoff's accurate forecast of sales included in his memorandum to justify the scheme, were realised when, in the three years 1922, 1923 and 1924 his company's sales of receivers exceeded $83 million. By that time, the organisation had become the giant Radio Corporation of America and in 1930, Sarnoff became its President.

The American experience had immediate repercussions throughout the world, and within a short time pressure was being exerted on the Commonwealth Government to have broadcasting introduced in Australia.

Early Planning Considerations

It was evident from overseas experience with broadcasting that the authorities in Australia needed to act quickly and to have a properly prepared plan if it was not to be a state of 'chaos of the ether' as happened in the USA. By the end of 1924, some 530 stations were in operation there. The reason for such astronomical growth was economic rather than development in the technology. The boom enticed business people and investors looking for a 'fast buck' to pour money into the establishment of broadcasting stations. The mortality rate was very high with the powerful pushing aside competition as it grappled to obtain a greater share of the listening market. During a three month period in 1923, about 120 stations ceased transmission and by mid 1924, 572 had closed down for various reasons. Even as late as 1939 when there were 660 stations in operation, 240 operated at a financial loss. As at January 1996, there were 11765 licensed radio broadcasting stations, including 4909 AM, 5306 FM and 1550 FM educational services. In addition, there were 78 short wave transmitters operating from 20 stations.

There was just as much rivalry between makers of domestic receivers as there was between the station promoters, and patent issues had become thorny problems. The large firms like Radio Corporation of America employed the best Patent Attorneys to protect their patents and made life difficult for small manufacturers.

Internal conflicts were unresolved and attempts by the government to apply external pressure failed. There were well over five million broadcast receivers in use and it was almost impossible to receive interference free reception from any one station. Everyone suffered — station operators, equipment manufacturers and, most of all, the listening public.

It was in this atmosphere that the authorities in Australia set about developing a plan for broadcasting to prevent the chaos that had been allowed to develop in the USA.

When Postmaster General Poynton took up his post on 21 December 1921, not a great deal of planning for a broadcasting service had been undertaken by his Department. People like Ernest Fisk of Amalgamated Wireless (Australasia) Ltd appeared to be putting pressure on the Government to adopt a scheme which would provide commercial advantage to the company. However, Poynton was not entirely satisfied that planning a broadcasting service by private enterprise was a good thing and asked the head of his Department to set about preparing a plan for consideration by Parliament.

Poynton was replaced as Postmaster General by William G Gibson on 9 February 1923 who supported the policy laid down by Poynton. However, interested citizens wanted a say in how a broadcasting service should be set up and run. Typical proposals included;

- People in rural areas were concerned that stations would be established only in the capital cities because of the high cost of establishing and running the stations. A plan suggested by a number of people in letters to the press was that 'powerful receiving stations be established in major country towns for the purpose of receiving programs off air from metropolitan based transmitters and for the programs to be rebroadcast locally using low power transmitters'.

The Mayor of Wingham near Taree on the mid north coast was a strong supporter of the idea. In February 1923 he called together a group of hand-picked residents of 'standing in the community' to plan a scheme to provide residents of Wingham and surrounding areas with a top quality broadcasting service using programs from a Sydney based station when it became available. The plan was to install the station on the 'town common' in the middle of the town.

Investigations by the group revealed that one local resident a Mr R C Cross of Farquhar Street, Wingham possessed a Licence to operate a receiver so could be called upon to operate the receiving station. However, they were unable to find any resident who possessed a Licence to operate a transmitter, so the scheme was abandoned.

The residents had to wait until January 1925 when B Class station 2HD began operation in Newcastle but because of the low power of the station, reception was not satisfactory. Signals from Sydney stations 2BL and 2FC were not much better.

- A man living in Port Augusta in South Australia wrote to Jim Malone, Chief Manager Telegraphs and Wireless of the Postmaster General's Department suggesting that as the Department controlled telegraph wires already linking major country towns throughout Australia, that broadcasting planners should consider putting the metropolitan station programs on these lines when not being used for telegraph purposes. Subscribers would only need a small audio amplifier and loudspeaker to enjoy the same programs as their city cousins.

It was suggested that the confidentiality of telegram messages would not be compromised as very few people could read Morse Code, especially at the speed sent by the skilled Post Office Telegraphists.

- A grazier living near Mildura in Victoria wrote to the Postmaster General suggesting that all work for planning the broadcasting service be stopped as the nation could not afford the huge cost involved.

He suggested that the Government should take advantage of the 'free programs' already circling the earth day and night from stations operating overseas, particularly in the USA.

The grazier's plan was for the Government to licence a person in each major town to receive these programs and retransmit them over low power local transmitters and charging listeners a fee for the use of receivers which could be rented only from the program provider.

The writer said his plan was practical as he had been listening to station KDKA in the USA since it has been carrying out experimental transmissions from the date of its official opening in November 1920 using a variety of receivers he had built himself.

He said that at the time of writing in 1922 there were at least 30 licensed broadcasting stations in the USA and it was possible to hear many hours of programs by selecting the right stations. He had logged at least 15 of the stations over a period of one week so there was always a useful signal available.

The receiver which performed best used two stages of RF amplification with transformer coupling, a carborundum crystal detector and three stages of audio amplification.

- A lady in Broken Hill suggested that the planners should consider allowing for a mobile station which would travel around the State using either trucks or the train to provide a service for country people for at least one week every year.

EARLY TECHNOLOGY

By the time the Government had agreed to the establishment of a broadcasting service in Australia, the technological aspects had reached an advanced stage. There were many skilled people experienced in Radio Engineering and there was a manufacturing base in the country capable of designing and constructing transmitters and receivers. A considerable amount of early work associated with wireless technology had been undertaken by experimenters in the Colonies before Federation on 1 January 1901 to establish the Commonwealth of Australia.

The first experiment in wireless appears to have been carried out by Professor Richard Threfall in New South Wales in 1888, the same year that the historic paper 'Electromagnetic Waves in Air and Their Reflections' was published by the German physicist Heinrich Hertz in May 1888. He undertook the experiments to test the fundamental hypotheses of Maxwell's theory. James Clerk Maxwell is credited by wireless historians as the discoverer in 1867 of the ether, a hypothetical medium which at the time, was believed to fill all space and to support the propagation of electromagnetic waves.

The announcement by Hertz in the existence of free electromagnetic waves created a sensation throughout the scientific world.

Professor Threfall repeated the experiment of Hertz in the Laboratory of the University of Sydney. Richard Threfall was appointed Professor of Physics in 1886 following work at Cambridge in the Cavendish Laboratory. By 1888, he had constructed the first physical laboratory in Australia. It was acknowledged to be as good as any other physical laboratory in the world at the time and made a profound impression on contemporaries such as William Bragg and Ernest Rutherford both of whom made significant contributions to the advancement of the technology in later years.

William Bragg was appointed Professor of the Chair of Mathematics and Physics at the University of Adelaide in 1886 after graduating from Cambridge as Third Wrangler in the Mathematical Tripos. He took a great interest in the work of Hertz and in the practical application of wireless following the granting of a patent to Guglielmo Marconi in 1896 for a system of wireless telegraphy. On 21 September 1897, he gave the first recorded public demonstration of the working of wireless telegraphy during a lecture program at the University of Adelaide. It was reported in considerable detail in the Adelaide press at the time. In July 1899, in association with Charles Todd, Postmaster General and Superintendent of Telegraphs, he established the first wireless telegraphy link between stations established in the grounds of the Adelaide Observatory and in a building on the sand hills at Henley Beach. Paper tapes are still in existence recording messages received during wireless telegraphy trials just prior to establishing the link. Spark transmitters and iron filing coherers were employed.

In the same period, experimental work was also being carried out in other Colonies, mainly with the assistance of the Post Office in those colonies. They included;

- Tests to a boat on the Swan River, Perth by Messrs Stevens, Knox, Phillips and Rosser in October 1899. All were Post Office employees.
- Work by Messrs Hallam, Medhurst and Bowden of the Post Office establishing contact between transmitting station on land and a boat on the Derwent River in 1900. Many other trials were undertaken including establishment of communication with visiting UK warships on 3 July 1901.
- Experimental work by Post Office Engineer Jenvey using a station at Red Bluff in 1901. He also established communication with the visiting UK warships in May 1901.
- Tests by Naval authorities in Brisbane in 1900 between a base at Kangaroo Point and HMCS Gayundah.

Before the start of the First World War, the Australian authorities had arranged for construction of a large network of Coast Radio Stations right around the Australian coastline and in the Papua-New Guinea area. With the exception of the Sydney and Perth station's equipment which was imported from Germany, equipment for all the others including transmitting and receiving equipment and aerial systems were manufactured in Sydney by the Maritime Wireless Company. The transmitting equipment employed circuitry developed by John Graeme Balsillie and known as the Balsillie or Commonwealth System.

Balsillie, a Queenslander by birth, was recruited in London in 1911 to become the Government's first 'wireless expert' with the title 'Engineer for Radiotelegraphy' in the Postmaster General's Department. At its peak, the Maritime Wireless Company under the control of Father Archibald Shaw, a former telegraphist in the PMG's Department employed 172 men and apprentices. The works closed in 1916.

The Balsillie System was said to be the first and only unidirectional impulse system in operation. It differed from the Marconi and other systems in that there were no oscillations in the discharge circuit. The transmitter was fundamentally a shock excitation transmitter with quenched gap employing air blast, and capacitor coupling between circuits. The original receiving system used galena crystals obtained from a mine in Western Australia.

During the War years, a consignment comprising 30 combinations of Audion and Ultra Audion valves were imported into Australia from USA. They were manufactured by the de Forest Radio Laboratories managed by Lee de Forest, inventor of the triode.

The Audion designated Type T had been first produced in early 1916, it was a single tungsten filament type and employed a tubular glass envelope with two leads protruding from each end. Earlier designs had used round glass envelopes. The Ultra Audion was also provided with a tubular envelope. The name meant that the valve was capable of producing oscillations when used with the de Forest 'Ultra Audion circuit'.

It is likely the units were used by the Royal Australian Navy for ship and shore installations. The USA Navy had large numbers of the units in service and reported favourably on their performance.

Interest in speech and music broadcasts was aroused soon after the War following the tremendous developments in radio technology during the War period and the availability of war surplus wireless equipment, particularly valves such as the R type from Europe and the Audiotron and Moorhead types from the USA. The Postmaster General's Department and private enterprises like Amalgamated Wireless (Australasia) Ltd became heavily involved in developing the technology for peace time application.

PUBLIC DEMONSTRATION OF BROADCASTING

Australia's first public demonstration of radio broadcasting took place in Sydney on 13 August 1919 as a result of the initiative of the Royal Society of New South Wales.

The Honorary Secretary of the 'Section of Industry' of the Royal Society of New South Wales, Mr R Greig-Smith DSc., authorised a publicity notice which announced:

'The following lecture and demonstration will be given in the Society's Hall, 5 Elizabeth Street on Wednesday August 13th, 1919 at 8 pm:

"Wireless Communication"
by Mr E T Fisk

Managing Director, Amalgamated Wireless (Australasia) Ltd.

The lecture will be illustrated with lantern slides.

Wireless telegraphy and telephony are of great importance to us industrially and we are glad to have been able to get Mr Fisk to tell us about the latest development.'

In reporting on the lecture, a press article was headed, 'Wireless Wizardry the Sydney Experiment'.

'The Sydney Morning Herald' reported:

'A remarkable experiment of wireless telephony was given with the aid of apparatus designed and manufactured in Sydney by the Amalgamated Wireless Company.

A gramophone was played into a wireless transmitter at the works at Clarence Street and the music was received on a few wires strung along the wall in the lecture room in Elizabeth Street. The music was clearly audible in all parts of the hall and the lecture was suitably closed with the audience standing while the National Anthem was played by wireless telephone.'

The transmitter employed a single Marconi Q type valve, which the operator ran with the anode fed with 240 volts DC — well above the recommended voltage — causing the anode to glow a bright cherry red colour, but the fragile valve gave its all, and the transmission was a success. The Q type valve was a receiving triode of tubular construction having small pointed contacts arranged at both ends and at the sides. This construction enabled a reduction in self capacity compared with the usual four pin socket used with most valves at the time. The valve had an unusually large anode for a receiving valve, and was a tight fit within the tubular glass envelope. The grid was of wire mesh material considerably longer than the anode.

The transmitter had been earlier designed and built by George Apperley, William Bostock and Eric Burbury of AWA's Technical Department to conduct ship-to-shore radio telephony tests.

The transmitting aerial employed for the broadcast was a simple T type construction 20 metres in length mounted on the roof of the AWA building, known as Wireless House.

The normal method of listening to wireless signals at the time was with headphones. However, these were not satisfactory for a public demonstration of broadcasting, so Fisk had a tinsmith build up 20 tin horns to surround Baldwin headphone receivers.

They were then strung along the ceiling of the Society's room. The Baldwin headphone was designed by Nathaniel Baldwin, a devout Mormon who discovered an entirely new method of moving the diaphragm with a driving rod. He made the diaphragm of mica. The sensitivity of the unit could be accounted for by the fact that the magnetic circuit was one of low reluctance; the armature of the magnet was under no strain until current passed through the receiver winding, hence giving greater deflection of the diaphragm. Also, the armature was acted upon at both ends, and since the flux was produced differentially like that in a polarised relay, the deflection for a given magnetising current was accordingly increased.

The Society later participated in another milestone in broadcasting when the Presidential Address was broadcast over 2FC on 7 May 1924. It was recorded in the Minutes of the Society to be the first occasion on which an address had been broadcast from a scientific society in Australia.

On 13 October 1920, members of Federal Parliament were provided with their first taste of broadcasting at an historic demonstration in Queens Hall, Melbourne. Prime Minister Hughes had asked Ernest Fisk to arrange the demonstration.

AWA had imported two Marconi manufactured 500 watt radio telephony transmitters for broadcast demonstration purposes and one was installed in the home of AWA's Melbourne Manager, Lionel Hooke at Middle Brighton and this transmitter was employed for the demonstration. It was the first broadcast by AWA of a live performance by an Artist. The Artist was Miss Hilda Walker, a winner of the Melba Scholarship. The same Baldwin earpieces and tin horns were used for the demonstration. The broadcast program was picked up by an AWA built receiver and an aerial mounted on the roof of the building.

Fisk as Managing Director of AWA was convinced that there was money to be made in broadcasting, particularly in the manufacture of transmitters and receivers, an area in which AWA was ideally placed, already having a strong Radio Engineering manufacturing base established.

In order to convince the public that broadcasting should be provided as a public service and to enlist support from the increasing number of businesses already selling radio parts and indeed, fully assembled receivers, Fisk sought approval from the PMG's Department to implement regular broadcasts in Melbourne using a 500 watt Marconi transmitter for transmission periods on a regular basis. Approval was granted for program transmission for periods of one hour duration one day per week for 'experimental purposes'.

Transmission commenced during January 1921 providing programs of vocal and recorded musical selections initially on a wavelength of 1100 metres (270 kHz) and later on 400 metres (750 kHz) using station callsign 3ME. The 'concerts' were provided using a carbon microphone placed in front of a gramophone loud-speaker when using records. The programs were first produced in AWA's office during daytime, and later from the residence of Sydney Newman at Canterbury every Monday evening.

Full details of the transmitter are not readily available but notes and sketches from the Radio Inspector's log following a visit to the station, indicate that it was a ½kW cabinet type radio telephony set manufactured by Marconi's Wireless Telegraph Company, Chelmsford in 1920 and designed for marine application. The transmitter comprised three valves including an MR1 half wave rectifier valve with ripple filter circuit and two MT4 type amplifier valves. The carbon microphone in series with a dry cell battery and primary of a step-up audio transformer fed audio frequency signals to the grid of a valve designated 'control' valve (modulator). These frequencies produced varying potential surges across a large choke, so varying the potential applied to the anode of the oscillating valve (RF output) in a typical Heising circuit arrangement.

The aerial circuit consisted of an aerial tuning inductor, a variometer and a fixed retroactor coil to which was coupled a grid circuit inductor. Two ammeters were provided. One measured the DC current in the RF output valve and the other measured the RF aerial current using an RF transformer coupled into the aerial tuning network.

The transmitter was designed for an operational range of 100 nautical miles (184 km) in daylight when fed into an aerial 30 m high and 70 m in length.

When operated on 400 metres (750 kHz), the Radio Inspector noted that the aerial current was 4 amperes with the aerial employed which was much smaller than that recommended by the manufacturer.

Radio Shops provided considerable publicity about the broadcasts and staff were hard pressed to meet demand. Some shops opened at night to set up receivers for prospective purchasers to listen to the broadcasts. Crystal sets outsold battery receivers by a ratio 4:1.

Service covered a large area with good reports being received from listeners across Bass Strait in Northern Tasmania, from a listener in Maryborough with a two valve locally built receiver, from a listener in Bendigo with a one valve receiver and a listener in Geelong with a crystal set. A Ship's Wireless Operator reported to Coast Radio Station Melbourne that he heard music being transmitted on a wavelength of about 1100 metres when the ship was off Lorne on way to Adelaide. He reported the matter to VIA the Coast Radio Station in Adelaide when he arrived at Port Adelaide. The news spread to local experimenters and two, Roy Cook 5AC and Fred Williamson 5AH both reported receiving the station when broadcasts were being conducted during evening hours.

This was the first time regular broadcasting had been undertaken for an extended period in the LF/MF bands using a commercially manufactured transmitter and may be considered as the starting point of broadcasting in Australia. However, it was not until late 1923 that broadcasting began with stations that were not considered to be 'experimental'. The long wavelength 1100 metres used by 3ME during its broadcasts was later allocated to 2FC Sydney when it began operation in 1923 using an AWA built 5000 watt transmitter while 2BL which began operation in the same month was allocated a medium wavelength.

Sydney Newman played a major role in these broadcasts. He had joined the AWA Engineering and Research staff in 1920 and in addition to involvement in broadcast experiments during 1921–22 was later associated with short wave telegraphy and telephony tests to England, New Zealand and Pacific Islands during the 1920–30s.

In 1922, AWA carried out further experimental test transmissions, but this time including both Melbourne and Sydney. The Sydney tests were from the old AWA building in Clarence Street and the factory in Knox Street, using both long wave and medium wave transmissions in order to make comparison between the two. Design of the technical facilities, including the 100 watt transmitter was carried out by Joe Reed who later became associated with the design and installation of the company's 5000 watt transmitters for A Class stations.

A makeshift studio lined with hessian was set up in a vacant room on top of the factory. Microphones were standard PMG's Department solid back carbon granule telephone types and a locally designed and constructed mixing unit enabled programs to be selected from several microphones placed at various locations in the studio catering for singer, piano (two) and violin.

Joe Reed was ably assisted by Alton Vipan in constructing and operating the studio facilities.

A great deal of experience was obtained during the trial broadcasts and was of great benefit when the company later took on responsibility for operation of the technical facilities for 2FC and 3LO. The mixing unit which was referred to as a fading box was one of the first such devices used anywhere in the world for using multiple microphones during a broadcast. The BBC did not begin to use mixers until 1925. Prior to the development of the mixer two microphones were placed back-to-back and connected in parallel.

On 31 March 1922, Her Majesty's Theatre in Melbourne was the venue of one of the first broadcasts of a live performance from a theatre. The program, intended mainly for convalescent ex-servicemen in the Anzac Hostel, Melbourne included a recital by a Russian pianist and a singing duet by Madge Elliot and Cyril Richard, and other performers.

This was followed by a demonstration in May to staff of the Melbourne 'Argus' newspaper with music being transmitted from the AWA office in Collins Street. Lionel Hooke made a speech to the staff outlining the possibilities of broadcasting in Australia and the press gave considerable coverage of the speech and the demonstration arrangement.

People in Sydney who had receivers were also entertained from another source in the form of concerts from the W H Paling and Co., Concert Hall. The programs were produced by Oswald Anderson who later became General Manager of 2FC from December 1923 until 1930. Technical aspects of the broadcasts were handled by Ray Allsop an experienced Radio Engineer. At the time, he was Technical Manager of New System Telephones Pty Ltd and was assisted by Basil Cooke a well-known Amateur broadcaster with his station 2DJ at Northbridge. The programs were broadcast regularly from February 1923 until 1 August 1923 when the station closed because new broadcasting Regulations came into force at that date. The 10 watt transmitter used for the broadcasts was owned by New System Telephones Pty Ltd and operated on 215 metres in accordance with the temporary permit granted by the PMG's Department. The transmitter 2ZH, was installed in a room on the 6th floor of Paling's Building with the aerial being erected on the roof top. Equipment in the Concert Hall included an His Master's Voice Gramola, an Autotone Player Piano, an Electric Behning Art-echo Reproducing Player Piano and a parabolic reflector type carbon microphone.

In Adelaide, The South Australian Radio Company with station 5AB carried out a series of program transmissions on a regular basis with transmissions taking place in the medium wave band. The operating wavelength was 340 metres (888 kHz) and the transmitter was rated at 20 watts. The first major broadcast was on 5 April 1924 when the State election results were broadcast. The transmitter was located in Salisbury Chambers in King William Street and it fed a T type aerial on the building roof top, with a counterpoise.

The Manager of the Company, Bill Smallacombe, announced the results as they came to hand with music being played as fill-in. One of the many receivers tuned to the broadcasts in the city was located in the Theatre Royal Building in Hindley Street where a packed audience listened to the broadcast. Loudspeakers were installed outside the building to cater for those who could not be seated in the Building. It was estimated by the press that well over 4000 people assembled in Hindley Street to listen. The broadcast was received by many country listeners as far north as Bute on Yorke Peninsula and at Mount Gambier in the south east.

AMATEUR BROADCASTERS

Experimental broadcasts were also undertaken by many Amateurs in the 200 metre band in the 1920s. Magazines such as Listener-In and some newspapers published programs of leading experimenters. 'Concerts', as the broadcasts were called at the time, grew in number and attractiveness as resourceful Operators improved their facilities and techniques. Very few listeners thought seriously of the quality of the speech or music being produced at the output of their receivers. The novelty and wonder of hearing a voice or music in headphones with a crystal set or with a cumbersome horn loudspeaker and battery receiver was sufficient appeal. Most broadcasters played records with the program being interspersed with plentiful 'hellos' and comments on technical aspects of the transmitter, the modulation system, microphone type, aerial system etc.

One enterprising operator, Mr J W Hambly-Clark of Adelaide, cut his own Edison type cylinders as he played violin solos and broadcast these from his station 5AA by placing a candlestick carbon microphone down the throat of the long phonograph hornspeaker. The up and down movements of the speaker were evident in the output, but he had a great following of dedicated listeners who appreciated his efforts.

Some well-known operators maintained their transmitter power at about 25 watts DC input into the final stage, while 7 to 15 watts was also popular with many others. The aerial systems were, as a general rule very inefficient at the operating wavelength and in some cases would have produced only a few watts RF as radiated power.

Most later transmitters were crystal controlled, but those which did not employ a crystal had the oscillator until isolated from the power amplifier by a buffer stage. However, this was not always the case as witnessed by some of the experimental broadcast transmitters which were on display in the Adelaide Telecommunications Museum when it was located in Electra House in Adelaide.

One of the earliest attempts by an Amateur to provide a regular experimental broadcast service was made by Charles Maclurcan with his station 2CM situated at Strathfield, Sydney. From 1922 until early 1924 he provided a variety of programs varying in duration from one hour to one and a half hours during Sunday evenings, usually commencing transmission about 7.30 pm. Transmissions were conducted initially on 1400 metres (214 kHz). Maclurcan had a number of transmitters at various stages of construction, modification and power output for his wide ranging experimental activities. The experimental concert broadcasts during 1923 were conducted on a transmitter tuned to 388 metres (773 kHz). He also conducted transmissions on short waves with low power transmission being a feature of his experimental work.

Two aerial systems were available at his residence. One was a centre fed cage dipole supported by a single mast at the centre and the other located on a nearby block was a 30 m cage type supported by two 24 m wooden masts.

Even though broadcasting on 388 metres at relatively low power, reports of reception were received from all the eastern States and also New Zealand.

In February 1923, Miss Josie Melville, a musical comedy star broadcast from 2CM and became the first Professional Artist to broadcast in Australia.

Programs were regularly advertised in the Evening News.

Joe Reed, an Engineer with the Postmaster General's Department Radio Service, and later with Amalgamated Wireless (Australasia) Ltd assisted Maclurcan with some important design and construction aspects of the transmitter employed for broadcasting purposes, particularly on improvements to the transmitter modulation and high voltage systems.

In building the high voltage transformer Reed used the shell method of construction using laminations cut with garden shears from black iron stove flues used with wood fired kitchen stoves at the time. The laminations were held together by a small bolt placed at each corner with an insulating bush. The secondary winding consisted of several sections connected in series. The HT secondary voltage was 1200 volts. About $3\frac{1}{4}$ pounds of No 28 B&S gauge wire was used for the secondary. The core dimensions were four inches by three inches with a core cross section of $1\frac{3}{4}$ inches square.

Reed and Maclurcan devoted a lot of time to the design and construction of the filter circuit in order to reduce hum to a very low level. They decided on a choke coil of 50 henries and capacitor of 0.02 MFD. The conductor size was No 24 B&S gauge wound on a core of dimensions four inches by three inches and core cross section of two inches square. An air gap of $\frac{3}{8}$ inch was provided to keep the iron flux to an acceptable level. The capacitor was made of glass plates and tin foil. Twenty three glass plates and tin foil $6\frac{1}{2}$ inch by $8\frac{1}{2}$ inch were used.

While Reed was in Melbourne with the PMG's Department, he collaborated with Maclurcan in Sydney on medium wave transmission tests by using a radio telephony transmitter owned by the Department.

One broadcast of particular interest was undertaken by the SA Division of the Wireless Institute of Australia on the occasion of the First Social and Radio Dance held at the Royal Institution for the Blind Hall, North Adelaide on Thursday 28 June 1923. It was one of the earliest occasions in Australia that music for dancing was supplied per medium of radio. It was reported in the press at the time, that the Hall was so packed that it was difficult for the dancers to move.

The music for the dance was transmitted from Hal Austin's station VK5BN located at Norwood. Austin was a regular broadcaster on 220 metres using a transmitter of 100 watt input to the final stage and feeding an inverted L aerial 16 metres high. The receiver at the Hall consisted of a three valve receiver feeding a two valve power amplifier. Large horn loudspeakers provided by Harris Scarfe Radio Department were distributed around the Hall. The equipment was operated by well-known experimenters Harry Kauper and Lance Jones.

In welcoming the guests Mr J W Hambley-Clark who had been President of the WIA since its formation in 1919 said:

'We are all individually honoured by being participants in an historic event of the first importance.

In the history of South Australia there have been many proud moments, for example, the first mail route, the first tramcar, the first train, the first telegraph wire, the first telephone, and these are each indelibly recorded in the archives of the State and pointed to with interest and pride as the milestones of progress. But all these achievements had been in use in the world before their achievement here.

This milestone, a public wireless broadcasting demonstration under official recognition, assumes Gargantuan dimensions, for while eclipsing in wonder the relative scientific importance of many other things, it comes here almost simultaneously with its appearance in the rest of the world, showing that this State is abreast of the times and has a place in the vanguard of progress.

The wonder of wireless broadcasting is that music, speeches etc, made anywhere in the world may be heard by us in the same fullness as though we were at its source. Time and space are annihilated. The voices of those we love may come to us from afar as though by spiritualistic energy, without its indefinite and cloudy trickery. As if by supernatural energy, just through the great void are the antipodes united.

The world knows nothing more wonderful at the present moment, and we are here at the first public official demonstration, and we will dance to music coming to us through the skies. The services of many have been generously given, without which the demonstration would have been impossible.

Now we will listen to a selection and then dance to music from the skies.'

In Victoria, the commissioning of 3AR in Melbourne on Australia Day 1924, by Associated Radio Company fired up enthusiasm of country people to have part of the action of home entertainment using the new medium. People in Bendigo were amongst the first to be able to tune into a local broadcast when the Bendigo Manager of New System Telephones Pty Ltd, H J Tippett using callsign 3HT, broadcast a program from the company's office in Bull Street on 3 March 1924.

The program consisted of music from records played on an Edison Diamond Disc Gramophone loaned by Messrs Paton and Co., together with vocal and instrumental numbers provided by talented Bendigonians. Mr A M Bush a Bendigo professional man who lived on the outskirts of the town in Brougham Street, and who also operated an experimental station, reported thus:

'The concert was beautiful. It was tip top and we could hear every word. The articulation was perfect. We were delighted.'

Unfortunately, the people of Bendigo had to wait until 1931 before a local full-time station was established in the town.

The 1924 broadcast was not the first time that Bendigo had featured in a broadcast. As early as 1922, when Prime Minister Billy Hughes gave a speech in Bendigo the speech was broadcast to an outside audience. It was probably the first speech broadcast by a politician in Australia.

Station 4CM licensed in 1919 to Dr Val McDowall and operated jointly with Tom Elliott who constructed the station was the first station in Queensland to transmit regular speech and music programs using records and live performances.

The station was located on the 3rd Floor of Preston House, Queen Street, Brisbane where Dr McDowall had his medical practice.

A brass plaque in the building foyer commemorated the event.

Broadcast transmissions began in February 1921 on 800 metres with 20 watts into a T type aerial installed on the building roof top. The transmitter comprised two UV202 valves in the modulator stage and two UV202 types in the oscillator stage. Filaments were heated by accumulators, while 500 volts HT was provided by a motor-generator unit. Studio facilities included a Magnavox Speaking Microphone fed directly into the transmitter without any preliminary amplification. Concerts which included vocal and instrumental concerts and records were broadcast for two hours every Sunday evening for two years. Many outside broadcasts also formed part of the programs.

The 800 metre broadcasts ceased at the end of 1922 and the station converted to experimental work mainly on short waves.

Following considerable upgrading work, the station recommenced broadcasting with tri-weekly concerts on 7 December 1924 financed by Brisbane Radio Dealers. The studio located in T & G Building Albert Street was connected by Post Office cable circuits to Tivoli Theatre, Trocadero Dansant and the transmitter. Broadcasts continued until 25 February 1925 when financial support by the Brisbane Radio Dealers was discontinued.

There is no doubt that the popularity of broadcasting would have taken much longer to develop after the establishment of the official stations from late 1923 if it had not been for the activities of the Amateur broadcasters.

Even before the commissioning of the major broadcasting stations, there were Radio Shops selling radio parts, imported receivers and some firms such as Newton, McLaren Ltd, of Adelaide began local manufacture of receivers for commercial sale. Their first receiver was sold to a Doctor in Gawler who listened to Amateur broadcasters in Adelaide, some three years before 5CL began service.

Magazines describing receiver circuits were snapped up by eager radio enthusiasts as soon as the magazines rolled off the presses. Newspapers also carried advertisements by dealers, photographs of receivers and circuit descriptions. Radio Clubs began to appear in the suburbs and it was in this atmosphere that people prepared for the introduction of broadcasting by the licensed entrepreneurs.

Progress in experimental broadcasting by the Amateurs was dramatic. The number of transmitters operating in the 200 metre band increased rapidly and to minimise interference problems, leading Amateurs transmitted on a co-operative roster basis.

Typical of the arrangements was the roster for leading Amateurs in the Adelaide area published in 'The Saturday Journal' of 26 April 1924:

- Lance Jones, Westbourne Park (5BQ), 220 metres, Sunday 8.30 pm to 9.30 pm.
- Ray Snoswell, Exeter (5AD), 250 metres, Monday, Wednesday and Friday, 7.30 pm to 10.00 pm.
- Roy Buckerfield, Parkside (5DA), 170 metres, Tuesday, Wednesday and Thursday, 7.00 pm to 10.00 pm.
- Fred Williamson, Kent Town (5AH), 190 metres, Tuesday 8.00 pm to 8.30 pm.
- Henry Lloyd, College Town (5AI), Thursday 8.00 pm to 8.30 pm.
- S.A. Broadcasting Co., (5AB), every evening except Friday, 8.00 pm to 10.00 pm.
- St Peters College (5DO), 265 metres, Saturday, Tuesday, Wednesday, 7.00 pm to 9.30 pm and Sunday 10.00 am to 1.00 pm.

In Brisbane during mid 1930, the following Amateur broadcasters were active:

- Tom Starkie, Toombul, (4NW), 249.9 metres, nightly and weekends.
- Pat Golden, Wynnum, (4PG), 245.8 metres, weekends.
- Wooloowin Radio Club, (4WN), 241.8 metres, Thursday and Sunday.
- Cec Morris, Rosalie, (4LW), 238 metres, nightly and weekends.
- George Hams, Northgate, (4GW), 234.2 metres, nightly.
- Harold Walsh, Hamilton, (4HW), 230.6 metres, nightly and weekends.
- Bob Browne, Toowong, (4RB), 227.1 metres, nightly and weekends.
- G Oxlade, Newmarket, (4GO), 223.7 metres, nightly and weekends.
- Bruce Munro, Hawthorne, (4AL), 220.4 metres, nightly.
- Frank Nolan Spring Hill, (4JU) 217.3 metres, weekends.
- Cliff Gold, Hill End, (4CG), 214.2 metres, weekends.
- Bill Young, West End, (4WA) 202.6 metres, nightly.

When the officially approved stations began operation, the Government was concerned about the activities of the Amateur experimenters and following decisions made at the International Radio Conference in Washington in 1927, it gave consideration to the removal of the experimental broadcasters from the 200 metre band. However, the Amateurs had built up a strong following of listeners and as a result of persistent representations from listener's groups and the Wireless Institute of Australia, the experimenters were allowed to continue broadcasting musical programs on Sunday mornings before the A Class and B Class stations came on air, and after about 10.00 pm when the A class and B Class stations closed down. Although the number of Amateur experimental stations operating in the 200 metre band declined over the years, those that provided regular programs had many supporters. The arrangement continued until about the start of the Second World War when all experimental stations were compulsorily closed down. The privilege was never restored.

A great many experimenters were involved in the 200 metre broadcasts and very few of them foresaw the immense strides that would be made in broadcasting technology and program presentation techniques in only a few years.

One of the best known long term experimental broadcasters was Vic Coombe of Adelaide who operated 5WS which belonged to the West Suburban Radio Club. The Club was formed in 1924 and the voice of Vic Coombe, who was an invalid, conducted the programs from his bed. It was known to many people with hundreds of letters being received each month from all parts of Australia and New Zealand.

The early A5WS 10 watt transmitter operated on 245.8 metres and used a shunt fed Hartley oscillator circuit with a UX210 valve. The modulator employed a UX210 valve in a Heising circuit arrangement. The station had several microphones including a standard candle stick carbon type, a special cigar box type and one modelled on the WE microphone used at the A Class station.

Transmissions from 5WS were conducted regularly every Sunday morning and after close down of the local A Class and B Class stations. Mr Coombe was in possession of a library of over 1500 records and had access to thousands more from supporters. The equipment was well constructed and maintained by Club members, many of whom were qualified Radio Engineers. In the 1930s when VK5WS was still active, the accessories in use such as amplifiers, pick-ups, microphones, measuring equipment etc., compared favourably with facilities in use at the B Class stations.

In May 1930, in response to numerous requests from listeners for extended week-day and Sunday transmissions, permission was sought to establish a B Class station. Supporters had guaranteed finance for the establishment of new facilities including a 100 watt transmitter and a new aerial but the authorities would not grant a licence. The reason given was that there was a shortage of frequencies. At the time, the stations in operation in Adelaide were 5CL, 5DN, 5KA and 5AD. Applications were lodged again at various times until the late 1930s but without success.

The situation with regard to Amateur broadcasts was similar in the other States. A short listing of active broadcasters in the early 1920s includes:

- Queensland.
  4CM, Dr Val McDowall and Tom Elliott; 4EL, Eric Lake; 4FK, Vern Kenna; 4LW, Cec Morris; 4CG, Cliff Gold; 4EG, Ted Gold; 4PW, Percy Wood; 4XN, Eric Nissen; 4JU, Frank Nolan and many others.
- Western Australia.
  6AG, Walter Coxon; 6AM, Peter Kennedy; 6BN, A E Stevens and others.
- Tasmania.
  7AG, J C Milne; 7BP, J C McMillan and others.
- Victoria.
  3BM, Howard Kingsley Love; 3BQ, Max Howden; 3DP, N Culliver; 3MP, Stan Hosken; 3SW, S W Gadsden; 3UZ, Oliver J Nilsen; 3ZN, Morris Israel; and others.
- New South Wales.
  2BB, E B Crocker; 2CM, Charles Maclurcan; 2DS, Jack Davis; 2HP, William Maclardy; 2JM, R C Marsden; 2KC, R H Fry; 2LO, Len Schultz; 2YG, Ray Allsop; 2UW, Otto Sandel; 2MO, Marcus Oliver and others.

Many of the Radio Clubs also broadcast programs in the 200/300/400 metre bands.

The Amateurs and radio businesses frequently combined to publicise broadcasting as an entertainment medium and to demonstrate the technology. Typical was a demonstration at North Shore Church of England Grammar School, North Sydney on 6 October 1923 on the occasion of the School's annual garden fete. The demonstration was a joint effort by Messrs Wireless Supplies Ltd with Mr Evans of the company operating the receiving equipment at the School and R C Marsden, later of David Jones Radio Department transmitting recorded music from his station 2JM at Edgecliffe. An aerial was erected in the School grounds and connected to a two valve Radak battery operated receiver and Western Electric loudspeaker in the school library. The demonstration attracted a large and interested audience. Students and visitors were encouraged to operate the receiver and to tune-in other experimental stations which were broadcasting at the time. Mr Marsden was also well known as one of the founders of Wireless Weekly which began publication on 4 August 1922.

The radio Amateurs or experimenters made a major contribution to the development of broadcasting. In fact, it was these early experimenters who founded the science we know today as Radio Technology.

The debt modern society owes to these people cannot be quantified. The introduction of broadcasting as a public service was made so much easier by the work of this dedicated group of Technologists.

In the early 1920s, the fact that Radio Broadcasting was already a practical science having graduated from spark transmitters, magnetic detectors and the mysteries of Morse Code, that there was in existence people skilled in Radio Technology and that the public had already been initiated into the reception of broadcast programs in the home as a result of the experimental programs transmitted in the 200/300 400 metre bands ensured that once officialdom had approved the establishment of broadcasting as a public service, it would have a flying start. It grew quickly as an entertainment medium as experience was gained in the manufacture and operation of high power transmitters, the mass production of receivers for the home and improved programming techniques and services. Today, 75 years on, the broadcasting industry has been firmly established with technical and programming people being trained specifically for the industry, and now the present generation of licensed Amateurs who in March 1993 numbered some 18222 can look back with a great deal of satisfaction on the contribution the early pioneers made to broadcasting while they themselves become absorbed with visions for the future employment of Radio Technology.

THE FIRST PROPOSAL

The first proposal for a systematic broadcasting service was submitted by Ernest Fisk on behalf of Amalgamated Wireless (Australasia) Ltd on 27 July 1922. The submission to Prime Minister Hughes proposed an Australia wide broadcasting service in the form of radio concerts employing a limited number of high power broadcast transmitters designed and manufactured in Australia. Following encouragement from the Government, the proposal was followed on 1 November of the same year, with a formal application for the establishment of stations in all States.

Fisk's plan would have given AWA a monopoly of broadcasting in Australia and created tremendous business opportunities for the company. The company would have been the sole provider of transmitters and broadcast receivers in the country. The proposal called for the banning of the importation of broadcast transmitters and receivers, with listeners being required to hire receivers from the company in order to pay for the cost of operating the service.

The Government gave its endorsement for the proposal except for the importation restrictions, in November 1922 but the proposal did not proceed.

Other organisations saw the advantages of early involvement in the broadcasting industry and wanted to be part of it.

Some were of the opinion that commercial interests should provide the service while others considered it a matter for the Government, as it already had a monopoly in other wireless fields. The Government was only lukewarm to the idea but rather than make a firm decision itself, decided to bring together interested parties to determine how best a public service could be inaugurated. However, to ensure that it had the power to control broadcasting, the Government amended the Wireless Telegraphy Act 1905, to include a new category of licences-Broadcasting Stations.

THE SEALED SET SCHEME

On 24 May 1923, Postmaster General Gibson convened a Conference in the Postal Institute Hall, Melbourne where about 70 people from Wireless Institutes, Radio Associations, the Press and other bodies and individuals who had an interest in the establishment of a broadcasting service in Australia, attended.

The Conference was opened at 2.30 pm with the Government being represented by Postmaster General the Hon. William Gibson, M.P., Justinian Oxenham, Secretary PMG's Department and Jim Malone, Chief Manager, Telegraphs and Wireless of the PMG's Department.

Organisations, representatives and individuals included; Amalgamated Wireless (Australasia) Ltd, Messrs Ernest Fisk, Lionel Hooke and Arthur McDonald; Argus Newspaper, Alfred Holtz; Australian General Electric, C G Seely; Australian Press Association, P Hull; H S Beattie; Bonham's Press Agency, W H Sweeting; British General Electric Co., Messrs Hirst and Mattes; A Brown; Burgin Electric Co., Oswald Mingay; Chambers and Co., J A Chambers; J T Collas; Collingwood Technical School, Mr Slater; Continental Radio and Electrical Co., John Taylor; Cumming and Co., W Cumming; Edison Swan Electric Co., S Rolls and Mr Just; Electrical Federation, Mr Stevens; Farmer and Co., S E Wilson; Faulding and Co., and South Australian interests, Lance Jones; Herald and Weekly Times, R E Williams; Hordern A and Sons, Mr Pritchard; Horrocks, Roxburge and Co., Mr Hanna; Java-Sydney Trading Co., the Manager; Lawrence and Hanson, Stanley Salmon; Donald Macdonald; Wireless Weekly Newspaper, William J Maclardy; Homecrafts Ltd, E T Muir; Metropolitan Vickers Co Ltd, Messrs Maling and Wilson; Mutual Stores, R E Chubb; Myers Ltd, H Bennett; New System Telephones, Messrs E Holloway and H Butler; Milson C and Co., Messrs N J Boyd and Cromie; Norris and Skelly, C W Norris; Prell and Co., H Prell; Radio Company Ltd, Messrs Basil Cooke and van Gelder; Radio Communications Co., Walter Sweeney; Ramsay Sharp and Co Ltd, H Francis; Reuters Ltd, Mr Barraclough; Richardson, Orr and Co., N Nathan; Riverina Wireless Co., Mr Jewell; George Taylor; Thwaites E J, Messrs E J Thwaites and H U Alcock; Warburton, Franke Ltd, Mr Montgomery; Watson and Sons, W King Witt; Wertheim H Pty Ltd, Herbert Weitheim; Western Electric Co., Richard Hungerford; White O, O White; Wiles H and Co., Harry Wiles; Wireless Institute, Messrs Tom Court and H Maddick and others.

It is of interest that five of the delegates represented the Press, only one of which had a direct involvement in the technology. The others were concerned that broadcasting stations would pirate their news without paying for it.

Mr Gibson told the Conference that the Government was anxious to see broadcasting inaugurated in Australia and he desired to ascertain the wishes of the people and groups who would be responsible for running and supporting the service.

The Minister emphasised the importance of having broadcasting services placed under a proper system of control and referred to lessons to be learned from the American and British experiences. He suggested that the Conference put forward a scheme for consideration by Cabinet which would provide Australia with a broadcasting system superior to any system in use elsewhere in the world.

Mr Gibson referred to some of the overseas problems where broadcasting was already in operation and in particular mentioned that there were eight broadcasting companies then in operation in Great Britain and more than 500 in the United States of America where the number of problems needing immediate solution were enormous.

In his conclusion, the Minister said that matters to which the Conference should pay particular attention included the general control of wireless, the wavelengths to be employed, hours of transmission, licences for transmitting stations and for home receivers, inspection of the licences and also subjects to be included in the broadcast program such as market reports, news, weather reports, sports, lectures, church services, political speeches and others. The Conference elected George A Taylor of Queensland as Chairman. Mr Taylor had recently returned from an extensive overseas trip in which he made a detailed study of broadcasting developments. In January 1923 he had founded the Association for Developing Wireless in Australia, New Zealand and Fiji. The Association was keen to see the early establishment of broadcasting in Australia and approached the Postmaster General to call a conference of wireless experts 'in order that suitable broadcasting regulations might be devised to avoid the difficulties and mistakes of older worlds'. Taylor was concerned, as was also the Postmaster General that the powerful AWA organisation which was already solidly entrenched in the radiocommunication field should not be allowed to monopolise the broadcasting system.

As Chairman, Mr Taylor called on Ernest Fisk of AWA to deliver the first address. Fisk, like Taylor, had recently returned from a visit abroad to study broadcasting developments. Because of his position in the radio industry, he was a dominant figure at the Conference.

Fisk delivered a lengthy speech in which he put forward a proposition which became known as the Sealed Set Scheme. Although the meeting included representatives from radio trades, electrical firms, manufacturers, experimenters, newspapers and other interests, no other delegate provided a proposal which received the support given to Fisk's scheme. Such was Fisk's influence that a Committee was appointed to draft regulations along the lines of the scheme proposed.

The principal issues raised by Fisk in his proposal included the following:

- The cost of broadcasting is proportional to the area to be served, and also to the quality of the entertainment provided.
- A broadcasting system which catered only for people residing in the major cities, and provided no service, or indifferent service, to people in rural areas would not be acceptable to the Australian people.

- Because of the vast area of Australia, a small number of very high power and a large number of low power stations would be required to provide an acceptable service.
- If Australia followed the USA pattern of providing a very large number of small stations to cover the entire continent, the cost of providing programs to such stations all over the country would be prohibitive.
- The population of Australia was one tenth the population of Great Britain and one twentieth the population of the United States, so a broadcasting system would have to be devised to suit our own particular requirements, and not simply copy those already established overseas.
- If the cost of providing and operating a broadcasting station was to be paid for solely from the sale of domestic receivers, very few stations would be established, and those would only be of low power. When the boom in the sale of receivers disappeared, and no further revenue was forthcoming to the station operators, the public would be left with no service, and the costly receivers would be useless.
- The best and apparently the only method of providing an acceptable broadcasting service, was to provide for such arrangements that competitive services could be established, using a combination of both high and low power transmitting stations on appropriate wavelengths, and so financed that continuous income revenue could be assured so long as the station operators satisfied the listening public requirements.

Although one of the Committee's recommendations was that the regulations be administered by a Board comprising representatives of dealers, manufacturers, the press, broadcasting companies and the Government, the Postmaster General rejected the idea. In the scheme proposed, people who wished to listen to broadcasting stations would be required to pay a Government fee plus subscription charge to one or more broadcasting companies of their choice. The sets were to be sealed by the Post Office to receive only programs to which the owner had subscribed.

Even though the Government was keen to obtain the views of industry and the public on a broadcasting service, it intended to keep a tight rein on its introduction using the Wireless Telegraphy Act, which it had inherited since 1905, although broadcasting was not even a dream in Australia when the Act became law.

There was a minority of delegates, however, who considered that the air waves were a free public resource and it was for the broadcasting stations to meet all costs for their operation as was the situation in the USA at the time.

The principle of the Sealed Set Scheme was certainly not new. It had been tried in Germany in 1923 and later in Japan when broadcasting was introduced in those countries.

Receivers manufactured in Germany were designed to receive only the local broadcasting station. The tuning arrangement was sealed and out of sight. It was unlawful for owners to tamper with it. The fee charged depended upon the number of valves employed in the receiver. The effect of this led to the development of multiple type valves to reduce the fee payable. The Loewe company was a leader in the field, and brought out the 2-in-1 and the 3-in-1 valves which contained in a single envelope, not only the elements of 2 or 3 valves, but also the interconnecting stage networks of resistors and capacitors.

A similar scheme was implemented in Japan at the time broadcasting commenced there although the idea had been proposed many years earlier. Only one transmitting station was allowed in an area of approximately 160 km radius. Stations were not allowed to advertise, and the financial source was derived from subscriptions from equipment manufacturers and receivers' fees collected from listeners. Private installation of receivers was allowed on condition that such receiving equipment would comprise 'those capable of receiving only the wavelength for which they were made'. The decision to adopt the scheme was made in pursuance of the view that it would eliminate danger of infringing upon the security of public and military communications and that there was a need for preventing reception of 'foreign radio waves'. The first station was commissioned in Tokyo on 22 March 1925 with a 200 watt transmitter. It was estimated that 80 % of receivers were crystal sets.

Because of the unexpected rapid increase in the number of listeners and diversification of types of receivers soon after commencement of broadcasting, the Japanese receiver scheme was abandoned. Policing of the arrangement was made difficult because some 50,000 Amateur experimenters had constructed their own receivers with variable tuning.

On return from the Melbourne Conference, Lance Jones, Manager Adelaide Radio Company, and who represented 'South Australian interests' at the Conference, undertook development work with the aim of providing an alternative to the Sealed Set Scheme. He was of the opinion that the annual fee charging arrangement was unfair and should be based on a 'pay-as-you-listen' arrangement. By this way, a listener who used the receiver for only short periods would not pay as much as one who operated a receiver for long periods during program transmissions.

He had his workshop staff construct a receiver tunable across the band and fitted with a coin operated switch box connected in series with the B battery supply. The switch, a spring loaded type was wound up manually as required from time to time and insertion of a coin caused a contact wheel to rotate slowly. After one hour, the contact would open, stopping rotation of the wheel and disconnecting the B battery supply. To start the wheel rotating again, another coin had to be inserted. The switch box was constructed as a plug-in device and when full with coins it would be taken to the Post Office where the coins would be removed and the box resealed by Post Office staff with a press type lead seal. The device allowed for multiple transmitting stations with a standard charge per hour for all stations. Under the proposal put forward by Jones, crystal sets owners would not have to pay for broadcast reception.

Although Lance Jones took his prototype receiver to the office of the Chief Manager, Telegraphs and Wireless in Melbourne, it is not known what the official reaction was to the device.

Regulation No 46 (2) of Statutory Rule 97 set out the requirement for the Sealed Set as follows:

> 'Approved broadcasting receivers shall be constructed as to respond to the wavelength indicated on the stamped indication or to any wavelength not differing more than ten per cent from that specified. The receivers shall not respond to wavelengths outside the specified limits.'

Three months after the Regulation came into force, the PMG's Department had not passed any receiver as meeting the requirements. Reasons for the delay are not clear but the technical press and some so called 'experts' said that it was impossible to make a receiver which conformed with the Regulations and accused the Department of bungling. An article in 'The Wireless Weekly' said 'Broadcasters (Sydney) Ltd have had to postpone the opening of Australia's first broadcasting station on account of the Federal Government's bungling'. Even though late, the Department began testing receivers in Melbourne on Wednesday 21 November 1923 and in Sydney on Friday 23 November 1923, the official opening day of 2SB.

The technology of the Sealed Set, whereby the receiver was mechanically locked to specific station wavelengths (frequencies) had some merit and although abandoned in 1924 in favour of continuous tuning across the band, it was taken up by receiver designers in the mid 1930s when push button tuning became a feature of some models. It was also applied to television receivers.

PROPOSED REGULATIONS

As a result of the Conference deliberations, the following proposed regulations were agreed to and forwarded to the Postmaster-General:

- A number of wavelengths to be allotted for broadcasting purposes. Such wavelengths to be selected in respect of their

suitability for stations and various powers, and their suitability for standardisation of receiving apparatus and subject to their not being required for public wireless telegraph or wireless telephone services.
- Licences or concessions for broadcasting stations to be granted for all available wavelengths within a given area.
- Each broadcasting station to be licensed for transmission on one wavelength only, but transfers may be approved by Statutory Authority.
- Licences to be issued under the Wireless Telegraphy Act to the public for receivers of design approved by Statutory Authority and capable of receiving signals of one wavelength only and incapable of variation without intentional tampering.
- Licences of nominal fee to sell or hire receiving apparatus to be issued to bonafide manufacturers and electrical or other traders.
- All licences to be renewed annually excepting in the case of broadcasting stations and trading concerns which were to be for five years.
- Concessionaires and licensed dealers to be authorised to issue licences to all their customers who had paid their subscription to the concessionaire.
- Receiving licences and renewal thereof to be withheld from all persons who do not pay the annual subscription to the broadcasting stations.
- The Government to take effective measures to protect the industry.
- Dealers and traders only to supply receiving equipment or parts thereof to holders of receiving licences.
- Dealers and traders must collect the first year broadcasting subscription on all receivers sold.
- Since there will be ample room for competitive broadcasting services, it is unnecessary to place any limitations on the nature of the services provided. Each concessionaire may decide for himself the class of service that will bring him the greatest number of subscribers.
- Retailers to keep a record of all equipment sold, together with the name, address and licence number of purchaser and to notify the concessionaires of any particular wavelength accordingly.
- Any person, company or manufacturer dealing in or using wireless equipment without a licence from the Government shall be subject to an adequate penalty.
- The administration of regulations governing broadcasting to be in the hands of a Board having thereon representations of the Government, broadcasting stations, manufacturers, traders and the press.

The Conference also affirmed the principle of preference to Australian, British and foreign manufactured apparatus in that order, on such terms as would encourage the use of Australian and British manufactured apparatus, and made a recommendation accordingly.

Another resolution recognised the right of the fully qualified persons indulging in bonafide experimental work to be without hindrance, except as prescribed in Statutory Declaration No 169 of 1922, such right to be kept in mind in the allotment of wavelengths, subject to the experimenter giving an undertaking not to poach on broadcasting services.

Opposition to the Scheme

Many of the delegates who had attended the Conference and others with an interest in broadcasting used every opportunity to criticise the proposed Sealed Set or Single Wave Scheme while the Government was going about its business to bring in legislation to get broadcasting established.

Opponents were well organised, and George Taylor, who had been Chairman of the Conference, fired a broadside at the critics through the columns of the Wireless Weekly. He dismissed suggestions that the conditions recommended to the Government were 'cut and dried previously to the assembly of the Conference delegates and that no other person or organisation had opportunity to propose definite regulations'.

Mr Taylor pointed out that at the opening of the Conference he had asked whether any delegate had a proposition to put to Conference. Mr Fisk stated that he had a proposal but preferred that others be heard first. As there were no other proposals, Mr Fisk was invited to address the meeting.

Mr Taylor also emphasised that Mr Fisk's scheme had been thoroughly debated, every person had been given the widest opportunity to ventilate their opinion with many of the suggested amendments being accepted, and that the outcome was a definite set of regulations unanimously approved by Conference and handed to the Postmaster General to obtain Government approval.

The Conference Committee which had drawn up the proposed regulations had been given the opportunity by the Postmaster General to comment on the first and final drafts by his Departmental officers before printing for Gazettal, and the Committee had been satisfied with the results.

Mr Taylor's comments were aimed particularly at some Melbourne delegates who raised objections to the limitation of receivers to one wavelength but who had failed to put their case at the Conference.

He put forth strong argument to support the Sealed Set Scheme. The main thrust was that every broadcasting station providing costly programs should have some check upon those receiving the programs. He likened the Scheme to the telephone system where people paid for the privilege of participating in the service. He dismissed arguments by the critics that the broadcasters would charge a high price, pointing out that no listener would be compelled to pay for any particular wavelength and competition between the broadcasters would ensure the lowest possible subscription price. He suggested that some broadcasters may even allow listeners-in to have use of their wavelength free of charge provided that the receiver was purchased from shops licensed by that particular station.

Mr Taylor strongly urged the critics to cease their opposition to the Sealed Set Scheme so as to allow the Regulations to be put into operation as soon as possible. He stressed that if the Scheme was later found to be wanting, then there could be a united effort by all those with an interest in broadcasting to have amendments put into effect.

Gazettal of the Regulations

Regulations giving effect to the recommendations were gazetted on 1 August 1923. The main licensing conditions were:
- Licences were issued by broadcasting stations or their agents with fees being paid to the Postmaster General's Department at monthly intervals.
- All receivers had to be of a type approved by the PMG's Department with the sets being sealed for reception on one or more fixed wavelengths with ± 10% tolerance.
- Radio Dealers were licensed and charged an annual fee of £1 before being permitted to trade in receivers.

The listeners were required to pay a fee of 10/- per annum to the Government in the case of single station reception or £1 per annum for a set capable of multiwave reception. On payment of the fee, the listener was issued with a Broadcast Listeners Licence. The subscription fees fixed by the broadcasting companies varied from 10/- to £4/4/- per annum. The lowest fee was deliberately set by 2SB (2BL) in the hope that the owners — a group of radio retailers — would recoup any operational losses by increased sales of radio receivers. Station 3AR established by a Melbourne firm which manufactured radio apparatus set its fee at £3/3/-.

The Government preferred that receivers be professionally designed and constructed to ensure there was no interference problems with other receivers, as occurred with some regenerative designs. These circuits were well publicised in technical magazines of the period and were very popular with do-it-yourself constructors. They had a number of advantages over conventional straight circuits including a cost advantage, a major consideration with many people. With receivers constructed by manufacturers, the Government saw it as a way to reduce load on its employees in inspecting and approving designs to ensure they complied with the Regulations. Once a design was approved, there was no need for the Inspectors to be further involved.

Each approved receiver had to have a label attached indicating that it had been approved by the PMG, the Type No., and the sealed wavelength.

In the case of privately constructed sets the tuning elements had to be enclosed in such a manner to ensure they complied with Regulations. A charge was made for inspection and sealing, and boys who made crystal sets were not happy with parting with more money, so very few crystal sets were taken to the authorities for inspection. In Adelaide, not one crystal set or even crystal set plus one valve amplifier was submitted to Bert Harrington the local Radio Inspector for approval. He had taken up duty in January 1924 and was assisted by Phil Traynor Assistant Radio Inspector.

FIRST OFFICIAL BROADCASTERS

The Government gave approval for the establishment of two stations in Sydney, one in Melbourne and one in Perth under the plan. These were the only applications received, and indicated the extent of caution with which entrepreneurs viewed the new medium.

The planners of the service had intended, subject to the receipt of suitable interest, to make available licences for one high power (5000 watt) and one medium power (1,500 watt) stations in Sydney and Melbourne, and one high power station in each of the other capital cities. However, there was no mad scramble for entrepreneurs to raise capital as had happened in the United States.

Further evidence of the caution was seen when the Postmaster General capitulated to intense pressure from traders who opposed the Sealed Set Scheme and agreed to licence 'free stations' which would be supported by paid advertisements. The Postmaster General agreed, on the condition that the stations 'guarantee to provide a permanent service'. Although a total of 14 applications were received from groups and individuals in Queensland, Western Australia and Victoria, the scheme collapsed, as none of the applicants had sufficient backing to guarantee the provision of a permanent broadcasting service. This was a great relief to the four stations which had been already licensed as 'sealed set stations'.

The first station to commence operation was 2SB Sydney owned by Broadcasters (Sydney) Ltd. The callsign was later changed to 2BL because of confusion with callsign 2FC. Broadcasters (Sydney) Ltd was financed by a consortium of local retailers and business interests. The retailers included L P R Bean and Co., Ltd; Colville-Moore Wireless Supplies; Continental Radio and Electric Company; F P O'Sullivan; Pacific Radio Company; Pitt, Vickery Ltd; Radio Company Ltd; Radio House; Ramsay, Sharp and Co., Ltd; United Distributing Companies; O'Brien and Nicoll; Universal Electric Company; W Harry Wiles; Wireless Supplies; International Radio Company Ltd and others. Major financiers included David Jones and Hordern and Sons local Departmental Stores, and Smith's Newspapers Ltd a company formed by amalgamation of companies publishing Smith's Weekly and the Daily Guardian. The company was owned by Sir Joynton Smith, Claude McKay and Robert Clyde Packer who each had one third partnership. Sir Joynton Smith was also Chairman of the radio station company Broadcasters (Sydney) Ltd when it was formed in August 1923 with a capital of £113.

The Articles and Memorandum of the company were based on those used to set up 2YB for Wellington Broadcasters Ltd in 1923 in New Zealand. The group associated with the establishment of the New Zealand station were importers and distributors of radio equipment including International Radio Company whose Managing Director was Charles Forrest. Mr Forrest came to Sydney to establish International Radio Company Ltd in that city in 1923, and called a meeting of people associated with the radio trade to tell them of the New Zealand experience.

The Registered Office of Broadcasters (Sydney) Ltd was Radio House, 619 George Street, Sydney owned by Cecil Stevenson. In addition to being a shareholder, he was Treasurer of Broadcasters (Sydney) Ltd.

The Managing Director of Broadcasters (Sydney) Ltd was William Maclardy who was an active experimenter with his Amateur station 2HP at Rose Bay and was publisher of Wireless Weekly for the Proprietors at offices of Publicity Press Ltd, 33/37 Regent Street, Sydney. He was one of the principal parties associated with establishment of the station.

It became evident soon after transmissions began on a regular basis that the company was heading towards a financial crisis. Operating expenses greatly exceeded income, and a company, Associated Interests, was formed with shareholders being Smith's Newspapers Ltd, Anthony Hordern and Sons and David Jones Ltd to act as guarantor for bank loans necessary to keep the station operating.

Prior to the commissioning of the licenced 500 watt transmitter, experimental transmissions were undertaken from The Daily Guardian Building site using Mr Mclardy's Experimental 10 watt station 2HP. The equipment was transferred to the city and installed by Mclardy and Ray Allsop together with assistance from a group of willing enthusiasts. The purpose of the installation was to assess the likely service area of the transmissions when the 500 watt transmitter was commissioned with the cage type aerial and also to provide training for the announcing staff.

Transmissions were conducted from about 17 October 1923 on a regular basis every day from 3 pm to 5 pm and 7 pm to 10 pm in accordance with conditions laid down by the Postmaster General's Department.

The experimental transmissions were carried out on a wavelength of 350 metres (857 kHz) with considerable publicity being given to the exercise by 'The Daily Guardian' newspaper and 'Wireless Weekly' magazine.

The aim of Broadcasters (Sydney) Ltd was to provide what was called a 'FREE' broadcasting service by the company. It published a list of radio and electrical businesses which financially supported the company and requested people who intended purchasing a radio receiver to purchase the set from those businesses. Although the purchaser would be required to pay a fee of ten shillings a year as a Licence Fee plus ten shillings demanded as royalties on patents held by Amalgamated Wireless (A/Asia) Ltd, there was no charge for listening to the 2SB programs.

Listeners were invited to report on reception while Ray Allsop and others carried out field strength measurements at selected spots in the metropolitan and nearby areas. At least two reports were received from South Australia. One was from Roy Cook who received a good signal on two occasions with a three valve regenerative receiver. The other was from Roy Buckerfield who reported good signals and clear modulation on three evenings with slight fading on two occasions using a modified Flewelling circuit with an extra stage of audio. He observed some interference from local experimental transmitters which had drifted off their authorised wavelength in the 250 metre band.

Neither listener had prior warning of the transmissions. They were band searching while listening to local Adelaide experimenters operating on nearby bands. Other reports were received from Tasmania, Victoria and Queensland. One Queensland listener was an off duty Coast Radio Station officer at Rockhampton who was using a receiver with a Browning-Drake circuit.

The 500 watt transmitter and studio equipment were constructed and assembled by local wireless experts with Cecil Stevenson, Proprietor of Electric Utilities Supply Co., playing a major part. Stevenson was a qualified Electrical Engineer and provided not only technical equipment and design expertise with power equipment but allowed the construction of the equipment, including the transmitter to be carried out on his premises in Radio House in George Street, Sydney. Other businesses which supplied technical plant included The Western Electric Co., (Australia) Ltd and New System Telephones Pty Ltd. E Joseph was one of the many volunteers who assisted with the assembly work.

After assembly of the steel framed transmitter it was transferred with some difficulty to the top of The Daily Guardian Building in Phillip Street where space had been set aside for the transmitter, generating plant and a modest studio by the proprietors of Smiths Newspapers Ltd who also provided financial support to the new broadcasting company.

Following installation and testing of the transmitting and studio facilities, the station was ready to begin operations as from 13 November 1923 but the PMG's Department Wireless Branch asked the station management to defer full-scale operations using the licensed 500 watt installation as there were some technical problems associated with approval of 'sealed set' receivers. Listeners licences could not be issued until dealers and manufacturers had been granted approval for receivers submitted to the Department.

Broadcasters (Sydney) Ltd continued with the experimental 10 watt 2HD transmitter while waiting for the Department to grant permission to put the 500 watt transmitter into operation.

Bill Crawford the Department's Radio Inspector for New South Wales, maintained a close interest on the installation, commissioning and operation of the facilities from the start and decided that broadcasting would not begin officially until he was satisfied that all conditions of the licence had been met and that listeners could obtain a licence to operate a set approved by his Department.

Some after-hours testing of the 500 watt transmitter was allowed to carry out adjustments and to check equipment, but no programs were to be broadcast.

Following approval from the Department for the 500 watt transmitter to be put into service, full-scale program operations on a systematic basis began at 8 pm on Friday 23 November 1923 with the broadcast of a two-part concert featuring many well-known singers and musicians. The following day, the scale of operations was much more extensive with the first full day's program being broadcast. On the first Sunday, the transmitter was operated during the afternoon and evening only. The aim of the company was to provide broadcasting over a 12 hour period during week days, made up of sessions with breaks in transmission between sessions.

The licence for Broadcasters (Sydney) Ltd to operate the station was subsequently issued by the Department on 22 July 1924.

The PMG's Department began issuing approvals to dealers and manufacturers in Sydney under the 'sealed set scheme' on 23 November coinciding with the official date of transmission from the first broadcasting station to begin operation in Australia. This enabled licences to be issued for domestic receivers.

The official opening ceremony was conducted by Postmaster General William Gibson on 13 December 1923.

Special preparations were made to ensure that the Postmaster General's speech which was delivered from The Daily Guardian office and the entertainment program planned to follow could be heard by gatherings of people who did not have a receiving set at home.

Several Sydney theatres and halls were equipped with broadcast receivers and large horn type loudspeakers. An open air concert was given in Martin Place.

Thousands heard the broadcast at a function on the beach at Coogee where a large multivalve receiver and Magnavox loudspeaker were installed. The Real Estate Hall in Martin Place was packed to capacity and many people outside could not hear the broadcast. Officials had to clear the Hall on several occasions to allow people outside to come into the Hall to hear the proceedings from a top class installation which had been provided.

In concluding his speech, Postmaster General Gibson said:

'Tomorrow listeners-in all over the State will be receiving from this station their regular service of news and entertainment. I fancy the initiation of this service must have demanded some courage. Only men strongly imbued with the spirit of their age — a spirit extremely progressive and enterprising — would have had sufficient faith to launch an undertaking on such scale.

It is very greatly to the credit of the youngest of the Sydney newspapers that it has sponsored this enterprise. I am told that the experimental work of the past few weeks has been extraordinarily successful; and as I declare this station open, I offer my hearty congratulations to the founders and express the hope that the public will avail themselves of this up-to-date and speedy means of communication that will henceforth be offered.'

'The Daily Guardian' reported that messages of congratulations poured into the office from all quarters. Letters show comments as including 'The reproduction was wonderful', 'The concert was a glorious success', 'The modulation was superb and spot on', and 'The magic of radio is now upon us'.

The studio was only 4.3 m by 3.6 m and as it contained a full size grand piano and a small desk for the Announcer, there was not much room to accommodate performing Artists. When a choir or orchestra performed, they were assembled on the roof top — weather permitting — and the studio microphone extended by a long lead or placed near the open studio door. The facilities included two WE double button carbon granule microphones.

The station began transmission at noon each day with news items being broadcast every half hour up to 6.30 pm. At night they were broadcast during intervals in the concert program or the dance music.

A typical daily program comprised:

12 noon —	General news.
12.30 —	News, morning Stock Exchange calls, market reports, weather reports.
1–2 —	Broadcasters No 1 Orchestra selections.
2.30 —	Mid-day Exchange calls, general news.
3 —	News.
3.15 —	Afternoon chats to women.
3.30 —	Weather reports.
3.45–4.45 —	Orchestra.
5.00 —	News.
5.30 —	News.
6.00 —	News.
6.30 —	Stock Exchange calls.
6.45–7.45 —	Bedtime stories.
7.45–8.00 —	The Australian Orchestra.
8.00–10.00 —	Grand popular concert.
10.00 —	National Anthem and close.

In addition to the problem of accommodating groups of people assembled for a broadcast, the studio was far too small to meet the operational needs. In October 1925, new facilities were provided at Fuller's Building, Elizabeth Street. A further move took place in March 1926 when operations were conducted from premises at 4 Bligh Street.

Because of callsign confusion with 2FC which had commenced operation on 5 December 1923, the Department granted approval for the callsign to be changed from 2SB to 2BL as from March 1924.

The output from the 500 watt transmitter proved inadequate when competing against the 5000 watt transmitter of 2FC and the high level of man-made electrical noise, so permission was sought by Broadcasters (Sydney) Ltd to have the power increased and for establishment of a site outside the central business area.

It had been policy of the Government to allow for two broadcasting stations to be established in Sydney and Melbourne with one station operating on high power of 5000 watts and the other on medium power of 1,500 watts, so approval for the 2BL transmitter to be increased to 1,500 watts was soon granted. The

Government had decided that 500 watts was to be the minimum power for any broadcasting station.

In June 1925, a transmitter rated at 1,500 watts was commissioned at Coogee employing a modified AWA manufactured unit with upgrading of some of the original facilities. The company held on to the 500 watt original transmitter and other recovered plant as it had hoped to install a relay station at Newcastle.

The work associated with the installation of the new Coogee facilities was carried out under the direction of David Wyles of Amalgamated Wireless (A/Asia) Ltd who assumed the role of Project Chief Engineer.

Technical Consultant for Broadcasters (Sydney) Ltd was Ray Allsop who became the company's Chief Engineer in June 1925 on commissioning of the 1,500 watt transmitter. A transmitter which provided 3000 watts into the aerial was later commissioned.

It is surprising that those retailers associated with financing the station should have assumed that the station would have provided a means of increasing the sale of domestic receivers to the extent that it would provide increased profits. Receiver manufacturers in the USA had found that it was not necessary to own a transmitting station to sell receivers. In fact, some trading groups found that the financial costs associated with establishing and operating a station were too great whilst others ceased operations because they could not handle the cutthroat competition from other stations with aggressive marketing policies.

As events turned out, the Australian traders suffered the same fate as some of the American colleagues. Within two years, Broadcasters (Sydney) Ltd was in financial difficulties. It was temporarily saved by financial assistance from two of Sydney's largest departmental stores, Anthony Hordern and Sons Ltd and David Jones Ltd who also retailed receivers.

The radio retailers who were shareholders in 2SB paid a subscription fee towards operating costs of the station and hoped to make a profit from fees obtained for receivers tuned (sealed) to 2SB wavelength. A feature of company policy was that the broadcasting service was free — there was no charge for it. The only charge payable by the owner of a receiver was £1 subscription made up of 10/- Royalty to AWA and 10/- to the PMG's Department to offset administration costs of the broadcasting service. Listeners to 2FC were required to pay £3/13/- subscription which included the 10/- PMG's Department levy.

On 14 August 1928, Broadcasters (Sydney) Ltd amalgamated with the owners of 2FC to form the New South Wales Broadcasting Co., Ltd following an agreement reached by the two companies earlier in the year. Soon after, both stations were taken over by the Government when it established the National Broadcasting Service. Programs were provided by the Australian Broadcasting Co., Ltd from 16 July 1929 for 2FC and from 21 July 1929 for 2BL.

The Postmaster General's Department took over the assets of the A Class stations as their licences expired between July 1929 and January 1930. All stations except 2FC and 3LO were operated by Departmental technical staff immediately on takeover. A temporary arrangement was made with AWA to continue techincal operation of 2FC and 3LO.

The second Sydney station 2FC, operated by Farmer and Co., Ltd commenced regular transmission on 5 December 1923 using a wavelength of 1100 metres (273 kHz). The company was a large Sydney Department store established by William Farmer in 1854. The company was an innovator in retailing and became a public company in 1897. It was taken over by the Myer group in 1960.

The official opening ceremony of 2FC was performed on 10 January 1924. Authorised power was 5000 watts to the final stage, the maximum allowable power permitted at the time. Test transmissions had been conducted from about June 1923 from a site at Edinburgh Road Willoughby near present Castlecrag just north of the Sydney Harbour Bridge. An AWA 500 watt transmitter was installed to allow field strength measurements to be undertaken in the city and nearby country areas to assess the likely service area with the proposed 5000 watt transmitter. AWA had designed the 5000 watt transmitter as part of its plan to enter the Australian broadcast transmitter manufacturing industry.

The 5000 watt transmitter feeding into a cage type aerial system supported by two lattice steel 62 m high masts was commissioned on 5 December 1923 following about two weeks of test transmissions. The project was under the control of Arthur McDonald, Chief Engineer of AWA. He was assisted by Engineers Joe Reed and George Cookson and other company Technical staff. George Cookson remained at the station as Resident Engineer sharing part of the building as a residence until 1926.

The 500 watt transmitter became a standby unit for operation on a licensed wavelength of 880 metres. It was designated the Junior Service while the 5000 watt system was designated the Senior Service operating on 1,100 metres.

Farmer and Co. Ltd decided to concentrate their efforts on the programming side of broadcasting and contracted the design, installation and operation of the technical facilities to Amalgamated Wireless (Australasia) Ltd. AWA not only charged for the capital cost of the plant but received a considerable percentage of the station licence fee revenue.

In accordance with later amended procedures for calculating transmitter power, the station power was officially listed as 3,500 watts.

The well-appointed studios were located on the roof garden of the company's Pitt and Market Streets store. Facilities included a large studio, a small studio, a technical control room and a reception and waiting room for Artists. Studio walls were filled with seaweed to attenuate extraneous noise.

Early in 1928, new studios were built in Market Street alongside Her Majesty's Theatre. By that time, 2FC and 2BL had been incorporated into the NSW Broadcasting Company and both stations used the studios.

During 1925, the 2FC transmitting facilities were transferred to the AWA transmitting complex at Pennant Hills and maintained by staff at the Centre. It had been intended from the start that AWA would install the transmitter at their Pennant Hills site but there was insufficient space available to accommodate the transmitter at the time. Extension of the transmitter hall was carried out and the move undertaken on completion of the building work with transmission being conducted on 442 metres (678 kHz) instead of the earlier 1,100 metres.

The official opening of the 2FC transmitter at Pennant Hills was performed by the Rt Hon. W M Hughes on 29 March 1926. Mr Hughes had served as Prime Minister from 1915 until February 1923 and although he took a great personal interest in the development of wireless from the wireless telegraphy spark era, unfortunately he was not Prime Minister when broadcasting commenced in Australia. In February 1923, only nine months before opening of the first broadcasting station, Mr S M Bruce became Prime Minister. However, Mr Hughes continued his interest in wireless and later became a Director on the Board of Amalgamated Wireless (A/Asia) Ltd.

One of the AWA staff members who was responsible for the 2FC technical facilities was George Cookson. He assisted with the transmitter installation, worked at the studios from 1924 until 1926 and following a visit to England was appointed Engineer-in-Charge of the Pennant Hills Radio Centre in 1927. George began work as a Radio Mechanic at the Townsville Coast Radio station in 1917 when the station was under control of the Royal Australian Navy. He spent a total of seven years at various stations and when AWA took over responsibility for the Coast Radio service in 1922 George became a member of AWA staff.

Vincent Stanley who worked as a Technician on 2FC later became Officer-in-Charge of Pennant Hills after George Cookson. The Pennant Hills site had been associated with wireless activities from early days and later became one of the key transmitting centres in Australia.

In 1912, the Coast Radio Station transmitter was installed on the site with a spark transmitter manufactured in Germany by Telefunken and Co. It fed a 122 m radiator.

Until 1926, the Centre served as a combined transmitting and receiving station but with the growth of services, the receiving facilities were transferred to Willoughby. Later in 1927, when there were nine transmitters installed at the Centre including 2FC transmitter, a permanent Coast Radio receiving station was commissioned at La Perouse and thereafter Pennant Hills served purely as a transmitting station.

In 1931, another broadcast transmitter was installed on a site adjacent to the Centre. It was a 1000 watt transmitter employing series modulation commissioned for 2SM Sydney.

On 1 December 1927, the 2FC licence was transferred to 2FC Limited on formation of a new company when Farmer and Company Ltd relinquished involvement in the broadcasting industry.

The new owners of the station had plans to extend its service to country areas and in early 1928 wrote to the Postmaster General's Department enquiring about the lease of program circuits to various country centres. The Department replied that there were no lines specifically designed for the transmission of broadcast programs available at the time, and suggested the company erect an independent station in the Newcastle-Maitland area for the broadcast of local news, information received by telegrams from Sydney, and recorded music. However, the matter proceeded no further as it became evident during the hearings of the Royal Commission into broadcasting that the Government was likely to acquire all A Class stations. At the time 2FC was broadcasting on 442 metres and was on air from 7 am until 10.30 pm.

When the Postmaster General's Department took control of 2FC as part of the National Broadcasting Service in 1929, the transmitter remained at Pennant Hills and was maintained under contract by AWA until 1938 when it was shut down following the installation of a 10 kW transmitter by PMG's Department staff at a new site at Prestons near Liverpool.

In Melbourne, the first station was 3AR operated by Associated Radio Company of Australia Ltd. The station went to air officially on Australia Day, 26 January 1924 with a temporary 350 watt transmitter located at 51-53 A'Beckett Street in the city operating on 480 metres (625 kHz). The power was well below the minimum 500 watts required for a broadcasting service and provided an unsatisfactory signal level. The owners acted quickly to install a 1500 watt transmitter out in the suburbs.

The licence had been issued to Associated Radio Company of Australia Ltd on 8 August 1924 and Tom Court was one of the Technical staff engaged on planning the service and designing the transmitter.

The company engaged Consulting Engineer Donald Macdonald to plan and design the new station facility. Macdonald had been assistant to Graeme Balsille the first Engineer for Radiotelegraphy engaged by the Commonwealth Government with the task of erecting a network of Coast Radio Stations for communications with ships, and also to administer the provisions of the Wireless Telegraphy Act and Regulations.

Following comprehensive field strength and soil tests of many sites in the Melbourne area, a site was chosen at North Essendon on an open plateau about one kilometre from the Civil Aviation Aerodrome.

By October 1925, the new transmitter had been commissioned but as power was not available on site at the time, a local power generating unit was installed. The engine was a 10 horse power McKay engine provided with a large fly wheel to ensure uniform output during transmitter modulation cycles. The transmitter high tension generator produced 4000 volts DC at 4 kW with the filament generator producing 24 volts DC at 80 amperes.

About August 1927, the company contracted with Amalgamated Wireless (A/Asia) Ltd to upgrade the transmitter and to increase the power to the aerial using Australian built facilities. As part of the upgrading work, USA manufactured Western Electric 8B program input equipment was installed. Power into the aerial was increased to 3000 watts. The work resulted in considerable improvement in signal coverage and signal quality, with several hundred letters being received from listeners congratulating the company on the work.

The owners of the station had, before entering the broadcasting business been in the radio components business and manufactured receivers under the brand name Radio-Phone. The top range model, the Radio-Phone Emperor was advertised to receive all Australian stations and 1YA Auckland in New Zealand. The spare parts stocked by the Company included valves, headphones, transformers, loudspeakers, Neutrodyne kits and other components. By 1925 the studios and the Radio Shop had been established at Leonard House, 44 Elizabeth Street, Melbourne.

The Company had hoped that the Australian Government would introduce the same arrangements to assist radio manufacturers as had happened in Great Britain when broadcasting was established there. In Great Britain, there were a couple of dozen individual manufacturers interested in establishing broadcasting stations but they all wanted exclusive rights. The Government hoped they would combine and it took six months of intense negotiations before agreement was reached. A group formed the British Broadcasting Company in December 1922.

To prevent a monopoly, the Government decreed that any radio equipment manufacturer should be able to buy shares in the new company. The arrangement agreed to, was that the company would pay the cost of establishing the station and the Government would contribute towards the operational costs from its listener's licence revenue. The balance of the operating costs was to be made up by the Company from income received from the sale of receiving apparatus. To this end, the Government restricted the licensing of foreign made receivers, and all locally made receivers and major components such as loudspeakers, valves, capacitors, transformers etc., were to be approved by the Post Office and stamped 'BBC Type Approved by Postmaster General'.

The Company lasted until the end of 1926 when it was superseded by the British Broadcasting Corporation. However, it had made a tremendous contribution to the development of broadcasting and although it made little money for its shareholders, it left a radio industry well established, and the service could boast a listening audience of some 2 million.

The Associated Radio Company of Australia Ltd was not as fortunate as the British group. Like 2BL in Sydney, they found the establishment and operating costs to be very high and were soon in financial difficulties. On 1 March 1928, the company amalgamated with the other Melbourne station 3LO, to form the Dominion Broadcasting Co. Ltd, operating from studios in Russell Street, but both were eventually taken over by the Government and programs provided by the Australian Broadcasting Co. Ltd. In the case of 3AR this occurred on 7 August 1929.

Another role of the Associated Radio Company of Australia Ltd, was the installation of broadcast transmitters. In addition to 3AR, it was later associated with the installation of facilities at 5CL Adelaide and 7ZL Hobart. The Company Consulting Engineer Donald Macdonald had wide experience in Radio Engineering dating back to the spark wireless telegraphy era. Following design and oversight of the installation of the 5CL and 7ZL facilities, and a period in control of 7ZL, he left to form his own company. In 1927, he founded Television and Radio Laboratories Pty. Ltd, and carried out a great deal of developmental work in early television engineering and later facsimile picture transmission assisted by Lay Cranch, Ross Pitkethley and Gil Miles. Miles had built the first short wave transmitter for the RAAF in 1924. Macdonald had made an overseas tour to investigate television development and brought back to Australia circuits and some selected components used in the overseas systems.

In January 1929, television signals were transmitted through the 3UZ transmitter using equalised telephone lines between the Laboratory in Albert Street and the 3UZ transmitter in Bourke Street. However, there did not appear to be adequate financial backing from the Government and the public to continue the work, so experimental work was phased out in favour of facsimile picture transmission. A new company, Radiovision (A/Asia) Ltd was formed in September 1930 with a public facsimile service being provided through the 3DB and 3UZ transmitting facilities. Unfortunately, the venture was not a commercial success and the company turned to the manufacture of domestic receivers using the brand name Radiovision.

The service in Perth provided by 6WF and operated by Westralian Farmers Ltd, commenced on 4 June 1924 on reduced power on wavelength of 1,250 metres. The 5000 watt transmitter was similar to the one manufactured by AWA and installed at 2FC, and later for stations 3LO, 5CL and 4QG. The 6WF aerial was located on the roof of the building housing the transmitter and studios and was a four wire cage type suspended between two tapered steel poles, 27 m high and spaced 49 m apart.

In establishing the service in Perth, Westralian Farmers Ltd, had in mind the assistance that it could provide to the constituent members of its organisation by keeping them informed of such matters as market prices for primary products, weather reports, talks by experts on matters of concern to farmers and also as a means to make conditions of living, particularly in remote country areas, more pleasurable.

Although the company sold radio receivers and components with a special offer on parts to entice school boys and girls to assemble crystal sets and one valve battery receivers, the number of listeners to the station was not great. In fact, revenue received from licences fell far short of the station operating cost. With the management forced to reduce program budget allocation, the quality of the programs fell, resulting in a sharp decline of licensed listeners. Maintenance of the technical facilities also suffered as a result of budget cuts, and when the station was taken over by the Government on 20 December 1928 as part of the National Broadcasting Service, the Company was greatly relieved, to say the least. The Australian Broadcasting Co., Ltd, began providing programs from 21 July 1929.

When the station commenced service, the Chief Engineer and Manager was Walter (Wally) Coxon, and Chief Operator was George (Jack) Sutherland. Walter Coxon was the proprietor of W E Coxon and Co., Electrical and Radio Engineers, 30 King Street, Perth. For some years before 6WF commenced transmissions, his company manufactured a range of wireless apparatus specialising in components. Before releasing new designs on the market, they were tried out on his Amateur station 6AG which he operated from Bulwer Street.

His experience with wireless started with experimental spark wireless station XYK which he operated at his home in Maylands from 1907. Station callsign later became OA6AG.

During the First World War, he was in England working on the production of high tension transmission apparatus for employment on ships and submarines.

After the War, he returned to Australia, and for a time was an Instructor to Electrical Trades classes before establishing his business in King Street.

With the restoration of experimental licences after the cessation of hostilities, he was one of a group in Perth who operated their Amateur stations on the 200 metre band in the early 1920s. On obtaining a licence for establishment of 6WF, Westralian Farmers Ltd, appointed Walter Coxon as their Chief Engineer and Manager, a position he held until the station was taken over by the Government. In the 1930s he was Director of Reaudio Production in Perth with the studio being equipped with Telefunken recording equipment. He played an important role in the establishment of Commercial stations 6ML Perth, 6BY Bunbury and 6AM Northam.

Another involvement was Technical Editor of 'The Western Wireless,' a journal devoted solely to the interests of wireless enthusiasts both amateur and professional. It was the official organ of the Wireless Institute of Australia (WA Division), Wireless Development Association of WA and most of the local Radio Clubs and Societies active at the time.

In later years, Walter Coxon played an important role in the Royal Flying Service. He was associated with the Western Australian Section technical aspects from 1935 when the first base station at Port Hedland was commissioned. He was Technical Adviser to the Service and served for some 23 years before retiring in May 1957, having during the period temporarily relocated the Wyndham radio base to Halls Creek during the War years in 1942, designed and constructed the Carnarvon radio base station in 1951, upgraded the Meekatharra base in 1957, manufactured and installed transceivers including a portable model for the Service during the 1940–50s to meet the demand for these units when the official contractor, Alf Traeger, was unable to supply sufficient units, as well as many other projects.

Chief Operator George (Jack) Sutherland had been involved in wireless telegraphy since 1908 when he joined the Royal Navy as a Wireless Operator at the time when the Navy was fitting out its warships with wireless equipment. The Royal Navy saw the great potential of wireless and took a great interest in the development of the technology. Considerable use was made of the new science when the British cruisers attached to the 'Ophir' visited Australia with the Duke and Duchess of Cornwall in 1901. During the First World War, George served in the Submarine Decoy Fleet as an expert in the application of wireless in dealing with the menace of enemy submarines.

He took up an appointment with Westralian Farmers and worked at 6WF under Walter Coxon remaining at the station until it was taken over by the PMG's Department as part of the Governments plan to establish the National Broadcasting Service. He then became associated with the commercial side of broadcasting but left Perth to move to Queensland to take up a position as Assistant Engineer with Commercial station 4BC Brisbane under Chief Engineer Fred Stevens. He subsequently became Chief Engineer of 4BC.

Unfortunately, one idea embodied in the Regulations setting up the early broadcasting stations as a result of technical advice given at the Conference by Ernest Fisk was to have the transmitters broadcast on long wavelengths. Three of the early stations, 2FC Sydney, 3LO Melbourne and 6WF Perth began transmission on wavelengths above 1000 metres (300 kHz) and this meant that many expensive home receivers imported from overseas whose wavelengths were limited to 500 metres (600 kHz) were not suitable for reception of these stations. These three stations were all manufactured by AWA controlled by Fisk.

When 3LO Melbourne began operation its wavelength was 1720 metres but in July 1925, it was changed to 371 metres (881 kHz). Sydney station 2FC followed suit. From 2 October 1926 it changed from 1100 metres to 442 metres (678 kHz). Station 6WF Perth changed from 1250 metres to 435 metres (690 kHz) on 1 September 1929.

Although at the time of commissioning the transmitter powers of 2FC, 3LO and 6WF were rated at 5000 watts, later amended procedures for calculation of transmitter power resulted in these three stations being listed officially as 3500 watts stations.

CALLSIGNS

In determining the principle for callsigns to be used for broadcasting stations in Australia, the Postmaster General's Department apparently decided to continue with the arrangement already in use at the time with licensing of Amateur stations except that the first letter 'A' was not to be used.

Prior to 1920, callsigns were prefixed with 'X', for experimental. In 1914 just prior to the outbreak of the First World War when all experimental licences were revoked, callsigns in New South Wales had been allocated with letters XAA to XIZ, Victoria XJA to XPZ, Queensland XQA to XQZ, South Australia XVA to XVZ, Western Australia XYA to XYZ and Tasmania XZA to XZZ.

When licences were restored in 1920, numerical prefixes were allocated to each State, replacing the X prefix e.g. A2AB, A3AB, A4AB, A5AB etc. The reason for the use of a different number for each State is not clear, but in a letter dated 22 June 1981 to a boy in South Australia who raised the matter with the Minister for Communications at the time, Hon. Ian Sinclair, the Minister replied that numerical identification of States was based on a policy of the then Commonwealth Defence Department to divide Australia into numbered Military Zones. Apparently the numbering scheme only applied to States and not Territories. Until 1960, broadcasting stations in Northern Territory were allocated the same numerical prefix as South Australia i.e. 5DR and 5AL. In 1960, when the first Commercial station began operation and new NBS stations were commissioned at Tennant Creek and Katherine, the numerical 8 was used to identify stations in the Northern Territory. Stations in the ACT employed the same identifying figure '2' as New South Wales.

Under the Broadcasting Act introduced in recent times, there was no legislative requirement for broadcast transmissions to be identified by callsigns. However, there were a number of administrative advantages in stations being identified by specific callsigns, particularly those operating on the same frequency, and in November 1992 the Australian Broadcasting Authority proposed a new arrangement for allocating callsigns. Following discussions with the broadcasting industry, the Authority ratified the arrangements on 15 February 1993.

In 1995, the ABA decided that in future new broadcasting stations established in the Australian Capital Territory would be allocated State identifier '1' in lieu of '2' as in the past, to distinguish ACT stations from those in New South Wales. Existing stations could retain their '2' identifier if they so wished.

Although there is no legislative requirement in Australia for broadcasters to use callsigns, International Regulations require that transmissions be capable of being identified either by identification signal or by other means. For domestic services, this may be by means such as a name, location of the transmitter, operating organisation, call number or signal or by a feature which can be readily identified internationally.

Whereas as a general rule, AM stations have been allocated callsigns of two letters following a numeral such as 2MC, FM stations usually have three or more letters after the numeral such as 2DAY, 2ABCFM, 2ABCRN etc. HF Inland Service stations are identified by a combination of two letters followed by a numeral and another letter such as VL8T, which is located at Tennant Creek.

In practice today, many Australian broadcasters do not use their allocated callsigns on air, choosing instead, the organisation's name such as 'ABC Classic FM', a catchy phrase such as 'Triple J', or a position on the receiver dial, such as '102.2FM' or others.

An interesting example of changes in callsign relates to 4IP established by Ipswich Broadcasting Company Pty Ltd with studio and transmitter in Brisbane Street, Ipswich. The station commenced operation on 2 September 1935 with Fred Hoe Junior, as Chief Engineer. The 50 watt transmitter and studio equipment were manufactured by Colville Wireless Equipment Co., under licence and in collaboration with Philips Lamps (Aust.) Ltd. It was designated model KVFH50/2C. Within three years the transmitter was upgraded to model KVFH100/2C to provide 100 watts into an L type aerial with a counterpoise 25 m beneath the radiating top element. At that time, Keith Fairweather was Chief Engineer, having started at the station when it began operation. Operating frequency was 1440 kHz and the station slogan was 'Station 4IP, in the Heart of Ipswich'.

By 1972, owners were South Queensland Broadcasting Corpn, Pty Ltd with a 2 kW transmitter operating from a site at Bundamba on a frequency of 1010 kHz providing 24 hour service to listeners. The station slogan was '4IP Color Radio' and it was part of the Central Queensland Broadcasting Network with all stations using 'Color Radio' as slogan. It also used the slogan 'Radio ten ten', no doubt a pickoff of its operating frequency and advertised itself as 4IP Greater Brisbane, rather than 4IP Ipswich.

In order to consolidate itself as part of the Brisbane station group, decision was made to relocate to Brisbane. In July 1982, transmitting facilities were established on St Helena Island, the site of a former convict prison in Moreton Bay and known by the inmates as 'the hell hole of the South Pacific'. A 5 kW stereo transmitter fed a 141 m high directional aerial system with lobes towards north, south and west.

The station callsign was 4IO, with Announcers referring to the station as Radio 10. By that stage the station operating frequency had changed slightly to 1008 kHz following rationalisation of all station frequencies with a change in channel bandwidths.

The move to Brisbane did not result in the financial advantages the owners had expected, mainly because of the loss of many listeners to the new FM band stations, so in November 1989, the station reverted back to its original callsign 4IP.

In December 1991, the station was purchased by the Queensland racing industry using callsign 4TAB so removing the 4IP callsign from the official listing for the time being.

However, under the new callsign 4TAB, the former 4IP played a more expansive role in broadcasting than previously. The Totalisator Administration Board of Queensland (TAB) operated a network of stations throughout Queensland extending as far north as Thursday Island and programs for the network were sourced from 4TAB in Brisbane and relayed via satellite to the country stations in the network.

THE 1924 PLAN

The Sealed Set Scheme, as anticipated by many critics, proved to be a failure for a number of reasons including technical problems. Of 154 separate receiver designs submitted for approval by mid 1924, only 61 were accepted as reasonably conforming to the technical requirements. Between August 1923, shortly before test transmissions began, and the end of June 1924, when all four stations were operational, only 1400 licences had been issued, so the stage was set to abandon the Scheme and introduce a fresh proposal.

The failure of the Sealed Set Scheme proved to be a blow to many importers and Radio Shops which had invested heavily in stocks of receivers which met the technical requirements of the PMG's Department Sealed Set Specification.

Immediately after the Government announced plans to allow receivers to be tuned across the broadcast band without restriction, many firms had 'fire sales' to dispose of stocks rather than modify them to give unrestricted tuning.

One such firm was Adelaide Radio Company one of the largest Radio Shops in Adelaide. In October 1924, it draped an enormous calico sign across Rundle Street, the main street in the city, advertising the sale and also advertised in the local technical weekly magazine. The company proposed to sell 15 single valve reflex receivers and 10 two valve receivers at 'ridiculously low prices' to make room for new stock. The receivers had been a sample shipment imported from a manufacturer in England built to the Australian Sealed Set Specifications. They contained high quality components including Igranic transformers, Dubilier fixed capacitors, Ormond variable capacitors and Cossor valves. The public response to the sale was beyond expectation and when a delayed shipment of four and five valve receivers arrived a month later they were also heavily discounted and there was a queue of people stretching a whole block waiting for the shop to open.

When Alick Clarke became Manager of the Radio Department of Harris Scarfe Ltd in Adelaide in 1925, he discovered an unopened consignment of 'sealed sets' in the company warehouse and after discussion with company management, it was decided to donate the receivers to the YMCA Radio Club where boys under guidance of Roy Cook the Club's Instructor, modified the sets to enable them to operate across the band.

It is of interest that Adelaide was not one of the three cities where broadcasting stations were to be established under the Sealed Set Scheme but such was the faith in Australia-wide reception from Sydney, Melbourne and Perth stations, and the extensive publicity being given by the daily newspapers and the technical press about performance to be expected from the AWA 5000 watt transmitters, that businessmen with spare capital were prepared to invest in building up stocks of receivers for sale to an eager public.

Lance Jones, the Manager of the Adelaide Radio Company was a delegate at the 1923 Conference representing the interests of South Australian business and listeners, and apparently was prepared to commit his company to building up a large stock of Sealed Sets. Jones was also a driving force in seeking the establishment of a station in Adelaide. He had been an experimenter since before the First World War and later became an active broadcaster on the 200 metre band. He was also Consultant to Mr E J Hume a local businessman who was keen to establish a station in Adelaide. Mr Hume began negotiations with the PMG's Department early in 1923, as he believed radio had great potential, especially in the fields of culture and education. He was granted an Interim Permit in early 1924, and Lance Jones who held callsign 5DN for a transmitter at the Rundle Street office of the Adelaide Radio Company transferred his experimental station to Mr Hume's residence and so founded the first broadcasting station in South Australia.

The Postmaster General convened a second public broadcasting Conference during April 1924 in Sydney in an effort to develop an alternative broadcasting policy that did not include a Sealed Set Scheme and which would provide a role for Commercial broadcasting stations.

The Chairman was Major Charles Marr, a Member of the House of Representatives and a former Engineer and Army Officer with experience in wireless telegraphy technology. Charles Marr was educated at Sydney Technical College and joined the New South Wales Public Service in 1896. He was appointed Junior Assistant in 1899 in the Post Office and transferred to the PMG's Department on formation of the Commonwealth in 1901 and later became an Engineer in the Department. He supervised the construction of the Pennant Hills wireless telegraphy station POS (later VIS), which was commissioned on 19 August 1912. It was the third Coast Radio Station to become operational in Australia.

Marr had been involved in Army activities as a School Cadet for some seven years and in 1898 joined the volunteer Forces and served in an Electrical Company. In 1912, he commanded a Signal Troop and by 1914 was a Lieutenant with the Royal Australian Navy Wireless-Radio Service. He enlisted in the Australian Imperial Force in the Australia and New Zealand Wireless Squadron in April 1916, and in May embarked for Mesopotamia where he was acting Commander and Major from September until the end of the campaign.

After the War, he entered Parliament as MHR for Parkes becoming Government Whip 1921-25, and subsequently held a number of Ministerial posts. He was knighted in 1934. In 1941, Sir Charles was a member of the Joint Committee on Broadcasting which was given the charter to investigate whether control of broadcasting should be altered and whether the service provided by the ABC and Commercial stations was adequate.

On 11 July 1924 Prime Minister Bruce tabled new Broadcasting Regulations which created two categories of stations designated A Class and B Class. There was also a third class designated C Class which was for the provision of programs by large sponsors or advertisers. However, no C Class licences were ever issued.

The payment for a single licence enabled a listener to tune-in to any station. The ground work was thus laid for the introduction of the unique dual system of broadcasting in Australia. The Regulations were approved on 17 July.

The A Class stations which were licensed for a period of five years received the main portion of their revenue from listener's licence fees with the sum so collected by the Government being apportioned to the stations established in the States from which the revenue was collected.

The Government was anxious to see the extension of broadcasting beyond the metropolitan areas and the Regulations stipulated that the licensees of A Class stations should establish relay stations in country centres, if required.

It is of interest that the A Class stations were not denied the broadcasting of advertisements from which revenue might be derived, but there were some restrictions imposed on the extent of such advertising. The B Class stations received no support from the Government and were expected to pay their way and operate as a business by paid advertisements.

After the commissioning of 2BL, 2FC, 3AR and 6WF, other stations soon followed. These were 3LO which went to air on 13 October 1924 with an AWA 5 kW transmitter feeding a squirrel cage antenna supported by two 60 m high steel masts; 5CL which went to air on 20 November 1924 with a temporary transmitter employing two 240 watt valves in the final stage pending the installation of its 5 kW AWA transmitter; 7ZL which began transmission on 17 December 1924 on a temporary power of 250 watts and 4QG owned and controlled by the Queensland Radio Service, a sub-Department of the State Government began transmission on 27 July 1925 using a temporary 600 watt transmitter, pending the installation of its AWA 5 kW model.

The temporary installation of 4QG was located at the Executive Building, George Street, Brisbane. As the mains power supply was direct current, a motor/generator set was installed to provide alternating current for the transmitter. The unit was loaned by Professor Hawkes and Dr Boyd of the University. The Director, John Robinson vacated his office to enable a temporary studio to be set up.

The transmitter was installed in a temporary building erected by the Department of Public Works in the courtyard of the building while the T type aerial with counterpoise was supported on the building roof by two poles with the feeder dropping down to the transmitter at ground level via a lead-through porcelain insulator. Syd Newman AWA Engineer installed the unit and put it to air. The transmitter cost £1671, with installation costs amounting to £184.

The AWA 600 watt series modulated transmitter was designed and built in the company workshops in Sydney. As manufactured, it comprised three separate units, each of steel frame and lattice construction with control and meter panels being made of bakelite or glass. The first unit housed the rectifying equipment, the second contained the oscillator equipment and the third accommodated the modulating equipment. The transmitter was Serial No 1 and became a standby unit after commissioning of the main 5000 watt unit. In 1930, the transmitter was sold to the Brisbane Broadcasting Co., which used the unit for 4BK which went to air on 29 September 1930 on the top floor of King House, Queen Street. It was subsequently transferred to 4AK Oakey as a standby transmitter, and in 1993 was housed in a museum at Oakey.

Like other stations where the transmitter and aerial were located on the top floor of a high building, the installation of 4QG created a number of problems, not the least of which was getting the equipment up to the installation area. When the 5 kW transmitter arrived in January 1926 it arrived in over two thousand parts. The unpacking, installation, testing and at the same time, operating the temporary installation put a lot of pressure on the station staff. The permanent facilities were installed on the roof of the State Insurance Building at the corner of George and Elizabeth Streets and commissioned on 22 April 1926 on a wavelength of 385 metres (780 kHz). AWA Engineers Joe Reed and Syd Newman supervised the installation and commissioning.

The Queensland station was unique in that it was owned by the State Government which had decided earlier, that wireless broadcasting had such a great future that it really should be a public utility controlled by the State. It set up the Queensland Radio Service to operate the facility. Technical plant establishment cost amounted to £33552, including the temporary station. Even though located in Brisbane, it was expected that the station would be of great value to the rural population. Special arrangements were made with the Council of Agriculture for the supply of full and authoritative market reports daily, and special sessions were set aside during which interesting and important agricultural talks were to be presented for the benefit of the country community. A scheme was also proposed to equip each school in Queensland with a wireless set to receive special educational sessions to be broadcast.

As part of its plan to eventually cover the major populated areas of the State, the Government intended to follow 4QG with a 500 watt station located in Rockhampton. Callsign 4RN and wavelength 323 metres had been allocated, but before work commenced, the Commonwealth Government took over all the A Class stations throughout Australia in 1929 and established the National Broadcasting Service. Fortunately, the provision of a station at Rockhampton was a high priority and a station with callsign 4RK came into service in 1931.

When transmissions commenced with 4QG, the station Director was John Robinson and Technical staff comprised Frederick W Stevens, Chief Engineer, Mr W F Bardin, Assistant Engineer, and Cyril D Moran, Cadet Operator.

John Robinson (Robbie), a former journalist with 'The Sydney Morning Herald', was an expert in Radio Technology, having held an early experimental wireless licence. He received his technical training at the Marconi School of Wireless in Sydney, and in 1923 took up a position as Assistant Manager at 2FC Sydney. He was appointed in late 1924 by the Queensland Government to manage 4QG, and held the position of Director until 24 January 1930 when the Australian Broadcasting Company Ltd took on program responsibilities when 4QG became part of the National Broadcasting Service. Mr Robinson remained with the Company until 1 July 1932 when the Australian Broadcasting Commission replaced the Company. He continued as the station Manager with the Commission until January 1934 when he resigned.

Mr Robinson made a further contribution to the development of broadcasting when he was co-author with Mr G Williams, an Instructor with the Marconi School of Wireless, and produced one of the first books published in Australia on the subject of broadcasting. Entitled simply 'Wireless' and published in 1926, the book was well illustrated with circuit diagrams and photographs. It was popular with Radio Club members as it dealt with complex broadcasting problems in a simple easily understood manner. Overall, the book comprised 25 chapters with 12 illustrations and 60 diagrams of tested broadcast receivers. He also wrote the book 'Broadcasting' which gave a history of broadcasting in Australia and included three speeches which he broadcast over 4QG entitled 'The Divine Spark'.

Another of his ventures into technical writing was as Publicity Officer of the Australasian Radio Relay League, before his shift to Queensland. The Editor of the 'Wireless Weekly', William Maclardy, who was also Treasurer of the League, accepted the invitation of the League for the 'Wireless Weekly' to be its official organ. The President of the Committee was Charles Maclurcan, a well-known Sydney experimenter and Consulting Radio Engineer. The League was modelled on the American Radio Relay League, but never attained the status of that body because of declining interest by the Australian Amateur movement.

Fred Stevens, the Chief Engineer, in addition to being involved in the installation of the temporary 4QG facilities and later the permanent installation remained at the station until it was taken over by staff of the Postmaster General's Department in 1929. In 1927, he was promoted Deputy Director of the station.

After leaving 4QG, Fred took up a position as Manager of the Radio Service and Demonstration Department of King and King Ltd, Queen Street, a Music House but also registered distributor of Stromberg-Carlson receivers and stockists of a large range of radio components. In 1930, he became Chief Engineer of 4BC Brisbane, the first Commercial station to go to air in Brisbane. About 1935, he left the radio industry, subsequently becoming a Pilot with Qantas and later joining the Department of Civil Aviation as Equipment Inspector.

Mr Bardin began his career in radio as a Wireless Operator at the Coast Radio Station at Townsville after being interested in the technology for many years. He was an active experimenter and operated Amateur station A4AB and joined 4QG to be involved in the installation of the temporary facility pending the installation of the high power transmitter and the studios. He subsequently left 4QG and in the early 1930s was on the Technical staff of Commercial station 4BH.

Cyril Moran left 4QG to work at 4BH about the same time as Mr Bardin. He started at 4BH as Assistant Engineer and was still on the staff at the outbreak of the Second World War in 1939.

These were all A Class stations, but a number of B Class stations were soon broadcasting. By December 1925, the eight A Class stations had been joined by nine B Class stations. These were 2BE Sydney, 2UE Sydney, 2HD Newcastle, 2UW Sydney, 5DN Adelaide, 3UZ Melbourne, 4GR Toowoomba, 2KY Sydney and 2MK Bathurst. Station 2BE ceased operation in April 1929 and 2MK closed down in 1930. All the others were still in operation at 1990 but some subsequently closed down to take out FM licences.

Station 2SB was not the only station that had an initial callsign problem. Central Broadcasters Ltd, in Adelaide were allocated callsign 5AB for its Grosvenor Hotel installation in Adelaide. The company was reluctant to use the allocated callsign and requested 5CB as being more identifiable with their name Central Broadcasters Ltd. However, this callsign was already in use by an electrical firm in Adelaide, Newton McLaren Ltd, and two days after the station went on air it was allocated 5CL. This satisfied the company as it was at least a combination identifiable with the full title Central Broadcasters Limited.

THE 1927 ROYAL COMMISSION ON WIRELESS

The infant broadcasting service was subjected to far more criticism than praise. The daily press, together with the technical press, bombarded the Government and station management with an unbroken stream of articles prepared by journalists, technical experts and disgruntled citizens. Groups of concerned people banded together to form organisations in order to put pressure on the authorities and station owners. They all seemed to have one aim — the establishment of a Royal Commission or at the very least, a select committee to investigate the position of broadcasting in relation to the efficiency of the distribution of revenue collected from listener's licence fees; the real ownership of the A Class stations; whether ownership by large vested interests in the entertainment industry would lead to a restraint or hampering of radio as a competitive institution; the adequacy or otherwise of listener's and dealer's licence fees; the question of Royalties to copyright owners and patentees who between them claimed about 40% of the revenue, and other issues.

In December 1926, Acting Prime Minister, Dr Earle Page, announced that the Government had decided to appoint a Royal Commission to inquire into wireless in Australia. In selecting members of the Commission, the Government did not include any person directly involved with broadcasting or other related technology, such as radio communication. The Chairman was John Hammond KC, with other members being Sir James Elder, John McMaster and Claude Crocker (President of The Institution of Engineers, Australia).

The terms of reference of the Commission were:

1. To inquire into the report on wireless broadcasting within the Commonwealth in all aspects, making recommendations as to any alterations deemed desirable in the policy and practices at present in force.
2. To inquire into, and report on the development and utilisation of wireless services for public requirements within the Commonwealth.

The Commissioners assembled in Melbourne on 5 February 1927 for the purpose of considering the necessary arrangements for the conduct of the inquiry.

At its first sitting, the Chairman announced that the Commission would deal with the following:

- Broadcasting station finances.
- Available revenue and distribution thereof.
- Copyright and patent royalties.
- Licence fees.
- Programs.
- Scientific research and schemes of education.
- Land and coastal wireless stations.
- Weather forecasts.
- Country districts and relay stations.
- Defence, naval, military and air.
- Police, town and country.
- Fire prevention.
- Lighthouses and radio beacons.
- Present control and future development of wireless.

These present represented various broadcasting stations, wireless companies and wireless traders.

The meeting was adjourned and opened in Melbourne on 8 March and during some 50 public sittings which were held, about 165 witnesses were examined. The work of the Commission attracted a great deal of public interest and attention with considerable publicity being given to the evidence presented by the various parties and individuals.

Witnesses were examined from all parts of Australia and the views of country listeners were ascertained. In addition, companies operating the A Class stations and B Class stations; Amalgamated Wireless (Aust.) Ltd; Radio Dealers Association; Association for Development of Wireless; Performing Rights Association and the Listener's League were represented, and assisted in the investigation.

Comments by some of the South Australian witnesses when hearings were held in that State, are typical of those expressed by witnesses in other States.

- Mr A L Brown, General Manager, Central Broadcasters Ltd, operators of A Class station 5CL gave a detailed account of its negotiations with AWA for transmitting equipment. He expressed concern about the high Royalty charges and urged the Commission to recommend relief from the AWA Royalty charges which amounted to 20% of the gross income of the company.
- The Manager of Sport Radio Broadcasting Company Mr C R Brown, who operated B Class station 5KA, told the Commission that broadcasting transmitters should be located 10 miles (16 km) from the city. He also said that interference from howling receivers was a problem and regenerative types should be prohibited and not licensed.
- The representative of the Wireless Institute, Arthur Cotton, asked that Amateurs be allocated specified wave bands which would not interfere with other stations. He also requested that Amateurs be permitted to use 500 watts with their transmitters and be allowed to broadcast on the same wavelengths as broadcasting stations when the latter were not transmitting.
- Mr F A Pennington speaking on behalf of the Radio Dealers Association, suggested that all A Class stations should be widely separated in wavelength and that the operation of receivers be kept simple so that any listener could tune in a station easily. He said some receiver tuning operations were so complex that a Science Degree was necessary in order to fully understand their tuning technology.

  He was critical of the licensing system, pointing out that dealers were required to take out a £5 licence to operate a set at their usual business address and a £5 licence for each traveller who might be sent to the country seeking sales of receivers. He considered the one licence should cover all employees of the business. Another matter he raised was the restrictions placed on the demonstration of receivers for sale. The Association considered that leaving a receiver in the home of a prospective buyer which was the most effective way of securing a sale should not be an act of grace but a right enjoyed by the trader under the law. A further handicap to wireless was that a listener's licence applied to a particular place and should the licensee wish to take the set on a holiday trip or to a friend's home, the owner had to obtain a permit in advance. He felt there should be no more difficulty in moving a wireless set than in moving any other personal possession.
- The Managing Director of 'The News' told the Commission that his company was concerned with the way stations obtained their news items. He said some broadcasters stole the news collected at great cost by the newspapers.

After hearing evidence in all States on the matter of broadcasting and the provision of relay stations to country centres, the Commission came to the conclusion that very little change to the system in existence was desirable. The broadcasters had to pioneer the development of radio as applied to entertainment and the transmission of popular programs of music and other items, and in the majority of cases the station owners had carried on their operations at considerable financial loss.

The evidence disclosed that a large proportion of listeners were enjoying the advantage of wireless by means of crystal sets. In Adelaide and Melbourne, the Radio Inspectors estimated about 60% of listeners possessed crystal sets. Another large section utilised cheap valve sets employing one or two valves with regenerative circuits. The range of reception of these types of receivers was limited and the larger station owners recognising that many persons in the country would be induced to take out listener's licences if the cheaper types of receiving sets would enable them to enjoy the advantages of broadcasting, were considering the establishment of relay or regional stations in the vicinity of the more densely populated country centres. However, cost was a major factor and those companies operating at a loss with city stations were not keen to invest in capital and incur further operating costs for relay stations.

Much evidence was submitted dealing with the relative merits of high power metropolitan stations as against relay or regional transmitters but the evidence established that the former would not enable many country listeners to utilise crystal receivers.

At the time the Commission heard evidence, there were 2797 licensed Dealers throughout Australia. Evidence put before the Commission suggested that a number of Dealers had no knowledge of the Technical side of the receivers they were selling and the legitimate Dealer complained of competition from backyard set constructors who had no overhead expenses to meet, and offered no guarantees on performance.

Suggestions had been made that Dealers should pass an examination to qualify for a licence and that they should only be permitted to sell receivers which had been stamped with the approval of some central authority. However, the Commission was of the opinion that the more healthy competition and the greater freedom permitted, the better it would be for the public.

The Commission found that the demands by Amalgamated Wireless (Aust.) Ltd for patent Royalties both on broadcasting stations and radio traders were a constant subject of discussion. The evidence disclosed that the operations of the company extended over every field of radio and created considerable friction and dissatisfaction. The company had become legally entitled to a large number of patents and it had been claimed that no valve receiving set could be manufactured without utilising one or more of the company's patents and likewise, no broadcast transmitting station could be lawfully operated without a licence from the company. The Commission further observed that even in cases where AWA has sold and erected transmitting stations to broadcasting companies, the contract insisted upon by AWA included an obligation on the part of the broadcasting company to pay Royalties on patents employed in the equipment sold and erected by AWA. The Royalty demanded by AWA from A Class broadcasting station operators was five shillings for every listener's licence, amounting to 20% of the station's gross revenue from licence fees.

The Commission considered the Royalty demanded was entirely out of proportion to the capital cost of the equipment in respect of which it demanded. In the case of 5CL Adelaide, the price of the plant supplied by AWA was £7240 and the Royalties demanded or paid during 1926 amounted to a staggering £4025. The Brisbane station 4QG paid out more than £5000 in Copyright and Royalty fees in a ten month period.

The Commission presented its report to the Government on 14 July 1927, and it was made public during October 1927.

One result was a new arrangement with AWA under which the broadcasting companies and traders were not required to pay anything to AWA — at all events for a period of five years — but the company was to receive three shillings per annum from each listener's licence fee.

In October 1927, the Prime Minister, Mr S M Bruce, convened a Conference in Melbourne attended by representatives of the A Class stations to consider a number of important issues raised in the Report.

One of the recommendations of the Royal Commission was that an Australian Wireless Committee be appointed to control radio in general within the Commonwealth. The Conference unanimously opposed the recommendation claiming that the Wireless Branch of the Postmaster General's Department had controlled radio so effectively and efficiently in the past that no change was justified.

When the Commission handed down its Report in late 1927, there were 20 broadcasting stations in operation throughout Australia, comprising 8 A Class stations and 12 B Class stations with 3 of the B Class being located in country regions. Although a number of individuals and group representatives appeared before the Commission putting forward requests for the expansion of broadcasting stations into country regions, particularly for A Class stations, it is evident from an examination of the many letters written by country listeners to newspapers, technical magazines, Radio Inspectors and the owners of existing broadcasting stations that there were many listeners in far away places enjoying the benefits of broadcast programs, particularly programs which were typically broadcast during the Evening Session program times 6.30 pm to about 9 pm with some Saturday night programs going until about 11 pm. Typical is a letter written by a listener from far away Mosman in North Queensland to the Editor of 'Queensland Radio News' complaining about the increase in distortion being experienced with reception of 4QG Brisbane, the nearest broadcasting station. The writer explained that there were eight receivers in operation in the Mosman district and they had for some years received 3LO, 2BL, 5CL and also 4QG 'quite clear' and at good strength, but in recent months, distortion of 4QG had increased considerably. He sought an explanation as to why this had occurred.

There were also at the time, many Radio Shops and even manufacturers in remote areas making a reasonable business from the radio industry. One of these country manufacturers was Messrs Saville and Co., Charleville in western Queensland who manufactured Eureka receivers for listeners in the country.

A considerable number of submissions were presented to the Commission on the aspect of power of broadcasting stations and the method used to calculate this power for licensing purposes. Several Technical experts questioned the method of determining the power of a transmitter and several methods were suggested, but some were not practicable.

Although station Engineers commented that the practice being used in Australia at the time was far from ideal, it was nevertheless the same technique being employed in many overseas countries.

The official method used by the PMG's Department for licensing purposes, consisted of determining the input power in watts to what was known as the 'high frequency generator circuit'. The product of the volts applied to the anode element and the anode current was used as the rating of the transmitter, in watts.

The same method was used in England and most European countries where broadcasting services had been established, but in the USA, the power input to the Main Oscillator was measured, and half that measured power was taken as the rated power of the station, it being assumed that 50% of the power was transferred to the aerial and the rest lost in the aerial circuit components.

One Technical expert indicated to the Commission that a fairer method would be to measure the energy available to the listener. He suggested that this could be done by measuring the electric field strength intensity in millivolts per metre at a specified distance from the transmitting station, such as one mile, to indicate the efficiency of the transmission system overall.

However, Engineers had to wait until 1929 when a decision handed down by the CCIR, introduced a definition of rated transmitter power for use world-wide.

The Government decided to acquire all the A Class stations on expiration of their licences. Expiry dates were 2FC Sydney, 16 July 1929; 2BL Sydney, 21 July 1929; 3LO Melbourne, 21 July 1929; 6WF Perth, 21 July 1929; 3AR Melbourne, 7 August 1929; 5CL Adelaide, 13 January 1930; 4QG Brisbane, 29 January 1930 and 7ZL Hobart, 13 December 1930.

THE 1929 PLAN

With the establishment of the National Broadcasting Service in 1929, the Post Office which had been given the task of planning and providing for the technical facilities, took immediate steps to expand the service to country or regional centres. The plan envisaged the ultimate establishment of up to 30 stations. In 1980, when the ABC celebrated its Golden Jubilee, there were 92 MF stations in service.

Commercial stations whose continued operation depended on the support of paid advertisements had an uncertain period of development. However, they gradually became more popular with the listening public and more widely appreciated by advertising interests, as a valuable publicity medium. As a result, more people were prepared to finance the establishment of new stations and the demand for licences increased considerably. In 1931 alone, fifteen new Commercial stations began operation.

This made it necessary for the future technical development of both the National and Commercial services to be carefully planned in order that the best use could be made of the available channels and that listeners could be assured of good quality reception with the minimum of interference.

The planning process involved the consideration of a wide range of subjects including the following:

- Population disposition throughout Australia.
- Determination of the most suitable location of transmitting stations to ensure the satisfactory reception of at least one National and one or more Commercial programs.
- The topography, physical features and soil conductivity of the areas to be serviced.
- Typical types of broadcast receivers in use or readily available from manufacturers or distributors with due regard to sensitivity and selectivity.
- The transmitter power into the aerials necessary to provide primary and secondary coverage in the areas the stations were intended to serve.
- The allocation of carrier frequencies, taking into account the above factors and including the sharing of channels.

The primary service area required that the ground wave be relatively strong as compared with any interference present and also that it be several times the strength of any sky wave present. The primary service area was as a general rule smaller at night than during the day.

The secondary service area, depending as it did on the sky wave, resulted in poorer quality signal, because both selective and intensity fading were present.

The distance at which the ground wave could provide primary service area coverage was very sensitive to frequency and was much less at the high frequency end of the band than at the low frequency end.

The disposition of the relatively small population throughout Australia and the vastness of the land presented difficulties without parallel in other countries. It meant that more MF stations were required to provide a satisfactory broadcast service to the scattered population than would be necessary if the population were grouped in a smaller more densely populated area.

When the Post Office took over responsibility for the technical aspects of the National Broadcasting Service in 1929, the first action taken in preparing a plan was to initiate a survey of those factors which would have an influence on the propagation of medium wavelength transmissions. Important factors of major concern included the noise level produced by atmospheric electricity (static), the electrical conductivity of the soil which had an important influence on attenuation of radio waves and the ionosphere which, because of reflection and refraction of radio waves, particularly at night-time, resulted in interference to reception at distant points due to arrival of two waves — one along the ground and the other slightly delayed via the ionosphere.

One of the early decisions was to equip a party of Research Laboratories staff with a portable MF transmitter and field strength measuring apparatus for the purpose of undertaking soil conductivity surveys. In the meantime, another group had prepared a tentative layout of the transmitting station sites using topographical, geographical and population distribution maps and statistics. This indicated in broad terms the areas in which one or more National stations should be established.

With the arrival of data from the soil conductivity survey staff in the field, the study became more detailed and the best location for stations in the areas examined soon became evident.

Soil conductivity values vary widely throughout Australia and even in some cases within station service areas. In the case of 3WV in Western Victoria, for example, conductivity in different directions from the transmitter site showed widely different values.

Following settlement of the preferred location for a station site, other factors were then considered. These included availability of access roads for transport of installation materials and later for the operations staff, the availability of public power supply, water, accommodation for staff, telephone trunk route for the program circuit, environmental aspects such as might cause corrosion of metallic parts such as the steel radiator and suitability of the soil for foundations for the building and the radiator.

The selection of sites for Commercial stations had its own problems. Although technical requirements were identical, sites were largely influenced by the availability of organisations prepared to establish and operate the services in country districts.

There were plenty of applications to establish Commercial stations in the Capital cities, but there was considerable reluctance by entrepreneurs to establish stations in country districts where the prospects of obtaining adequate revenue were not as certain. The history of Commercial broadcasting reveals many instances of stations either closing down temporarily or permanently or selling out when they could not attract sufficient revenue to keep operating.

During mid 1925, 3UZ closed down temporarily in response to financial problems and did not resume operations for several months. Station 5DN was kept operating with the private finances of the founder Mr E J Hume. Mr Hume had set out originally to ensure a high standard for the station even though it meant that some advertisements were not accepted. It was his policy not to advertise on Sunday, to investigate the truth of advertisements and to be discriminating in the placement of advertising matter in relation to its suitability to other items being broadcast. Sessions for music lovers were kept free of advertising matter, except for brief announcement of sponsorship where appropriate. Mr Hume continued to inject his own money into the station operations up to his death in 1928.

Some capital city stations which were operating with a reasonable profit acquired small country stations which were in financial difficulty, to establish a network. Such example was 5AD Adelaide which acquired 5PI in Port Pirie in 1932 and 5MU Murray Bridge in 1935. The wheel eventually turned full circle and both 5PI and 5MU again became independently owned many years later.

THE TRANSMITTER ZONE PLAN

In 1930, a plan was prepared by the Department to serve as a guide in deciding the transmitter powers to be allotted to capital city Commercial broadcasting stations. The scale of power was graded in four zones designated Zone A, Zone B, Zone C and Zone D. The plan grouped Sydney with Melbourne, Brisbane with Adelaide, and Perth with Hobart. The zones were approximate circles of increasing radii described about the city with the GPO as centre. An appropriate area for each zone was chosen for each capital city.

In the cases of Sydney and Melbourne, Zone A was an area within one mile (1.6 km) of the GPO and maximum allowable unmodulated aerial power of stations in that zone was 200 watts, Zone B comprising the area between 1 mile (1.6 km) and 8 miles (12.8 km) permitted a power of only 50 watts, Zone C between 8 miles (12.8 km) and 10 miles (16 km) permitted maximum power of 700 watts and in Zone D between 10 miles (16 km) and 20 miles (32 km) the maximum allowable power was 1000 watts. The main difference with the other capital cities was in the radii of the Zones.

In developing the plan, the designers took many factors into consideration including:

- The signal intensity necessary to provide a satisfactory service to listeners.
- The relative magnitudes of the signal intensity from National stations serving the same area.
- The degree of freedom to be allowed to the station operator in choosing the site.
- The advertising value to a Commercial broadcaster of the amount of power allocated.
- The probable effects of ultimately having a number of Commercial stations situated around the periphery of a city, as compared with the effect of concentrating such stations towards a small single area i.e. a Radio Centre.

The reason the planners fixed a lower power — 50 watts — in Zone B arose from the fact that in that Zone was found the greatest proportion of suburban residences where listening in the hours of recreation was at a maximum. It was considered that listeners in this Zone should be protected against the swamping or blanketing that would result from the location of a relatively high power transmitting station in their midst.

The plan called for either adjustment of the powers of some stations, or alternatively their transfer to sites in other Zones as opportunity arose. For example, in Sydney only 2UW was located in Zone A (200 watts) and it operated with an aerial power of 750 watts, stations 2GB with an operating power of 1000 watts was located in Zone B where the permitted power was 50 watts while 2UE, 2KY, 2CH and 2SM all using 1000 watts were scattered over Zones C and D where powers were fixed at 700 and 1000 watts respectively.

The thrust of the plan was to entice the broadcasters to move out to the periphery of cities. It was not welcomed by many broadcasters as they considered that the location of stations in a ring around a city was the antithesis of that which had often been spoken of as the ideal method, namely the establishment of a Radio Centre at which was grouped all the broadcasting stations serving a city and wherein all stations operated on equal power.

The establishment of a Radio Centre in the centre of the city was not a practical situation and would have had many problems, not the least of which was the acquisition of a large area of land, ownership and operating aspects for plant on the site.

However, in later years, the concept of the Radio Centre was partly put into practice, but with the Radio Centre being located some distance from the centre of the city. Some broadcasters pooled resources at sites and shared a building, aerial and emergency power plant. A number were still operating in this manner in the 1990s.

The 5AD and 5KA facility in Adelaide was a typical example. The other Adelaide stations 5DN and 5AA were located on sites in the same general area. In Sydney, nine stations, 2GB, 2KY, 2CH, 2UW, 2SM, 2UE and 2EA as well as two stations, 2UV and 2RPH operating off the 'broadcast band', transmitted from the Homebush area. Only 2CH and 2UW had a shared facility but 2KY and 2EA shared a common site.

THE 1935 PLAN

In the early 1930s, difficulties began to multiply and the planners realised that a revision of the current frequency plan would soon be necessary.

A new plan was prepared and arrangements made to bring it into operation after midnight on 1 September 1935. There were then 71 stations in operation and 35 of them were involved in a change of frequency because of a re-allocation of channels. The planners had hoped that the new frequency plan would have provided for controlled development for six years, after which a further revision would be undertaken. This would have taken the plan up to 1941 but the plan was suspended soon after the outbreak of the War in 1939.

At the end of 1935, there were 73 Commercial transmitters on air using aerial powers ranging from 50 watts to 2000 watts. Some of the stations for various reasons were not transmitting on their maximum authorised power at that stage. Stations operating with 500 watts comprised 19 % of the total while those operating on 100 watts comprised about 23 %. Details are as follows:

- 2000 Watts.
  2GZ Orange, 4AK Oakey, 5PI Crystal Brook and 6WB Katanning.
- 1000 Watts.
  2CH Sydney, 2GB Sydney, 2KY Sydney, 2SM Sydney, 2UE Sydney, 4BC Brisbane, 4BH Brisbane, 5KA Adelaide, 5RM Murray Heights and 6AM Northam.
- 750 Watts.
  2UW Sydney.
- 600 Watts.
  3AW Melbourne, 3DB Melbourne, 3KZ Melbourne, 3UZ Melbourne, and 3XY Melbourne.
- 500 Watts.
  2CA Canberra, 2HD Newcastle, 2KO Newcastle, 2WG Wagga, 2XN Lismore, 3BA Ballarat, 3TR Sale, 3WR Shepparton, 4BK Brisbane, 4GR Toowoomba, 6IX Perth, 6KG Kalgoorlie, 6ML Perth and 6PR Perth.
- 300 Watts.
  2WL Wollongong, 3HA Hamilton, 4AY Ayr, 4LG Longreach, 5AD Adelaide, 5DN Adelaide, 7LA Launceston and 7UV Ulverstone.
- 200 Watts.
  2GN Goulburn, 3AK Melbourne, 3BO Bendigo and 4TO Townsville.
- 100 Watts.
  2AD Armidale, 2AY Albury, 2BH Broken Hill, 2DU Dubbo, 2GF Grafton, 2KA Katoomba, 2LV Inverell, 3MA Mildura, 3MB Birchip, 3SH Swan Hill, 4BU Bundaberg, 4CA Cairns, 4MB Maryborough, 4MK Mackay, 5MU Murray Bridge and 7HO Hobart.
- 50 Watts.
  2MO Gunnedah, 2QN Deniliquin, 2TM Tamworth, 3GL Geelong, 3HS Horsham, 3YB Warrnambool, 4IP Ipswich, 4RO Rockhampton, 4VL Charleville, 4WK Warwick and 7BU Burnie.

A problem that was of some concern to planners and operators of transmitting stations located in the Sydney area, was the excessive number of complaints made by people who expressed the view that reception had deteriorated from about 1930 when the Sydney Harbour Bridge had reached an advanced stage of construction.

Whether the real reason for the deteriorating reception was due to failing batteries, poor aerial systems, bad receiver design, ageing valves or any other reason, it was popular approach to blame the Bridge. Excuses advanced included:

- the massive lattice structure reflected the signals backwards.
- the earthed steelwork caused the signals to be short circuited to ground.
- the structure was large enough to be resonant to the station broadcasting wavelengths, and therefore absorbed the signals.
- signals were picked up by the structure, and re-radiated skywards by the arched top.

However, measurements by the PMG's Department Radio Inspector in Sydney, and some Commercial station Technical staff, did not reveal any evidence that the Bridge had any major effect on signal strength in the Sydney area. One extensive investigation was undertaken in 1935 by Keith Blackwell on behalf of Commercial stations. Keith was Chief Technical Engineer of Ducon Condenser Pty Ltd and had been involved in signal strength investigations over a number of years going back to 1928. He had previously worked with AGE Co., and Philips Lamps Ltd. Keith carried out measurements at 38 chosen sites measuring the signal strengths of 2GB, 2UE, 2KY, 2UW, 2CH and 2SM at each site.

An analysis of the figures confirmed that the Bridge could not be blamed for poor reception at the residences of those who had lodged complaints, but it did reveal one interesting phenomenon. Nearly all stations showed a considerable increase in signal strength under the bridge arch. Only 2KY did not follow the pattern. Many theories were advanced to explain the reason, with one popular theory being that the arch acted as a reflector to direct signals towards the ground.

At sites where signal strengths were shown to be low, the reason could be explained by topographical irregularities.

During the mid 1930s a number of station owners were giving serious consideration to extension of hours to provide unbroken 24 hour transmission. The first station in Sydney to implement the scheme was 2UW Sydney which began 24 hour operation on 22 February 1935 using a 1 kW AWA series modulated transmitter as the main transmitter feeding a tower on the top floor of the State Theatre Building, Market Street in the city. Chief Engineer was Alec Marshall, with other technical staff including Roy Allen, Stan Tonkin, H Buzacott and N Bonnington.

One of the PMG's Department staff who played a major role in development of the 1935 Plan was J D (Jock) Campbell. He joined the Department in 1921 and was a member of the PMG team which operated 3AR when the Department took over the station from Dominion Broadcasting Co. Ltd, in 1929 as part of the plan for establishment of the National Broadcasting Service.

In 1934, he transferred to the Research Laboratories and participated in a wide range of activities including planning of the broadcasting network, frequency standards, measurements, field measurements for siting of transmitters, and the design of transmitters and receivers.

In addition to many overseas visits to attend CCIR Conferences he visited Germany, UK, Italy and Japan in the 1950s and 1960s to oversight and arrange acceptance testing for broadcasting and radio communication equipment manufactured in those countries.

By 1964 Jock had reached the level of Assistant Director General (Radio) in the Department and his area of responsibility encompassed licensing and planning for various radio services and co-operation with Commonwealth countries on broadcasting problems. He retired from the Department in 1968.

Hopes that the planners had of opening up VHF bands with frequency modulation broadcasting were shelved while the nation went about the business of winning the War.

At the time of the outbreak of the Second World War in 1939 there were more than 120 AM broadcasting stations in service with 25 being associated with National service and the remainder

Commercial stations. Some of the original A Class stations which began operation during 1923–25 had undergone modification and upgrading and by 1939 operating powers into the aerial were 2BL, 3000 watts; 2FC, 10000 watts; 3AR, 10000 watts; 3LO, 10000 watts, 4QG, 2500 watts; 5CL, 5000 watts; 6WF, 3500 watts; and 7ZL, 2000 watts. The highest power of Commercial stations was 2000 watts with stations operating with this output including 2CA Canberra, 2WG Wagga, 5PI Port Pirie, 6AM Northam, 3LK Lubeck, 2NZ Inverell and 4SB Kingaroy.

By mid 1941, there were more stations on air than the 96 separate channels allowed, with a result that it was not possible to allocate an exclusive or clear channel to every station. It was therefore, necessary to introduce a shared channel arrangement whereby two or more stations operated on the same frequency. There was at the time, 124 stations licensed and the policy for the distribution of frequencies was:

- National stations were allocated clear channels on the lower frequencies and high power so as to ensure the widest possible area of signal coverage.
- A small number of Commercial stations were allocated clear channels and medium power to cover a comparatively wide area. These included 3BO Bendigo, 4TO Townsville, 6AM Northam, 4AY Ayr, 2KA Katoomba, 2GZ Orange and 4SB Kingaroy.
- A number of Commercial stations were allocated shared channels taking into account the power allotted, the location of the transmitter, the local coverage area and the type of aerial used.

The sharing system, although permitting additional stations to operate, imposed in many cases definite limitations on the powers and service areas of the stations concerned. The power into the aerial which could be authorised was not the only factor to be considered as sharing conditions imposed limitations which were dependent upon the geographical separation, operating frequency, aerial radiation characteristics and the topography of the surrounding country. Even under the best conditions and with such widely separated sites as between eastern and western Australia and even New Zealand, the reliable primary service area coverage was frequently curtailed during hours of darkness. Indeed, the situation has not changed today.

Up until about the 1940s, minimum geographical separation for planning purposes for stations operating on a shared channel basis was approximately 1000 km for 100 watt stations, 1300 km for 500 watt stations and 1600 km for 1000 watt stations. In practice this was not easy to achieve as stations were not equally distributed throughout the continent. At the time when the number of Commercial stations in operation reached 100, about 88 % of the transmitters were locate in the eastern and south-eastern parts of the land.

Determining frequencies for new stations became a major problem and the problem still exists today. To make best use of the 96 channels available, the broadcasting plan as it applied half a century ago allowed for 25 National stations with exclusive frequencies, six reserved for future Nationals, three channels then occupied by Commercial stations to be later transferred for allocation to new National stations, 29 Commercial stations with exclusive frequencies, 24 Commercial stations with shared frequencies, three reserved for future Commercials, four Commercial stations then occupying exclusive frequencies to be converted to shared operation and two channels to be shared by National and Commercial stations.

In determining the radiated power, the policy allowed for powers up to 10000 watts to be approved for National transmitters with the intended coverage area being the major consideration and up to 2000 watts for Commercial transmitters in clear channels and intended to cover a large service area. Commercial transmitters on shared channels intended to.provide only local or district coverage were granted power up to 500 watts. There were, however, some isolated instances where departure was allowed from this policy because of geographical separation considerations.

ONGOING DEVELOPMENTS

The greatest period of expansion of the MF broadcasting network occurred in the 1930s. Between 1930 and 1939 inclusive, 113 new stations were commissioned, although there were some closures. Until the mid 1970s when the VHF FM band was opened up for broadcasting, the MF service expanded slowly with a steady trend towards increased power for both National and Commercial services. However, new stations established in the FM band in recent times has resulted in a growth rate even greater than the halcyon days of MF broadcasting in the 1930s.

Although many inquiries and studies have been undertaken over the years, plans for the broadcasting service have not changed to any great extent. Some of the changes have included increase in power of National stations up to 50 kW; increase in power of Commercial stations up to 5 kW; synchronised operation of selected transmitters; encouragement — at a price — for Commercial MF station operators to transfer to the VHF FM band so releasing frequencies for other services such as transmitters for Parliamentary broadcasts, Print Handicapped services etc.; reduction in channel separation from 10 kHz to 9 kHz; use of directional aerial systems and others.

As at the end of 1993, the number of approved MF-AM radio services comprised 113 National, 16 Community (previously Public), 135 Commercial and 3 Open Narrowcasting. Open Narrowcasting services were mostly limited licences.

A New Band Plan, an initiative if the International Telecommunications Union came into force on 23 November 1978. It required that all MF broadcasting stations in Australia operate with a carrier spacing reduced from 10 kHz to 9 kHz. The new 9 kHz band plan increased the number of MF channels available in Australia by 12. The audio bandwidth of the broadcasting system remained at 10 kHz.

Of the 90 National stations in operation at the time, 78 required changes to the technical facilities. About 14% operated at 50 kW, 30% at 10 kW, 1% at 4 kW, 19% at 2 kW and 36% at 1 kW or less. The frequency shift for many stations was relatively small and it was possible to carry out the work using the existing range of adjustments available with the transmitter, aerial coupling unit, aerial sectionalising loading and off-air receivers, although some component changes were necessary. The major component changes were associated with the carrier generating equipment. The network employed a range of crystals including AWA units with crystal oven, Philips plug-in crystal oven units, D style crystals with crystal ovens and operating at 2 to 4 times the required frequency, glass vacuum ovenless crystals and Sulzer Laboratory Frequency Standard.

At those stations where AWA and Philips units were in operation they were replaced by commercially available package oscillator units using a D style crystal without oven. The unit included a transistor oscillator with frequency divider and power supply.

A change of frequency can be a problem for stations employing directional aerial systems but fortunately of the 12 directional systems in service at the time, although 11 had to be changed, the changes in frequency shift were small. The two Queensland stations 4QO and 4QD which operated in a synchronous mode had to be shifted 55 kHz.

Modern technology with improvements in transmitting equipment performance and receiver design have also assisted the planner in making adjustment to the broadcasting plan from time to time.

The greater employment of directional aerial systems has probably had the greatest impact on enabling more stations to commence operation than previously. Most new stations with authorised powers of 500 watts or greater or existing stations seeking power increases to above 500 watts may be required to install directional aerials with pattern of minimum suitable depth and in specified directions to enable the further sharing of their channel with existing or potential future services.

Of the 262 MF stations operating in mid 1990, 83 or nearly 32 % employed aerials with directional patterns. The over-whelming proportion employed two mast arrays to provide the specified directional characteristics. Typical directional aerials had radiation in the minima reduced by up to 20 dB. This, in most cases, provided the necessary degree of protection to co-channel services at typical co-channel separation. Directional aerials are most effective when bearings to be protected do not coincide with areas to be served. As example, there were five stations operating on 531 kHz — the lowest frequency in the band — and three of the stations 2MC Kempsey, 3GG Warragul and 4KZ Innisfail employed directional aerials with null or minima bearings, to protect 5UV Adelaide and 6DL Dalwallinu, which used omnidirectional radiators.

In some areas in mid 1990s such as Sydney with 11 stations, Melbourne with 11 stations, Brisbane with 8 stations, Adelaide with 7 stations and Perth with 8 stations, directional aerials in such close proximity did not help sufficiently to allow more MF stations to operate in the immediate area. A number of solutions were possible, including slight frequency change which is not a problem for an omnidirectional radiator, synchronised operation of a transmitter with another outside the primary service area or transfer to the FM band.

Whereas initially, the service area of a transmitting station was considered to be the area bounded by a specified signal level contour, e.g. 0.5 millivolts/metre, from 1983, service area had a different definition for Commercial and Public broadcasting services. A broadcaster was granted a single licence to serve a bounded geographic area, determined by the Minister, with whatever number of transmitters might be necessary. The service area concept identified the service an area or town was entitled to receive, and was the basis for planning any service.

The guidelines for negotiating and defining service areas were approved by Minister for Communications, the Hon. Michael Duffy MP on 9 November 1983. The Department issued a book 'Commercial Television and Radio Service Area Maps' which identified the recommended Service Areas for all stations.

In preparing the Service Areas, a number of key elements were taken into account including signal coverage, social and economic links between inhabitants and the major urban centres in the area, topography and others. Between 1983 and 1992 the Department formally determined the service areas of 255 Commercial and Public broadcasting stations.

In addition to minimising interference to Australian stations, there was the matter of co-ordination of MF assignments between Pacific administrations, although Australia and New Zealand have had a bilateral agreement for some time. The 1975 Geneva Plan had formalised this co-ordination procedure for all countries in Region 1 and 3. The Plan was expected to lead to close co-operation in assignment co-ordination and in the long term to the enhancement of the level of service provided by MF broadcasting generally.

Present day technical standards which planners, designers and operators must comply with under the Broadcasting Act are, in most cases, much more stringent than earlier times. However, improvements in technology and measuring techniques make the standards achievable with little problem for both studio and transmitting equipment. Typical performance requirements in recent years included:

- Operating frequency to be maintained within 10 kHz of the authorised frequency.
- Spurious emission to be at least 35 dB below the unmodulated carrier level more than 15 kHz and less than 36 kHz from the allocated frequency and tighter limits beyond 36 kHz.
- Aerial power to be within ± 10 % of the authorised power for an omnidirectional radiator or + 15.5 % or –5.5 % for a directional system.
- Carrier shift not to exceed 5 % at 95 % modulation with 1 kHz test tone.
- The CMF of the aerial for stations operating with power less than 1 kW to be at least 225 V for a 1 kW input and at least 275 V for 1 kW input for stations operating with powers above 1 kW.

The cymomotive force (CMF) is expressed in volts and corresponds numerically to the field strength in mV/m at a distance of 1 km.

In the Broadcasting Services Act 1992, a number of changes were made relative to broadcasting in Australia. The Australian Broadcasting Authority was given responsibility for a wide range of matters related to broadcasting. Some of those of particular interest to Technical people include categories of broadcasting services and planning of the broadcasting services bands.

Broadcasting services have been categorised as follows:

- National broadcasting services comprising services provided by the Australian Broadcasting Corporation, the Special Broadcasting Service Corporation and services provided under the Parliamentary Broadcasting Act 1946.
- Commercial broadcasting services comprising services intended to appeal to the general public and are provided free to the public, and are usually funded from advertising revenue.
- Community broadcasting services comprising services that are provided for community purposes, are not operated for profit and are provided free to the public.
- Subscription broadcasting services comprising services that provide programs intended to appeal to the general public, are made available to the public but only on payment of subscription fees.
- Subscription narrowcasting services comprising services whose reception is targeted to special interest groups, intended for limited areas of service, provided during a limited period to cover a special event and are made available on payment of subscription fees.
- Open narrowcasting services comprising services targeted for special interest groups, intended for limited areas of service, provided during a limited period to cover a special event or provide programs of limited appeal.

In its planning role, the ABA is required to ensure the economic and efficient use of the RF spectrum having regard to demographics, social and economic characteristics within the licence area, the number of existing broadcasting services and the demand for new services within the licence area, technological developments, technical restraints relating to the delivery or reception of broadcasting services and the demand for RF spectrum for services other than broadcasting services.

As part of this role, the Authority is responsible for preparation of frequency allotment plans, development of technical planning guidelines and preparation of licence area plans that determine the number and characteristics, including technical specifications of broadcasting services that are to be available in particular areas with the use of the broadcasting services bands.

Included amongst a number of actions taken by the ABA in early 1993 was the release of frequencies in the AM and FM bands in response to proposals from TABs in each State for specialist channels for racing and betting information. Some of the early channels released for use by the racing industry were AM channels in Wollongong and Newcastle previously used by 2WL and 2NX which had transferred to the FM band. For north and western Queensland, 16 frequencies were allocated for racing services in Queensland, and in Tasmania, the 7HT frequency had been reserved pending transfer of 7HT to the FM band. Racing services were expected to be established in all States, with the rate of expansion being influenced by the demand, availability of channels and the interest of the racing industry.

The demand for licences to operate radio narrowcasting services was so great that in mid 1993, the ABA announced new procedures for allocating licences for high power services. Since October 1992, the Authority had received 640 applications for transmitter licences for narrowcasting.

Under the new system for services designed to cover more than 2 km in urban areas and 10 km in rural ares, the ABA intended to publicise the availability of high power channels and call for expressions of interest to replace the earlier arrangement of first come first served basis. At the time of announcing the decision, the ABA had 40 applications for high power channels to be satisfied. There was also a strong demand for low power (1 watt) information radio services under the open narrowcasting category service. These services provide for restricted coverage of 2 km radius in urban/suburban areas and 10 km radius (with 10 watt transmitter) in rural areas. By end 1993, the ABA had received 800 applications for such services. On 13 November 1993, the ABA announced that it would release five FM channels in the range 87.5 to 88 MHz for these low power services.

For many years the maximum transmitter power allowed for Commercial broadcasting stations has been 5 kW. However, following submissions from a group of Sydney Commercial stations to the ABA, the Authority announced in May 1993 that it may be prepared to licence a substantial increase in transmitted power using day-night switching where the licensee is able to demonstrate that the useable field strength of co-channel and adjacent channel stations will not increase and where adjacent markets remain acceptable.

Consultants representing the Sydney stations Des Foster and Henk Prins undertook extensive studies and were able to show that an increase in daytime power to 25 kW would achieve significant improvement in coverage of the Sydney service area without affecting co-channel and adjacent channel stations.

Much work had still to be done following the Consultants submission.

Australia, like most other countries of the world, is a member of the International Telecommunications Union (ITU) which is an international organisation responsible for the regulation and planning of telecommunications, including broadcasting, world-wide, for the establishment of equipment and systems, operating standards, for the co-ordination and dissemination of information required for the planning and operation of telecommunications networks and services and for the promotion and contribution to the development of telecommunications and the related infrastructure.

Included among the International Conventions of concern to broadcasting to which Australia is party are:

- International Telecommunications Convention, Final Protocol and additional protocols I-IV: Geneva, 21 December 1959. This includes the Radio Regulations of 5 December 1979.
- Regional Agreement concerning the use by the broadcasting service of frequencies in the medium frequency bands in Regions 1 and 3 and in the low frequency bands in Region 1: Geneva, 22 November 1975. This agreement applies only to the MF-AM band and provides that member countries shall adopt for their broadcasting services operating in the MF-AM band, the characteristics specified in the Plan annexed to that agreement.
- Final Acts of the World Administrative Radio Conference for the Planning of the Broadcasting Satellite Service: Geneva, 13 February 1977.
- Final Acts of the World Administrative Radio Conference: Geneva, 5 December 1979 and which introduces new Radio Regulations.
- International Telecommunications Convention with Final Protocol, additional protocols and optional additional protocol; Nairobi, 6 December 1982. It imposes obligations on Australia in relation to the rational use of the radio frequency spectrum and operating stations in such a manner as to not cause harmful interference.
- Final Acts of the Second Session of the World Administrative Radio Conference for the Allocation of High Frequency Bands Allotted to Broadcasting: Geneva, 8 March 1987.

With regard to radio frequency management in Australia, this became the responsibility of the Spectrum Management Agency (SMA) as from 1 July 1993. The Agency was a Commonwealth statutory agency operating independently within the Communications portfolio. In 1997, SMA became part of the Australian Communications Authority.

Compared with the rapid speed of progress in many other areas involving electronics technology, some observers have expressed concern at the comparatively slow rate of advancement into new fields by radio technology. However, major changes cannot be rapidly implemented particularly where it concerns investment in new costly equipment by the radio listening public.

At least four levels of adoption must be approved in many cases. They include approval by the Commonwealth Government on the recommendations of the Australian Broadcasting Authority; acceptance by the broadcasters who may have to inject considerable capital expenditure; acceptance by the broadcast manufacturing industry to design and promote the new technology, and most importantly, adoption by the listening public.

All four levels of adoption are essential for the introduction of a new technology to be successful. The introduction of AM Stereo broadcasting is a case where a new technology has not been as successful as many had hoped mainly because the receiver manufacturing industry was only lukewarm to the scheme, and the buying public decidedly cool to the introduction of the new technology.

THE 1993 PLAN

With the creation of the Australian Broadcasting Authority in accordance with the Broadcasting Services Act 1992, the Authority assumed some of the powers and functions of the former Australian Broadcasting Tribunal and the Station Planning Branch of the Department of Transport and Communications in relation to Commercial and Public (Community) broadcasting services.

In its role of planning broadcasting services which occupy the existing AM radio band, the FM radio band and the spectrum allocated to VHF and UHF television broadcasting services, the Authority is concerned with the efficient allocation of the available spectrum resource to best serve the broadcasting needs of the nation in accordance with assessed needs.

Prior to the establishment of the ABA and introduction of the Broadcasting Services Act 1992, the planning procedure was in essence technology driven. There was no such plan as a Public Master Plan for Broadcasting. Planning was undertaken by Engineers in response to request for establishment of a new broadcasting service or change to an existing service. There was no public involvement in the planning decision-making process. Under the ABA charter, the planning task must be undertaken through a process of public consultation in which all submissions and material used in determinations are available for public scrutiny.

The planning and licence allocation for a broadcasting service involves a multi faceted approach comprising determination of Planning Priorities, preparation of Frequency Allotment Plans (FAPs) and preparation of Licence Area Plans (LAPs).

* **Planning Priorities**

The Authority made an initial call for public submissions on the priorities for planning of broadcasting services in December 1992 with a Draft being released for public comment in May 1993.

In September 1993, the Authority produced its publication 'Planning Priorities 1993' in which it outlined priorities for planning broadcasting services throughout Australia over the following three years. With the framework in place, work began on detailed planning to develop and improve broadcasting services.

The plan divided the country into planning areas with the areas being in five priority groups. The plan was to consider priorities between quite large areas (zones) rather than individual towns or communities. The basis for this hinged on the fact that spectrum planning in one area has implications in terms of interference and channel availability for adjacent areas.

These larger planning areas also allowed consideration of all planning issues across existing service areas at the same time, rather on several different occasions during which changes could have occurred.

Having divided the country into zones, the Authority based its priority decisions between those areas and between spectrum, on consideration of a number of factors among which was the relative abundance or lack of existing broadcasting services. This enabled remote areas of the nation where there may be no, or very few stations, to receiver a higher priority than large cities which may be relatively well served by local services or from nearby centres.

In supporting the plan, the Authority indicated that it had given considerable weight to public submissions and to expressed demands for new services. In examining need and demand, it took account of submissions and demographic, social and economic factors.

There were 23 radio planning zones defined as follows:

- R1-Remote Australia including remote areas of Queensland, New South Wales, Northern Territory, South Australia, Western Australia and offshore islands. These areas are currently served by satellite services.
- R2-Northern Queensland.
- R3-Central Coast Queensland.
- R4-Darling Downs.
- R5-Brisbane, Sunshine Coast, Gold Coast, Richmond/Tweed and Gympie.
- R6-Hunter and Northern New South Wales.
- R7-Central New South Wales.
- R8-Sydney and Central Coast New South Wales.
- R9-Illawarra, South East New South Wales and Australian Capital Territory.
- R10-Murrumbidgee/Riverina.
- R11-Albury, Shepparton and Wangaratta.
- R12-Gippsland.
- R13-Northern Tasmania.
- R14-Hobart/Southern Tasmania.
- R15-Melbourne and Geelong.
- R16-Central Victoria and Central Murray.
- R17-Western Victoria.
- R18-South East South Australia.
- R19-Adelaide.
- R20-Spencer Gulf.
- R21-Central and South West Western Australia.
- R22-Perth.
- R23-Darwin and Top End.

As a result of seminars conducted in capital cities to explain the process, some 567 submissions were received from the general public and others. A further 303 submissions were received following the publication and release of a Draft Determination for comment.

* **Frequency Allotment Plans**

All radio services transmitting in the radio frequency spectrum must obtain a transmitter licence under the Radio-communications Act which is administered by the Spectrum Management Agency (SMA). For administrative convenience, the SMA has delegated to the ABA responsibility for issue of licences for transmitters operating in the broadcasting services bands.

Frequency Allotment Plans (FAPs) determine the number of channels that are to be available in particular areas to provide services operating in the broadcasting services bands. It does not cover the HF band.

The plan provides a framework on which the spectrum capacity can be distributed on a national basis to cater for future demand as well as existing services. The number of channels in any area cannot be determined in isolation from the number in other areas, particularly for MF transmissions which have potential for interference during night-time periods with other distant MF services.

The plans do not show actual frequencies.

Factors which need to be taken into consideration in developing the FAP include frequency spacing of services, minimum field strengths for adequate quality reception and protection ratios between operating services.

The first draft FAP plans were released in May 1993 for public comment with the Plans being published on 19 August 1994.

* **Licence Area Plans**

This document determines the number and characteristics, including technical specifications of services operating in the broadcasting services bands that are available in particular areas of Australia.

The LAPs provide the proposed frequency or channel, the maximum effective radiated power for each licensed service and any constraints which may be applicable to particular channels. The plans indicate the nominal sites of existing transmitting stations in order that the integrity of the frequency plan can be maintained.

In order to provide frequencies or channels to satisfy the licence area plan, the ABA will have reserved capacity as notified by the Minister to provide for National and Commercial stations. The Authority may also have made additional reservations of capacity for these services within each frequency allotment plan and licence area plan. Where demand exceeds capacity for Commercial services, the ABA will use a price based allocation mechanism to allocate available licences. In the case of Community broadcasting services where the demand exceeds the available capacity, the ABA will use an allocation procedure for selecting the most suitable applicants.

The Broadcasting Services Act 1992, has for one of its objects the promotion of the availability of a diverse range of radio services offering entertainment, information and education. Narrowcasting services were introduced to help achieve this diversity.

A narrowcast service is one whose reception is limited in one or more specified ways. There are two categories:

- Open narrowcasting whose reception is limited by being targeted to special interest groups, intended for limited locations, to cover a special event or of limited appeal.
- Subscription narrowcasting services which are made available only on payment of a subscription fee.

Examples of narrowcasting services include services established to broadcast a special event such as a grand prix or a festival. They may also be provided to broadcast a sporting event such as a football match or a horse race meeting. Other services may be Tourist Radio, Tiny Tots Radio, Supermarket News and Specials, Farm Service, Market Service and many others.

In mid 1994, the ABA announced that it planned to offer a number of high power AM channels for open narrowcasting services on an interim basis. The channels became available as a result of AM broadcasting stations transferring operations to the FM band. At the time, frequencies were available in Adelaide (1539 kHz); Perth (1206 kHz); Sydney, (1539 kHz); Geelong (1341 kHz); Newcastle, (1413 kHz); Penrith, (1476 kHz); Gosford, (801 kHz); Katoomba, (783 kHz); Wollongong, (1575 kHz); Gold Coast (1197 kHz); Southport, (1593 kHz); Townsville, (891 kHz); and Melbourne, (1593, 1422 and 1116 kHz).

Licences to cover the services were to be issued under the Radiocommunications Act 1992. The Spectrum Management Agency following consultation with the ABA determined the price based system which was to be used by the ABA.

Between July 1994 and June 1995, the ABA approved the issue of licences for 343 low power narrowcasting broadcasting services. Under a new policy adopted in February 1995 for granting of transmitter licences for special events, the ABA issued 110 special event licences for distinct and organised events of major sporting, cultural or community significance prior to end June 1995.

A transmitting licence for an open narrowcasting (ONC) service is issued under the Radiocommunications Act 1992. The Act provides for the determination of a price-based allocation system by the Spectrum Management Agency, although it is implemented by the ABA. As a general rule, the licence is issued to the highest bidder following an auction style allocation exercise if there is more than one bidder. A typical reserve price for each licence is $4000.

The open narrowcasting service is popular with the racing industry. On 15 March 1997, of 39 ONC licences issued by the ABA, all but five were issued to bodies associated with racing and included NSW Race Narrowcasts Pty Ltd (3); TAB Queensland (5); South Australia Totalisator Agency Board (6) and Totalisator Agency Board of Western Australia (20).

Special event or limited broadcast licences have been a feature of the broadcasting scene for some time. A typical example is the licence granted in 1992 by the then Australian Broadcasting Tribunal, to Festival Diary Radio, Adelaide.

The station temporarily established for the 1992 Adelaide Festival, transmitted 24 hours a day from 21 February until 22 March. A 1 kW NEC FM transmitter broadcast on a frequency of 101.5 MHz using an omnidirectional aerial supported by a six metre pole. The station was located on top of Telecom House in Pirie Street and programs were generated in the studios of 5UV at the University of Adelaide. A microwave radio link carried the programs from the studios in North Terrace to the transmitter. The transmitter installation was carried out by Telecom staff including Wayne Croft, Greg Kinnear, Paul Salvemini, Murray Fopp and Peter Tsoulos.

One of the great challenges facing broadcast planners is the future role and expansion of the Community broadcasting service which for over 20 years has occupied a unique position in relation to other services associated with the media.

In planning Community broadcasting services the ABA assumes that the term 'community' refers to a group of people who share a common identity. This may include groups with class or ethnic background, geographical location or who share a special interest. The planning priorities generally provide for highest priority to geographical areas least well served by existing broadcasting services.

In considering an application for a licence, the ABA needs to be satisfied that the group has financial and technical capacity to deliver the service, that a community of interest exists and the group applying for the licence has attempted to foster the establishment of a locally based Community broadcasting service.

At a conference of the Community Broadcasting Association of Australia (CBAA) held in Queensland in December 1996, a number of important issues were highlighted by many speakers. Items of interest included:

- Federal Government financial support to the extent of $4.5 million over three years was assured.
- Community broadcasters had a history of embracing new technology and using it for maximum benefit and efficiency.
- The Government was committed to the development of the Internet-based Community Access Network (CAN) and an online Community Data Base (CBD) and had set aside funding over a three year period for the development to ensure beneficial information can be disseminated throughout the section and to the wider community.
- The Government was also committed to the further development of the Community Radio Satellite (ComRadSat) service and had ensured funding provision over a three year period. ComRadSat had been set up in 1990 to nationally distribute program material.

As at 20 March 1997, 210 Community broadcasting radio licences had been issued by the Australian Broadcasting Authority. Of this total, 195 operated in the FM band and 15 operated in the AM band. New South Wales and Queensland both had 44 stations in operation, followed by 38 in Northern Territory, 31 in Victoria, 26 in Western Australia, 17 in South Australia, 7 in Tasmania and 3 in the Australian Capital Territory.

STATION ESTABLISHMENT

In the 1920s, during the period of establishment of broadcasting in Australia, technical expertise in the planning and design of equipment and facilities was limited to staff of Amalgamated Wireless (Australasia) Ltd and a few private Consulting Engineers who had studied development overseas. AWA provided equipment as well as installation and commissioning services for the majority of the A Class stations. In later years, the company established and owned a network of Commercial stations and provided technical services and equipment in the establishment of many other Commercial stations.

In the case of early B Class stations, the transmitter powers were low compared with the A Class stations and in the majority of cases were built by the station Chief Engineers using either new equipment or modified Amateur station equipment. From the early 1930s when there was a rapid expansion of Commercial stations, AWA provided technical services and equipment for establishment of many stations.

When the PMG's Department acquired the A Class stations to form the National Broadcasting Service in 1929, its Research Laboratories staff became heavily involved in planning, design and construction activities. Its first project in design, construction and commissioning of a new station at a new site was to replace 6WF Perth. The preparation of specifications and the development of specialised equipment and components for the project set the scene for placing Broadcast Engineering on a highly professional plane. This was the first and only case where the Department undertook a complete turn-key project, including the manufacture of the equipment.

In the establishment of subsequent stations, the Department confined its activities to the purchase of major equipment, including the transmitter, and for installation work to be undertaken by either Departmental staff or under contract.

The cost today of establishing a new large broadcasting station or relocating to another site, because of a number of reasons, is very high. The various costs associated with the planning and design aspects in order to determine the best location, taking into account the availability of suitable land for the transmitting station and in assembling information and data for the licensing authority, specification preparation and tendering, form a large proportion of the overall budget.

In one recent exercise concerning a feasibility study of relocating a group of metropolitan broadcasting stations, the preparation of the plan alone was undertaken by a communications consultancy company which specialised in advice, feasibility studies, research and strategic analysis in broadcasting and other communication fields. In addition to four technical Consultants who provided specialist input on Broadcast Engineering and planning aspects, other specialists undertook studies in demographic and related statistical matters, broadcasting policy and regulatory issues.

The preparation of a proposal in past years, often involved a number of complex financial, legal, regulatory and technical issues. For a new MF transmitting station proposal, the Technical Consultant's report usually covered in appropriate detail, such matters as the following:

- Transmitting site location including parish map with site indicated thereon; latitude and longitude of the radiator/s; the population within a radius of one, two and four kilometres respectively of the site for powers up to 5 kW; map indicating the calculated 0.5mV/m contour and population within the contour; a suitable survey map showing location of the site; a report on site suitability covering site elevation, topography, soil borehole log, nature of the soil and terrain generally at and immediately adjacent to the site, airports in the vicinity, ownership of the site, availability of program and telephone circuits, radio and radar installations nearby, environmental considerations which may influence equipment performance and reliability; availability of commercial power to meet in full transmitter requirements; accessibility of the site; transportation, meteorological data including 10 year figures on temperature, humidity, rainfall, isoceraunic level, wind velocity and probability of flooding or erosion with heavy rain.

- Transmitting site layout drawing to scale, showing equipment and other buildings; power mains feeder path; aerial system including foundations; station earth mat system; transmission line and aerial coupling unit and site security fencing.
- Aerial system (omnidirectional type) details of type of aerial; planned or assumed frequency of operation; principal structure details; height of structure above ground; top loading and/or sectionalising including its effective magnitude in degrees; aircraft warning, painting and lighting; windspeed loading design figure for structures, type and configuration of transmission line; height of transmission line above ground; circuit diagram of transmission line to aerial coupling unit; lightning protection facilities and details of earth mat system including number of radials, materials, wire diameter, depth of burial of wire in the ground.
- Aerial system (directional type) where specific requirements regarding directivity were known the report would detail calculations substantiating the electrical design; the number of elements in the system; the spacing between elements and the orientation of the system with respect to true north; the relative amplitude and phase of the current in each element; the horizontal polar diagram of the system; the method of monitoring and maintaining the relative magnitude and phase of the current in each element and the same information about associated facilities including the power dividing network and transmission line as required for an omnidirectional system.
- Equipment buildings on scaled drawing illustrating the external appearance of the building; building earth system; location of the power substation; floor plan layouts and location of the equipment; major duct and chase runs; a general description of the type of construction, room shielding, sound insulation, acoustic treatment, lighting, ventilation, air-conditioning, staff facilities, emergency power plant, fire protection facilities and security arrangements.
- Transmitter and associated facilities listing the equipment and facilities supplemented by performance specification; a block diagram illustrating the interconnection between units; equipment safety features; emergency program facilities; in-built fire protection equipment; testing equipment; dummy load details; program input equipment; remote control facilities; transmitter and aerial metering; spare parts stock and staffing arrangements.

The extent of detail assembled in the Consultants report would be governed by the size of the station, the requirements of the licensing authority, whether the station was to be constructed as a turn-key project, or fully or partly by station Technical staff and the extent of sub-contracting for various sections of the work.

New regulatory arrangements in the form of 'Technical Planning Guidelines for the planning of individual services that use the Broadcasting Services Band' issued by the Australian Broadcasting Authority, became effective from 10 August 1995.

Advisory information related to planning broadcasting services is outlined in 'Australian Broadcasting Planning Handbook', also published by the ABA. The guidelines replace 'Technical Planning Parameters' published in 1992 by the Department of Transport and Communications. The handbook sets out acceptable methods of computing field strengths from transmission systems and other parameters for determining compliance with the guidelines, and other specifications of the transmitter licence.

For the purpose of the guidelines, MF AM radio services are those operating in the frequency range 526.5–1606.5 kHz with each channel designated by its nominal carrier frequency and with 120 MF AM channels being spaced at 9 kHz intervals in the range 531 kHz to 1602 kHz inclusive. VHF FM services are those operating in the frequency range 87.5 MHz–108 MHz with each channel being designated by its nominal carrier frequency and channels spaced at intervals of 200 kHz from 87.7 MHz up to and including 107.9 MHz.

The licence area for national services is assumed to be equivalent to the coverage area within the 0.5 mV/m ground wave for MF AM services and within the 54 dBuV/m contour for VHF FM radio services.

The technical characteristics which the ABA Licence Area Plans prescribe, taken with the ABA Technical Planning Guidelines, provide a non-negotiable 'envelope' of technical parameters and procedures within which the licensee must do their detailed planning.

The Technical Planning Guidelines concerned with radio broadcasting are divided into a number of Sections including:

- Start Up Procedure which requires anyone planning to establish a new station or change the technical specifications of an existing transmitter for a Commercial or Community service, must follow a specified procedure to confirm that the transmitter is operating in compliance with the approved specification and the TPGs.
- Change of Transmitter Site Procedure. Where a licensee proposes to use a transmitting site not located at the transmitting site specified on the LAP, the licensee must complete appropriate electromagnetic compatibility calculations for the alternative site to show no interference will be caused to other services.
- MF AM Radio, covering location of transmitter site; Cymomotive Force (CMF); minimum level of service requirements; maximum field strength within the licence area; maximum field strength within the licence area; maximum field strength beyond the licence area; interference to other services; and radiated signal characteristics. The level of signal within the community being served is restricted to a maximum level of 1 volt per metre to prevent receiver overloading.
- VHF FM Radio covering location of transmitter site; required field strength between adjacent frequencies; effective radiated power (ERP); maximum level of service requirements; maximum aerial height; maximum field strength within the licence area; maximum field strength beyond the licence area; interference to other services; radiated signal characteristics; and sub-carrier signals.

Appendices detail Emission Standards for the AM and FM sound broadcasting services.

The ABA has determined that responsibility for compliance with the Technical Specification of a Licence and the Technical Planning Guidelines rests squarely with the licensee, not only for the initial design of the transmitting facility, but also for continuing surveillance of the facility to maintain compliance. The licensee is expected to maintain adequate records of inspections conducted, the technical competence of the testing Engineer and of the particular types of tests conducted, as evidence of due diligence.

The Broadcasting Services Act 1992, has removed responsibility for detailed planning of the service to the licensee. Previously, the licensee was assisted by procedures under which the regulator established all elements of the specification and conducted regular station inspections. The licensee had to do very little other than implement the specification and maintain compliance with it.

Under the new arrangements, the ABA and/or the Spectrum Management Agency may at any time, conduct or commission on the spot checks to confirm compliance with the licence specifications.

Following the issue of a licence by the ABA for operation at the nominal site, the start-up procedure involving test transmissions can be undertaken when installation works have been completed.

However, before commencement of the start-up procedures the licensee has a number of obligations. They include advising ABA and SMA, and placement of an advertisement in the local press at least seven days before commencement of the test transmissions. The press advertisement must include details of who should be advised if there is evidence of interference to reception of other services during the test transmission periods. Should a licensee wish to operate from an alternative site, then the licensee must comply with the technical planning guidelines which relate to change of transmitter site procedure.

LICENCES

Included in the Regulations gazetted on 2 August 1923 in relation to the establishment of broadcasting in Australia were matters concerning licensing of the stations, home receivers and Dealers.

* **Stations**
  Wireless transmission recognises no national boundary and various nations of the world work together under a form of agreement — through the International Telecommunications Union — to ensure freedom from interference.
  In Australia, the Postmaster General's Department administered control and supervision of broadcasting stations under the powers of the Wireless Telegraphy Act and Regulations. In 1992, nearly 70 years after commencement of broadcasting in Australia, the Department of Transport and Communications carried out this function for Government-funded stations, while the Australian Broadcasting Tribunal handled matters involving Commercial and Public broadcasting stations. The Tribunal replaced the Australian Broadcasting Control Board which was established in 1948 to co-ordinate National and Commercial programs, to monitor technical and program standards and to advise the Postmaster General on the allocation of Commercial broadcasting licences.

The ABT was an independent statutory authority established in 1977 to regulate certain aspects of Commercial and Public radio and Commercial television. Included among a series of responsibilities, the Tribunal had power to grant, renew, suspend and revoke licences. The Tribunal did not regulate the Australian Broadcasting Corporation or the Special Broadcasting Service. In October 1992, The ABT was replaced by the Australian Broadcasting Authority (ABA).

Twenty years after the establishment of broadcasting, the fee for a Commercial station licence was £25, irrespective of the location or power of the station or the fact that the transmitter operated on a clear or shared channel.

In more recent times, licence fees for Commercial stations were calculated as a percentage of gross earnings of the stations. Gross earnings were taken as revenue from the sale of air time, less commissions paid to accredited agents. The percentage for all stations throughout Australia in 1988 varied from 0.5% to 6.5%. The Government's share of the Commercial broadcasting industry exceeded $10 million annually. As at 1992, Public broadcasting stations did not pay annual licence fees.

In August 1991, the Government announced that licence fees for Commercial broadcasting stations would be reduced by 50%. The level of licence fees as a proportion of station gross earnings had risen over the years due to a number of reasons, and the Government was anxious to ensure that Commercial stations remained as a stable industry.

The original idea of imposing a station licence fee was to provide a fund sufficient to cover the cost of the PMG's Department administration activities in relation to Commercial broadcasting.

The granting of a licence imposed among other conditions, certain technical operating conditions. The power, frequency and aerial arrangement were fixed by the licensing authority and could not be varied without official consent. Each station had to be designed, equipped and controlled in accordance with rules which had been issued for the guidance of all licensees so that the stations were operated in accordance with Broadcast Engineering principles. Technical inspections were made to ensure that the conditions were fulfilled. Frequency Measuring Centres operated by Government instrumentality staff checked that the station operated on its authorised frequency within a specified tolerance range.

Steps were also taken to ensure that the Technical operating personnel were competent. Operators were required to possess certain qualifications laid down by the licensing authority.

A condition of granting a Commercial station licence was that an initial fee was payable prior to commissioning of the technical plant. At 1990, the fee was $500. During that year, five new Commercial radio licences were issued by the Australian Broadcasting Tribunal.

Under the Broadcasting and Television Amendment Act 1985, all transmitters used by a licensee to provide a service were covered by one licence. Appended to the licence were the relevant service specifications and the technical conditions determined for each transmitter.

Inspection of Commercial stations to ensure that technical, operational and safety requirements were met, was originally carried out by Radio Inspectors of the PMG's Department. This role was taken over by the Australian Broadcasting Control Board in 1949 but until the Board established its own State organisations to undertake the work, the work was performed on behalf of the Board by staff of the Engineering Department of the PMG's Department. The Inspecting team usually comprised an Engineer and a Supervising Technician and included a detailed inspection and performance testing of all transmitters and studio equipment. This arrangement continued well into the 1960s and many people participated in the work. Department staff included Jack Carnell, Des Fulton, Jack Ross, Neil Howard, Leo Moloney, Bruce McGowan, Chris Comas, Doug Sanderson, Gordon Gilbert, Bert Lampe, Wes Graham, Jack Wheeler, Jim Rule, Ron Kitchenn, Ralph Bongers and others.

Until 30 June 1997, the administration of RF spectrum employed for radio broadcasting and indeed, all radio-communications services in Australia, was the responsibility of the Spectrum Management Agency (SMA).

The Radiocommunications Act 1992 which provided for the establishment of the SMA became effective on 1 July 1993, following a public inquiry by the House of Representatives Standing Committee on Transport, Communications and Infrastructure. Head of the SMA was Christine Goode. She resigned in April 1997.

The Act provided for improvements to the administrative system and the introduction of a market system of spectrum management to operate in defined spectrum bands alongside the administrative system.

The SMA was a Commonwealth Agency within the Communications and Arts portfolio and responsible for management of the radio frequency spectrum. The radio frequency spectrum is the basis of the radiocommunications industry which forms part of other complex communication systems and provides an essential transmission medium for tele-communications and broadcasting and other industrial sectors. The Agency's functions include planning the spectrum, licensing and regulating its use, resolving interference issues and managing Australia's radiocommunications interests internationally. In 1997, the SMA comprised approximately 380 staff with Central Office in Canberra and 13 Area Offices throughout Australia.

To facilitate greater consultation with users of the RF spectrum the SMA established a Radiocommunications Consultative Council. Other important factors associated with the system of licensing services and overall management of the RF spectrum include:

- Introduction of a new Technical Standards Framework designed to place greater responsibility on manufacturers and suppliers of equipment for compliance of that equipment with approved Standards; nomination of accredited laboratories for equipment compliance certification and provision of allocation of Apparatus Licences by a price based process.
- Provision of a system of class licensing for specific categories of service or apparatus provided or used within defined conditions.
- Accreditation of persons such as Engineers, Frequency Planners etc., to undertake certain functions previously the sole prerogative of the Communications Department.

The Act also provides for the introduction of a licensing concept known as a spectrum licence and for the Minister to specify certain bodies or organisations which may be regarded as providing a public or community service. Such bodies may then be subject to special conditions such as concessional fees.

Following the establishment of the Australian Communications Authority (ACA) under the Australian Communications Act 1997, from 1 July 1997, the ACA merged the Spectrum Management Agency and AUSTEL with responsibility for competition matters of AUSTEL being transferred to the Australian Competition and Consumer Commission (ACCC). The ACA has taken on responsibility for regulating tele-communications and managing the radio frequency spectrum in accordance with radiocommunications and telecommunications legislation.

The allocation, renewal, suspension and cancellation of licences for broadcasting services is the responsibility of the Australian Broadcasting Authority which was created in October 1992 under the Broadcasting Services Act replacing the Australian Broadcasting Tribunal.

Broadcasting licences are in six categories:

- National (ABC and SBS) broadcasting.
- Commercial broadcasting.
- Community broadcasting.
- Subscription broadcasting.
- Subscription narrowcasting broadcasting.
- Open narrowcasting broadcasting.

Individual licences are provided for Commercial, Community and Subscription television broadcasting services but Class licences are issued for the remainder except the National broadcasters.

Commercial and Community service licences are subject to individual licensing and a higher level of regulation, particularly in relation to control and ownership. Class licensed services including Narrowcasting are subject to lower levels of regulation.

While the systems for allocating Commercial and Narrowcasting licences are the same in principle, there are a number of important differences including:

- Commercial broadcasting services are subject to certain ownership and control constraints while Open Narrowcasting are not.
- Licences for Open Narrowcasting services are governed by a determination under the Radiocommunications Act. The determination is made by the Spectrum Manager but administered by the ABA. The licence allocation for a Commercial broadcasting service is generally a determination made by the ABA under the Broadcasting Services Act.
- Only Australian companies may acquire a Commercial broadcasting service licence, whereas any person whether Australian or not, can secure an Open Narrowcasting transmitter licence.
- Commercial and Community licence renewals are automatically approved subject to the licensee being a suitable licensee, whereas licences for Open Narrowcasting services may be subject to reallocation on the basis of a price in the future.

* **Listeners**

Under the original Sealed Set Scheme of 1923, all receivers had to be of a type approved by the Postmaster General's Department with the sets being sealed for reception of one or more fixed wavelengths. The listeners were required to pay to the Government a fee for each station for which the set was capable of operating, plus a fee fixed by each broadcasting company providing the service.

From 1 August 1925 a new scale of licence fees came into operation. It involved the division of the country into various zones, such as Zone 1, Zone 2 and Zone 3 with a fee being set for each zone. It abolished the need for personal application for a licence. Previously the listener had to apply in person at the local Post Office.

The Wireless Telegraphy Regulations required that a Broadcast Listener's Licence be held in respect of each place in which equipment capable of being used for the reception of broadcast program was installed. The Department interpreted this to mean that a licence had to be held for each family circle.

Of the money collected from licence fees, part was paid to the ABC and the remainder retained by the Department to cover the technical aspects of the National service, the general administration of the broadcasting regulations, the cost of issue and recording of licences and investigations into interference to listener's reception.

The detection of unlicensed receivers was one of the responsibilities of the Radio Inspector and his staff in each State. The presence of a large outdoor aerial was good enough excuse for the Inspector to call and request to see the licence, but they also employed detection equipment employing a sensitive receiver and rotatable loop aerial to home-in on receivers which employed reaction or other circuits which produced signal radiation.

Just before Christmas 1924, the authorities in Sydney prosecuted a large number of people possessing unlicensed receivers and there was a rush by others to pull down aerials before the Radio Inspector appeared along the street next morning.

Commenting on the prosecutions, the Editor of 'Wireless Weekly' said:

> 'If the effect of the prosecutions had been to urge the undetected offenders into obtaining licences, they would have certainly been worth-while, but as the sole result was to drive a lot of people out of the radio circle, it is questionable whether it would not have been more sensible and better for everybody concerned if they had been postposed until next winter. In any case, since a list of unlicensed listeners was available, perhaps the broadcasters could have achieved something more practicable if they had secured a copy of the list and made a direct appeal by mail.
>
> It is reasonable to suppose that most of those who dismantled their aerials to escape prosecution were operating crystal sets which, to them did not warrant a further expenditure of thirty five shillings. But the point is that a lot of those people would today have possessed valve receivers had they been allowed to stay in the game. And, what must be considered now, is that having been scared off, how can they be brought back again and how numbers of citizens who can't afford that extra licence fee on top of the cost of a crystal receiver can be helped along to the enjoyment of broadcasting.'

An alternative to the large outdoor aerial was a loop aerial for those owners of receivers with a sensitive receiver, or people residing close to the transmitting station. A major advantage was that from outside the house, it did not publicise the fact to the Inspector that there was a receiver in the house. The Radio Shops highlighted this point to people who were hesitant about purchasing a receiver because of the additional cost of a licence.

Notwithstanding the wide publicity which had been given to the obligation of listeners to be in possession of a current licence, the Department was reluctantly obliged to continue the distasteful task of locating and prosecuting unlicensed listeners.

In mid 1924, when the Government introduced the concept of A and B Class stations, the Broadcast Listener's Licence fee was 35 shillings per annum for listeners located within 250 miles of an A Class station. This was nearly half a week's wage for a typical male factory worker employed in Sydney. In the case of a boy with a crystal set, the fee amounted to as much as what the parts cost, so it is not surprising that there were so many unlicensed listeners.

The first millionth Listener's Licence was issued by the Department on 30 November 1937. At the time, about 62% of homes had licensed receivers.

From the commencement of broadcasting in 1923 until mid 1941, more than 26000 convictions had been recorded against unlicensed listeners. In 1938, people without a licence were likely to incur a fine of £20 ($40).

Following the establishment of television, a combined television and radio licence was available to people possessing both types of receivers. By 1969, licences had been issued for 2.65 million television receivers and 20000 less for radio receivers.

The licensing system was abandoned in 1974.

One of the Department's senior staff responsible for administering the Regulations associated with radio and television receiver licences was Chris Comas who retired the year the licensing system was abandoned.

Chris entered the Postmaster General's Department in Adelaide on 27 June 1924 as a temporary Junior Mechanic in the Telephone Workshops. On 4 June 1925 he was appointed Junior Mechanic-in-Training, attending the School of Mines as part of the training course.

When the Government acquired all the A Class stations throughout Australia to establish the National Broadcasting Service in 1929, Chris was one the Departmental staff who took over control of 5CL Adelaide. He moved to Crystal Brook with the 5CK installation team in 1932 and after commissioning of the station remained there with the maintenance team.

In 1939, he returned to Adelaide working in various broadcasting areas including 5CL transmitter, ABC studios and the Transmission Laboratory.

During the War years, he undertook many major radio projects for the Services and other Government Departments including the installation of transmitting and receiving stations and direction finding stations.

In 1947 he transferred to the Department of Civil Aviation where he supervised many large works including the International Transmitting Station in Darwin.

After a period with the Weapons Research Establishment, Chris returned to the PMG's Department in 1957 and was associated with broadcasting projects in South Australia and Northern Territory for the National Broadcasting Service and inspection of Commercial broadcasting stations on behalf of the Australian Broadcasting Control Board.

In 1965 he was appointed Superintendent of Radio in Adelaide and occupied that position for nine years until retirement.

* **Dealers**

Even before the Government authorised broadcasting stations began operation in late 1923, the Government kept tight control on the sale of radio components and apparatus through Dealers.

Revised Regulations were issued on 1 December 1922 requiring Dealers to keep a Register of all transactions in wireless apparatus. The authorities hoped that this action would prevent the establishment of 'secret stations' by unauthorised persons.

At the time, experimental licences were divided into two categories — licences for receiving only and licences for transmitting and receiving.

Receiving licences were intended mainly for Technical Schools, Radio Clubs approved by the Controller of Wireless, for instructional purposes and scientific investigation. If an applicant was under age 21 years, responsibility for observance of the conditions had to be undertaken by the parent or guardian. All applicants for a receiving licence were required to satisfy the Controller of his/her technical qualifications to properly control the apparatus and if required, to submit himself/herself to such examination as the Controller may direct.

For a licence to transmit, the applicant had to pass a written and practical examination including one on Morse Code at 12 words per minute.

As a further safeguard, it was stipulated in the Regulations that no person or firm could sell or supply wireless telegraphy or telephony apparatus to any person unless the purchaser produced evidence that he/she was already in possession of, or was about to obtain a licence. All purveyors of wireless apparatus were to maintain a Register of Sales of Goods with the Register being available for inspection on demand by the Controller of Wireless.

When broadcasting began and Radio Shops and independent Dealers were established to meet the public demand for broadcast receivers, the activities of some Dealers were initially of some concern to the authorities even though they were given some assistance in the Regulations in the conduct of their business in selling receivers for the purpose of reception of broadcasting stations.

The majority of Dealers obtained a Dealers Listeners Licence but there were some who were also granted a licence to enable them to transmit a program in order to demonstrate the operation of a receiver in a prospective buyer's home, particularly during hours when the local broadcast station was not on air.

Figures of the numbers of Dealers with listening and transmitting licences are not readily available but as at 22 August 1925, there were 194 Dealers registered in South Australia alone, with 150 of the Dealers being located in the Adelaide area. The list included many businesses also registered in other States such as British General Electric Co.; Corbett, Dernham and Co.; Harrington Ltd; Paroso Ltd; Siemens Bros; United Distributors; Wireless Supply Depot and others.

The Broadcast Listener's Licence obtained by a Dealer in respect of a particular address did not entitle the Dealer to demonstrate or in any way use a receiver in the home of a prospective buyer. This point was often overlooked by many Dealers. However, the Department Radio Inspectors endeavoured to assist Dealers in the conduct of their businesses, as they recognised that the radio trade had a very important part to play in the development of broadcasting.

The Department recognised that Dealers must give demonstrations away from their shops and the Department granted the concession of allowing these demonstrations to be conducted without the obligation of obtaining another licence. Generally, it was practice to permit a demonstration period of three days in the metropolitan area and one week in country districts.

Notwithstanding these concessions, the Department was reluctantly compelled to take action against some Dealers who failed to reasonably comply with its conditions concerning demonstrations of receivers. In some instances receivers were seized and forfeited to the Commonwealth.

As at the end of December 1925, organisations and individuals who had been granted Dealers Licences with transmitting facilities included 3JG, Jones and Glew, Brunswick; 3WR, Wangaratta Sports Depot, Wangaratta; 3UD, United Distributors, Melbourne; 2AG, Ashfield Service Station, Ashfield; 2RP, R P Primer, Gordon; 2LB, L P R Bean and Co., Sydney; 2TH, T H Squelch, Bangalow; 2LE, Lismore Electrical Co. Lismore; 2PS, P G Stephen, Balmain; 2ZH, New System Telephones Pty Ltd, Sydney; 4BM, A B Milne, Mackay; 4WR, Harold Walsh, Hamilton; 4SM, W G Ikin, Strand Motors, Townsville; 4RP, Robertson and Provan Ltd, Toowoomba; 5BK, Electrical Supplies Depot, Adelaide; 5CB, Newton, McLaren, Adelaide; 5GB, G Bailey, Mt Gambier; 5LP, A L Perry, Strathalbyn and 7BN, Willis and Co. Ltd, Launceston.

Some stations operated by Dealers were fairly elaborate and on a par with many Commercial stations on air at the time. Station 4WR operated by Harold Walsh of Toorak Hill, Hamilton, on 248 metres was typical. He also operated another station, 4WH set up for experimental short wave work. In 1926–27 the 4WR transmitter employed a five watt valve in an Armstrong tuned anode circuit and another five watt valve as modulator employing the Heising method. A stage of audio amplification consisted of a DE5 valve and a Silvertown transformer which could be cut into circuit to increase the modulation level during the use of his piano with a musical program. Panel meters indicated aerial current, filament currents, anode voltages and anode currents. A patch panel was used to switch in various program sources to the transmitter. Classical music played from records was a major part of the program when receivers were being demonstrated. The aerial was a two wire T type fed at the centre and was 11 m high and 25 m long. The microphone was a standard telephone candle stick design and used a 4 volt accumulator for the microphone circuit. Power for the transmitter was provided by 6 volt car batteries charged by a Tungar rectifier for filaments, a bank of accumulator type B batteries for anodes with each bank being 90 volts with charging being provided by a homemade charger, and heavy duty dry cell 45 volt battery for the modulator valve grid bias.

With the help of his station, Harold was able to demonstrate receivers in the homes of prospective buyers up to 20 miles (32 km) from his Radio Shop.

At the end of June 1927, there were 2797 licensed Dealers throughout Australia. They comprised 1024 in Victoria, 916 in New South Wales, 344 in Queensland, 335 in South Australia, 129 in Tasmania and 49 in Western Australia.

During evidence to the Royal Commission on Wireless in 1927, it was suggested that a number of Dealers had no knowledge of the technical side of radio and in some cases had sold sets of inferior quality and performance. One person suggested that Dealers should be required to pass an examination to qualify for a licence and that they should only be permitted to sell sets that had been stamped with the approval of some central authority. However, the Commission was of the opinion that the more healthy the competition and the greater freedom that it permitted in competition amongst themselves, the better it would be for the public. Of 165 witnesses who appeared before the Commission eight were Dealers.

It is not known who was granted the first Dealers licence in Australia but in an advertisement in Radio Broadcasting, March 1925, Norris and Skelley Pty Ltd, 213 Elizabeth Street, Melbourne, claimed the honour.

Radio Inspectors were appointed to most States just prior to the commencement of broadcasting to handle on-the-spot technical and licensing problems. There was also an increasing number of Amateur stations in operation making it difficult to oversight radio matters from the PMG's Department headquarters in Melbourne.

In the mid 1930s, Radio Inspectors included Tom Armstrong, Brisbane; Bill Crawford, John Wetherall, Sydney; Bill Conry, Joe Dobbyn, Peter Dunne, Jack Martin, Melbourne; Eric Bowden, Hobart; Bert Harrington, Adelaide and George Scott, Perth.

Many of these people had been associated with the network of Coast Radio Stations established 1912–14 before the First World War.

- Bill Conry joined the Engineering Branch of the Postmaster General's Department in 1910 when 18 years old to be trained in the installation and maintenance of telegraph equipment, manual telephone exchanges, telephone apparatus and battery systems. He became proficient in Morse Code operation. He enlisted in the Royal Australian Navy in 1915 and served until 1918 as a Wireless Operator in the Radio Service (Transport) group. Bill returned to the Department after discharge and served as Radio Inspector at Hobart and later at Melbourne. He was a Full Member of The Institution of Radio Engineers (Aust.) and in 1935–36 was a Councillor of the Victorian Division Committee serving on the Lectures and Papers Board.
- Bill Crawford was the first Officer-in-Charge of the Hobart Coast Radio Station when it began operation on 30 April 1912 on a site in Queens Domain high above the River Derwent. It was the second station to be commissioned in the network and the building still functions today with a role in Radio Engineering. In 1914, Bill transferred to Melbourne to be Officer-in-Charge of the Melbourne station VIM. In the following year, he transferred to Naval Wireless as Radio Inspector, Melbourne. In January 1918, he was appointed Radio Lieutenant and Inspector, Sydney. After the War, he reverted to the PMG's Department becoming Radio Inspector for New South Wales on 20 October 1920. In May 1934, the position was reclassified as Senior Radio Inspector.

  In 1935–36 while a Member of The Institution of Radio Engineers (Aust.) he was a Councillor of The Institution serving on the Qualifications Board.
- Joe Dobbyn joined the Postmaster General's Department when 16 years of age as Apprentice in Electrical Engineering. Following completion of the training course during which he became proficient in Morse Code operation he was appointed to a position in the Electrical Engineering Branch, Melbourne in 1911. During the First World War, he enlisted in the Royal Australian Navy as Wireless Operator in the Transport Service. After the War, he resumed duty with the Department and was appointed Radio Inspector, Central Office. Joe was a Full Member of The Institution of Radio Engineers (Aust.) and in 1935–36 served as Hon. Assistant Secretary of the Victorian Division.
- Peter Dunne joined the Postmaster General's Department in 1914 serving with the Department until 1919 when he transferred to the Coast Wireless Service as Radio Telegraphist at various stations until 1925 when he returned to the Department to work in the Radio Section. In 1928, he was appointed as Radio Inspector in the Central Office, Melbourne. Peter was a Member of The Institution of Radio Engineers (Aust.).
- Bert Harrington commenced his career in wireless in 1912 during the spark wireless telegraphy era. With the outbreak of the First World War he enlisted in 1914 serving in the Transport Service 1914–16 and from 1917 to 1919 served with the Australian Flying Corps. In January 1924, he became the first Radio Inspector in South Australia taking a keen interest in the establishment of the first broadcasting stations — 5DN and 5CL. He signed the station log book of 5CL when the transmitter commenced transmission at 8 pm on 20 November 1924. The log book is now in a vintage radio collection. Bert was a foundation member of the South Australian Division of The Institution of Radio Engineers (Aust.) when the Division was established in 1936. He served as Radio Inspector in Adelaide for nearly 20 years.
- Jack Martin joined the Commonwealth Radio Service in 1913 when about 17 stations had been commissioned in the network. During the War years he held an RAN Commission when the Navy took control of all stations. In 1919 he was appointed Radio Inspector for Victoria serving in the PMG's Department Victorian and Central Office administrations until August 1940 when he was appointed Chief Inspector (Wireless) Central Administration, taking over from Jim Malone.

Over the years, the name of the Department's organisation has changed in name from the early Wireless Branch, and so has the designation of the Senior Officer from Radio Inspector to Superintendent and more recently to State Manager. From a broadcasting aspect, the role of these people has diminished considerably with their involvement in the early 1990s being confined mainly to the measurement of some specific transmission parametres and investigation into broadcast reception problems. During 1989–90, Technical staff carried out some 1255 investigations throughout Australia into interference to AM and FM reception.

One of the PMG's Department senior executives who was closely involved with the administration of the licensing regulations was James (Jim) Malone. As Chief Officer of the Wireless Branch for 20 years during the formative period of broadcasting, he played a major role in the determination of policy and in administration of the Regulations associated with the establishment and operation of the National and Commercial broadcasting services.

He joined the Post and Telegraph Department at Lismore in 1898 as Telegraph Messenger and two years later was appointed Relieving Officer.

In 1906, he joined the Engineering Branch and in 1907 was appointed Cadet Engineer in the Electrical Engineer's Branch. He then occupied a number of Engineering positions in New South Wales and Queensland and on enlistment for War service was appointed Instructor in Wireless at the Wireless School, Moore Park, Sydney. On being sent to the War front, he was placed in charge of all AFC Wireless activities in France. Jim had the honour of being awarded the Military Cross for his service. During service he rose to the rank of Lieutenant Colonel.

After the War, he remained in Europe for more than a year, studying wireless developments that had taken place in various countries during the War period. At one stage, he was at the RAF Wireless Experimental Establishment, Biggin Hill and later at the Signals Establishment at Woolwich in England.

On his way back to Australia, Jim spent five months in the United States where he made a detailed study of the latest technological developments, particularly in advances in valves, radio telephone transmitters, aerial systems and receiving equipment.

On resuming duty, he was appointed Deputy State Engineer, Perth.

In 1922, he was Technical Adviser to the Parliamentary Committee on Wireless, and later prepared the Wireless Telegraphy Regulations for the introduction of broadcasting. In 1923, he was the PMG's Department representative at the Conference convened by the Postmaster General for the purpose of obtaining the views of various organisations and representatives for establishment of a broadcasting service in Australia. He was instrumental in preparing the Regulations which were gazetted on 1 August 1923.

However, Jim did not fully support the scheme which became known as the Sealed Set Scheme recommended by the Conference delegates. As he had anticipated, the Scheme was a failure and on 11 July 1924, new broadcasting Regulations which he prepared were introduced into Parliament creating two categories of stations designated A Class and B Class stations.

One of his actions with the introduction of broadcasting was to establish an office of Radio Inspector in the States to oversight the technical and licensing aspects of broadcasting, to issue certificates of competency, to conduct examinations for Technical staff involved in the operation of the stations and to investigate interference to broadcast reception.

The Radio Inspector played an important role in the broadcasting service. He carried out regular technical inspections to ensure that the standards of transmitting and studio equipment were being observed, he undertook inspections of homes to ensure that those listeners in possession of a radio receiver held a current licence for operation of the receiver and he handled complaints from listeners concerning program matters.

In 1923, the position which Jim Malone occupied was changed to Chief Manager, Telegraphs and Wireless and in 1927 it was changed to Chief Inspector (Wireless).

On 8 June 1939, he was appointed Deputy Director, Queensland and on 8 November 1944 he transferred to Sydney as Deputy Director, New South Wales. Jim retired on 23 August 1946, and became the first Chairman of the Overseas Telecommunications Commission, a position he held until 22 August 1954.

Jim was awarded the Order of the British Empire for services to the Department, and during his working life was an active member of The Institution of Radio Engineers (Australia) serving as Chairman during the period 1935 to 1937.

From August 1940, Chief Inspector of Wireless was John (Jack) Martin.

Expansion of ABC Metropolitan Services

Although the early planners had hoped to serve the entire Australian population with local services from at least one National station and one Commercial, this has not eventuated. With its vast network of MF and FM stations supplemented by short wave, Inland Service transmitters in the Northern Territory and satellite services, there are very few populated centres in Australia which do not receive an ABC program. However, it is unlikely that the MF Commercial service will ever reach the original goal.

From the earliest days of broadcasting, both Sydney and Melbourne listeners were given the choice of two A Class station programs — even though the stations were operated by different organisations — and this continued with the establishment of the National Broadcasting Service with programs being provided by the Australian Broadcasting Company Ltd and later by the Australian Broadcasting Commission.

In 1937, the planners drew up plans to provide a second transmitter at the other capital cities. The first service was in Adelaide with 5AN commissioned on 15 October 1937, followed by 4QR Brisbane on 7 January 1938, 7ZR Hobart on 22 June 1938 and 6WN Perth on 12 October 1938. In later years, Newcastle was provided with a second outlet when 2NA went to air in December 1943, Canberra with 2CN followed its first station 2CY when the service was inaugurated in January 1953.

It was some time before clearly identified programs were broadcast over the two networks, but more light entertainment was noticeable during the last two years of the War in program content. The programs were generally referred to as State, comprising mostly locally produced material and Alternative, comprising national relay material.

From 1 September 1946, the ABC Commissioners made a bold move. For the first time, the listeners in the main centres of Australia could choose between quite different ABC programs. The Interstate program comprised light music, variety, talk sessions like Guest of Honour etc., and some symphonic music but of more well-known compositions. The National program carried the more serious material, such as Country Hour, Children's Session, Nation's Forum of the Air etc., weather reports and large amounts of classical music. This was one of the most significant program policy decisions since inception of the ABC in 1932. Implementation required considerable upgrading of the studio technical facilities and fixed OB points for broadcast of ABC orchestras, dance bands, choral groups and miscellaneous instrumental combinations.

The Interstate and National programs were later replaced by Radio 1, Radio 2 and Radio 3 programs.

By 1980, the stations transmitting Radio 1 programs were 2BL Sydney, 2CN Canberra, 2NC Newcastle, 3LO Melbourne, 4QR Brisbane, 5AN Adelaide, 6WF Perth and 7ZR Hobart.

Programs of Radio 1 concentrated on popular music, entertainment, news, public affairs, community information and the broadcast of the proceedings of Parliament.

The role of Radio 2 was to serve the interests of those listeners who had the highest expectations of radio, with programs being characterised by a wide range of styles and treatments. Radio 2 network comprised 2FC Sydney, 2CY Canberra, 2NA Newcastle, 3AR Melbourne, 4QG Brisbane, 5CL Adelaide, 6WF Perth and 7ZL Hobart.

Radio 3 programs were drawn from Radio 1 and Radio 2, programs produced specifically for Radio 3 and programs originating from major regional studios.

At that time, fully Engineered ABC Regional studios were located at Albury 2CO, Bega 2BA, Broken Hill 2NB, Grafton 2NR, Kempsey 2KP, Orange 2CR, Tamworth 2NU, Wollongong 2WN, Horsham 3WV, Sale 3GI, Cairns 4QY, Longreach 4QL, Mackay 4QA, Maryborough 4QB, Rockhampton 4RK, Townsville 4QN, Toowoomba 4QS, Mt Gambier 5MG, Port Pirie 5CK, Renmark 5MV, Albany 6AL, Bunbury 6BS, Geraldton 6GN, Kalgoorlie 6GF, Port Hedland 6PH, Launceston 7NT, Alice Springs 8AL and Darwin 8DR.

Today, these programs are known as Metropolitan Radio, Regional Radio and Radio National. Additionally, there are Youth Radio Triple J and ABC Classic FM programs.

On 3 October 1990, the ABC issued a Press Release indicating that Radio National, the Corporation's Radio specialist talks network, had a common callsign throughout Australia.

The Department of Transport and Communications had given approval for change of Radio National callsigns in capital cities to one callsign — RN.

RN replaced the network callsigns such as 2FC Sydney, 3AR Melbourne, 2CY Canberra, 2NA Newcastle, 4QG Brisbane, 5CL Adelaide, 6WN Perth, and 7ZL Hobart. Radio National in Darwin was already known as 8RN. Management of the ABC said the change was aimed to make station identification easier for listeners, and would reinforce the fact with listeners that Radio National was one national network.

At the time of the announcement, Radio National was available to some 80 % of the Australian population through more than 150 transmitting stations. Up to one million Australians listened to the program at some time each week. Plans were in hand to have the entire population covered by Radio National.

The change in callsign for these stations closed a chapter in broadcasting history which began in the 1920s. Station 2FC had commenced transmission on 5 December 1923, 3AR on 26 January 1924, 5CL on 20 November 1924, 7ZL on 17 December 1924, 4QG on 27 July 1925, 6WN on 5 October 1938, 2CY on 23 December 1938 and 2NA on 20 December 1943.

It was realised some years ago, that all the Metropolitan stations forming part of the National Broadcasting Transmission Network needed substantial refurbishment. Many of the valve transmitters were well 30 years old; maintenance parts, particularly valves, were becoming difficult to obtain, and substantial reduction in power operating costs could be made by replacing the old valve equipment with modern solid state equipment. Savings could also be made by replacing program input equipment and other internal and external plant.

A plan, budgeted to cost about $19 million, was implemented for redevelopment/refurbishment work with a completion target date of mid 1995. As well as transmitters carrying ABC programs, the plan included those carrying Parliamentary broadcasts.

By the beginning of 1995, a great deal of progress had been made involving a large number of projects, with the situation at that stage being:

- At the Brisbane Bald Hills centre where 4QR, 4RN and 4PB are located, emergency power plant was replaced; main station switchboard facility upgraded; and 4QR, 4RN and 4PB transmitters all replaced with solid state units. The 4RN service was upgraded to 20 kW power. A new standby aerial was installed for 4QR, and the heights of a standby mast for 4RN and main 4PB mast increased to 81 m.
- At the Sydney Liverpool site accommodating 2BL, 2RN and 2PB, all transmitters associated with these services were replaced and housed in a new building much smaller than the original. Standby transmitters previously providing 10 kW, were replaced by new 25 kW units. The standby aerials for 2BL and 2RN services were upgraded to operate at 50 kW input.
- Both STC transmitters at the Melbourne 3LO, 3RN Sydenham site were replaced during 1991 by a pair of 25 kW Nautel solid state transmitters for each service. Emergency power plant was upgraded and the station mains power system replaced. The standby aerial for 3RN service was upgraded to handle 50 kW input.
- Both STC 50 kW transmitters of 5AN, 5RN at Pimpala near Adelaide, were replaced during 1992–93 and the standby aerial for each service upgraded from 10 kW working to 50 kW working capability. The original emergency power generating plant was replaced, open wire transmission lines for 5AN and 5RN were replaced by air dielectric 50 ohm coaxial cables, and guys of the main 168 m dual frequency radiator were replaced during 1993.
- At Hamersley, the site of the Perth services, 6WF, 6RN and 6PB, all three transmitters were replaced, with 6RN being equipped with a pair of Nautel 10 kW transmitters providing a combined power output of 20 kW; new emergency power generating plant was provided and mains power system was replaced. The 6WF service was provided with a new radiator.

  Transmitters 7ZR, 7RN and 7PB at Ralphs Bay, Hobart site, were all replaced and aerial switching equipment replaced to allow for automatic and remote control operation. Other works included replacement of station mains power system, upgraded emergency power generating plant, and provision of standby aerials for each service.
- The Canberra services operating from Gungahlin with 2CN, 2RN and 2PB transmitters were equipped with new transmitters for all services, the station power system replaced, emergency power generating plant refurbished and installed at a new position, and the 193 m main radiator reguyed.

THE FM PLAN

The dream of the planners to provide a second ABC program to all country centres was somewhat thwarted by the problem of obtaining additional MF frequencies for the large number of transmitters required.

Fortunately decision to open up the VHF band for broadcasting purposes using FM and the advent of satellite technology came to the rescue and the dream is now a reality. FM broadcasting had been well established in the USA by the early 1940s.

The question of whether frequency modulation broadcasting should be introduced in Australia had been under consideration by Parliamentary Committees since 1942. Trials with experimental transmitters were undertaken in Sydney and Melbourne in 1947, followed by services in other cities. The service was discontinued in June 1961 following the recommendations of the Huxley Committee on radio frequency allocations. The VHF channels being used for the FM broadcasting experimental services were allocated to the TV service.

However, following pressure from groups wishing to have FM broadcasting restored, and long debates on whether VHF or UHF channels should be used, an Inquiry headed by Sir Francis McLean, former Director of Engineering of the BBC recommended, in 1974, among other things, that FM broadcasting should be introduced using the Pilot Tone Stereo system in the VHF band. The recommendation was accepted and steps were taken to introduce an ABC service with programs being provided from new stereo studies installed at Collinswood, Adelaide.

The principal characteristic of the system included frequency range (88–108) MHz, deviation 75 kHz, pre-emphasis/de-emphasis 50 micro seconds, stereo channel subcarrier frequency 38 kHz and pilot frequency 19 kHz.

The ABC-FM Stereo service designated ABC Fine Music from February 1993, is generally known as a classical music station and in essence is Australia's performing arts radio. Musical recordings including Australian music comprise about 95 % of the transmission time. The service commenced in January 1976 with transmitters in Adelaide, Canberra, Sydney and Melbourne followed by Hobart, Perth and Brisbane in August 1980 and Darwin in 1983.

The service is still expanding and by June 1990, there were 46 ABC Fine Music stations in the network comprising 1 in the Australian Capital Territory, 11 in New South Wales, 9 in Victoria, 8 in Queensland, 6 in South Australia, 8 in Western Australia, 2 in Tasmania and 1 in the Northern Territory. By June 1993 the number of transmitters had increased to 56.

The service is one of the largest FM stereo networks in the world, and during 1992, consolidated its commitment to the performing arts on radio by attracting an estimated audience of some 800000 listeners. As from 4 April 1994 the service became known as 'ABC Classic FM' and at the time comprised 62 transmitter outlets.

Transmitter powers are mainly 10 kW or 20 kW with effective radiated powers (ERP) up to 150 kW. Rural transmitting stations with ERPs of 100 kW and above included those located at Bega/Cooma, 100 kW on 105.7 MHz; Bendigo, 100 kW on 106.3 Mhz; Latrobe Valley, 100 kW on 107.1 MHz; Mildura, 100 kW on 102.3 MHz; Mt Gambier, 150 kW on 104.1 MHz and North/Eastern Tasmania, 120 kW on 93.3 MHz.

In addition, at the period, there were a number of stations licensed to rebroadcast the ABC Classic FM programs under the Self-help Broadcasting Reception Scheme (SBRS). These included stations located at Khancoban and Talbingo in New South Wales; Goldsworthy, Mt Whaleback and Shay Gap in Western Australia; Nonda in Queensland and Ngukurr and South Alligator in the

Northern Territory. Committees with facilities under the SBRS arrangement paid to have the technical equipment installed and were granted a licence to rebroadcast the ABC program.

Further expansion of ABC programs to rural areas took place with the implementation of the Second Regional Radio Network (SRRN) project following Government approval in 1983. The SRRN was the most important single step in the ABC's goal of providing all Australians with the Corporation's three main radio programs — Regional/Metropolitan Radio, Radio National and ABC Classic FM.

The SRRN plan involved the provision of a second set of transmitters to complement the existing wide coverage AM transmitters and where they existed, the ABC Classic FM services.

By mid 1992, 146 transmitters had been commissioned as part of the Second Regional Radio Network and when the FM transmitter was put to air at Albury-Wodonga on 29 October 1992, it brought the total number of transmitters broadcasting the Regional Radio program to 200. This number had increased to 219 by April 1992.

The Radio National network was also extensive. When the FM transmitter was commissioned at Mt Panorama in the Blue Mountains on 28 May 1993, it brought the transmitter outlets for Radio National programs to 200. By 1994, Radio National outlets comprised 221, made up of 20 AM and 201 FM transmitters and by 30 June 1996, the total number had increased to 232 transmitters.

As well as its Regional Radio, Metropolitan Radio, Radio National and ABC Classic FM services, the ABC operates the Triple J network. This is part of the Sydney Youth Radio Service 2JJJ-FM which began operation in the FM band in July 1980, and later expanded to all States, Canberra and Darwin. Prior to that, the station operated in the AM band with a 10 kW transmitter on 1539 kHz as 2JJ, since January 1975. It was the first ABC station to operate for 24 hours a day with programs for local listeners. The format includes a wide range of pop music and contact with youth lifestyles.

As at 1993, the Triple J stations included Adelaide, 5JJJ-FM 105.5 MHz; Brisbane, 4JJJ-FM, 107.7 MHz; Canberra, 2JJJ-FM, 101.5 MHz; Darwin, 8JJJ-FM, 103.3 MHz; Hobart, 7JJJ-FM, 92.9 MHz; Melbourne, 3JJJ-FM, 107.5 MHz; Newcastle, 2JJJ-FM, 102.1 MHz; Perth, 6JJJ-FM, 99.3 MHz; and Sydney, 2JJJ-FM, 105.7 MHz.

Typical of the Triple J installations was the 6JJJ transmitter commissioned at Bickley near Perth on 20 October 1989. The transmitter was an NEC 20 kW model using a single valve and cut back to provide 5 kW into the aerial on 99.3 MHz in order to give an effective radiated power of 25 kW. The transmitter shared the ABC Classic FM aerial system using an RF Systems combiner. Program for the service originated in Sydney, as for all Triple J stations, and was sent to Perth via satellite delayed to come into line with local time. It was processed by optimod audio processor before being fed to the transmitter.

On Australia Day, 26 January 1995, the Triple J network was considerably expanded and included regional centres in Northern Territory, Queensland, New South Wales, Victoria and Western Australia. Programs for the service were produced at various studio centres and sent to transmitters via ABC Sydney Master Control. Program materially was digitally encoded and uplinked to a satellite where it was down linked to the transmitting stations. It was then decoded and broadcast in the FM band.

When the expansion plans for the Triple J network were announced in September 1993, the plans allowed for 44 new transmitters to be installed by the end of 1996.

Contracts for completion of the expansion program were let to Broadcast Communications Ltd to install equipment at five sites in New South Wales and Victoria and to Kilpatrick Green Pty Ltd to install equipment at three sites in Western Australia and South Australia. Telstra was also involved in the work.

The work as planned was completed by end December 1996, resulting in the Triple J programs being available to 80% of the Australian population. Expenditure associated with the work was about $12 million.

The Broadcasting Reception for Aboriginal Communities Scheme (BRACS) comprising 42 transmitting stations at June 1990, was another service operating in the FM band which broadcast ABC programs. In the scheme, a local transmitter allowed broadcasting of either Regional Radio, Radio National, ABC Classic FM or locally produced programs. Of the operational stations, 14 were located in Queensland, 14 in Western Australia and 14 in the Northern Territory. By June 1993, the number of BRACS stations had increased to 80. BRACS was subsequently categorised under Community facilities.

In mid 1990, the number of FM transmitters broadcasting ABC programs was 301 compared with 100 AM transmitters in the MF band. The FM transmitters comprised 115 Radio National, 1 Metropolitan Radio, 91 Radio Regional, 46 ABC Classic FM, 6 Triple J and 42 BRACS. By mid 1994 the number of FM transmitters in operation had increased to 529 which included 80 Community facilities.

The FM band is also widely used by Commercial and various Public interests. Effective radiated powers for these services are as low as 10 watts for some Public stations, and as high as 35000 watts for some Commercial stations.

During the late 1970s, a large number of Public FM stations were commissioned. They included 2ARM, Armidale, 100W ERP; 2CBA, Sydney, 5000W ERP; 2MBS, Sydney, 10000W ERP; 2NCR, Lismore, 3000W ERP; 2NUR, Newcastle, 3000W ERP; 2SER, Sydney, 4000W ERP; 3GCR, Churchill, 50W ERP; 3MBS, Melbourne, 4000W ERP; 3PBS, Melbourne, 200W ERP; 3RRR, Melbourne, 10000W ERP; 4DDB, Toowoomba, 2000W ERP; 4MBS, Brisbane, 7,500W ERP; 4ZZZ, Brisbane, 7,500W ERP; 5MMM, Adelaide, 4000W ERP; 6NEW, Newman, 250W ERP; 6UVS, Perth, 5000W ERP; and 7THE, Hobart, 3000W ERP.

Early Commercial FM stations established in the major capital cities included 2MMM Sydney with 35 kW ERP, in July 1980; 2DAY Sydney with 35 kW ERP, in August 1980; 3EON Melbourne with 10 kW ERP, in July 1980; 3FOX Melbourne with 10 kW ERP, in August 1980; 4MMM Brisbane with 6 kW ERP, in August 1980; 6NOW Perth with 20 kW ERP, in August 1980 and 5SSA Adelaide with 5 kW ERP, in September 1980. All stations employed FM stereo mode of transmission, feeding aerial systems providing mixed polarisation.

Station 3EON operated by Melbourne FM Radio Pty Ltd, Bank Street, Melbourne was the first FM Commercial broadcasting station to begin operation in Victoria. It began operation on 11 July 1980 with a transmitter and aerial system located at Mt Dandenong. Effective radiated power was 10 kW, operating frequency 92.3 MHz and programs were transmitted on a 24 hour service. Station Technical Director was Neil McCrae.

During 1985, the station completed a major production upgrade and expansion program. The work included the construction of three production control rooms, two on-air studios and a voice-over booth. The two larger control rooms were each fitted out with Sony/MC1 JH 636–24 fully automated console with 24 input/output channels and eight stereo input modules. The smaller control room was a dubbing suite equipped with Ward-Beck system R1200 console with compact disc, cartridge and tape dubbing facilities. Callsign 3EON is no longer in service. It became 3MMM in January 1989.

Further expansion of metropolitan Commercial services took place with the implementation of Stage 1 of the Government's National Metropolitan Radio Plan when some AM broadcasters transferred operations to the FM band. Stations 3KZ Melbourne and 5KA Adelaide converted to FM operation on 1 January 1990 followed by 4BK Brisbane on 26 February 1990, 3TT Melbourne on 24 June 1990 and 5DN Adelaide on 9 September 1990, 6PM on 31 December 1990 and 6XY on 1 June 1991. Others followed.

Under Stage 1 of the Plan which received approval by Parliament during December 1988 as The Broadcasting (National Metropolitan Radio Plan) Act 1988, existing AM broadcasters were invited to tender for FM channels in each mainland capital city. Under the arrangement, the broadcaster's AM transmitting station and site were to form part of the tender bid with the AM facilities being transferred to the Commonwealth in exchange for an FM channel. Stage 2 followed with the release of further FM channels.

Tender bids were very high in some instances. One Victorian AM station paid $31.5 million for an FM channel while a Brisbane station paid $17 million. Later bids tended to be somewhat lower. In late 1991, Sydney stations 2UW and 2WS successfully bid at $9.4 million and $8 million respectively. The 2WS submission included the sale of its AM transmitter to the Government for $3.5 million.

Station 2UW converted to MIX on 106.5 MHz in April 1994 and 2WS converted in June 1993.

In October 1987, the Government released a phase program to cater for the expansion of Commercial FM services into regional areas. It was expected that at least three million listeners would be served within a period of five years.

The FM services were provided by the establishment of new Commercial stations, the granting of supplementary licences to existing AM station operators and the conversion of AM stations to FM. During the 1991–92 period, new FM radio services commenced at Nowra, Darwin and Geraldton, while supplementary licences were granted to 2BH Broken Hill and 8HA Alice Springs. Between early 1989 and late 1992, eight conversions from AM to FM services took place. They included 2GO Gosford, to 2GGO; 200 Wollongong, to 2WIN; 2NX, Newcastle to 2XXX; 2KA Katoomba to ONE FM; 3GL Geelong, to 3CAT; 4GG Gold Coast, to 4GGG; 6GE Geraldton, to 6GGG and 7HO Hobart, to 7HHO. At some sites, complex Broadcast Engineering problems needed resolution before the services could be installed and commissioned.

By mid 1992, the number of Commercial FM transmitters in service had increased to 79 while the number of AM transmitters fell from 140 to 132 as a result of AM services being converted to FM operation. In February 1997, according to Australian Broadcasting Authority figures, the number of FM transmitter licences had increased to 107 with 21 being for stations in capital cities. At the same period, there were 109 licensed stations in the AM band with 21 being located in capital cities.

Extension of Commercial radio to country areas was also facilitated by implementation of the Remote Commercial Radio Service (RCRS). In November 1988, the Australian Broadcasting Tribunal granted a licence for a mono service to Golden West Network Ltd, and a licence for a stereo service to Trans-West FM Pty Ltd, to serve listeners at isolated communities and homesteads via AUSSAT. The technical arrangement was for RCRS signals to be provided using supplementary sound channels of the Remote Commercial Television Service (RCTS) B-MAC TV signals.

Public broadcasting stations have been operational since 1973 with low power transmitters, usually operated by groups with a wide cross section of interests. There were three categories of licences covering educational bodies; particular interest groups, e.g. music, religion etc., and community groups. By 1981, 31 Public stations had been licensed and by March 1992 the number had increased to 100. Station ERPs ranged from 20 watts for 2VTR Windsor, commissioned in October 1982; 2YOU Tamworth, commissioned in July 1983; 8KIN/T Ali Curing and 8KIN/T Santa Teresa both placed in operation in February 1985 to 16000 watts ERP for the Gold Coast station 4CRB commissioned in March 1983.

As with the administrative and programming staff, many of these stations operated with volunteer Technical staff.

Station 3RRR Melbourne was typical of this class of station. In November 1976, the Royal Melbourne Institute of Technology commenced broadcasting with station callsign 3RMT. In August 1978, the station became known as 3RRR-FM, the licence being transferred to Tripe R Broadcasters Ltd, a company comprised of six tertiary institutions. By August 1979, the number had increased to eight.

In 1983, the company comprised the Royal Melbourne Institute of Technology's Technical College (TAFE), La Trobe University, Swinburne Institute of Technology, Melbourne State College, Melbourne University and the combined Teacher's Unions.

The studio was located at 25 Victoria Street, Fitzroy with the transmission facilities being located at Mt Dandenong. The station broadcast using stereo format on a frequency of 102.7 MHz feeding an aerial system which produced an effective radiated power of 10 kW with mixed polarisation.

Staff included Reece Lamshed, Manager: Steve Warne, Spokenword Program Co-ordinator; Jules Taylor, Music Co-ordinator; and Dion Weston, Engineer.

The station received a substantial proportion of its income from subscribers, sponsorship and government grants and because its role was basically educational it had a high content of spoken word programs.

The first community station to be commissioned in Australia for operation in a country area was 2MCE FM based at the Charles Sturt University, Bathurst. It was installed in 1975 and licensed in May 1976 using a transmitter on 92.3 MHz situated on Mt Panorama and providing 1 kW ERP into an omnidirectional aerial system serving the Bathurst area. Another outlet was later provided with a transmitter on 94.7 MHz providing 500 watts ERP with a directional aerial at Orange to cover the Orange area. Costs of operating the service were met by Charles Sturt University, subscription and sponsorship.

Although the majority of Public stations operate in the VHF FM band, at mid 1993, there were a number operating in the MF band. These included 2XX Canberra with community/news/current affairs/ethnic/Aboriginal and womens program formats operating on 1008 kHz with 300 watts into a 70 m high omnidirectional aerial commissioned in July 1976; 4EB Brisbane with ethnic program format operating on 1053 kHz with 500 watts into a 50 m omnidirectional aerial commissioned in December 1979; 6NR Perth with educational/access/ethnic and Aboriginal program format operating on 927 kHz with 2000 watts into a 63 m directional aerial system commissioned in October 1976; 2WEB Bourke with 2000 watts into a 91 m aerial on 585 kHz, and 5UV Adelaide on 531 kHz with 500 watts into a 138 m omnidirectional aerial with education/access/ethnic and Aboriginal program format.

Station 5UV originally operated with a licence granted in 1972 to the Adult Education Department of the University of Adelaide for the purpose of transmitting lecture material — other than music — to students. It was licensed under the Wireless Telegraphy Act as there was no provision in the Broadcasting and Television Act for authorisation of such service. It commenced service with a callsign VL5UV on 28 June 1972 on frequency 1630 kHz with a 500 watt transmitter located in the Dry Creek area north of Adelaide. The studio technical facilities located on the University grounds in North Terrace were designed by Staunton McNamara who also oversighted the installation and commissioning.

Approval was later granted for the station to be transferred to the AM broadcasting band. As from 27 February 1975 it operated under callsign 5UV on a frequency of 530 kHz. On 17 March 1989, the station programming staff moved into new studios at 228 North Terrace, directly opposite the University.

One of the problems for planners in expansion of the FM network services was that the TV service occupied bands which in other parts of the world were used for FM broadcasting purposes.

In a two stage plan, the Department of Transport and Communications took action to shift certain TV channels to enable more FM radio services to be established. In stage 1 which took place over the period 1989 to 1990, some thirty three VHF stations were shifted out of the band and in stage 2 which commenced in 1991, another thirty three services located in New South Wales, Victoria, South Australia and Tasmania were transferred to the UHF band.

In order to meet a need for low power information services to include such services as tourism radio, commentaries at sporting fixtures, parking control for outdoor public events etc., the

Australian Broadcasting Authority decided to grant licences to the extent of five channels at the bottom end of the FM band. In early 1993, the ABA had received some 270 applications and licences had been issued to 130 services spread over all States and Territories.

By early 1994, over 300 licences had been granted. The five channels were between 87.6 MHz and 88.0 MHz and although licences were originally given for a 12 month period, they were later extended until 1 January 1997.

By the end of 1993, the number of approved VHF-FM station assignments included 378 National, 237 Community (previously Public), 113 Commercial, 346 Narrowcasting and 76 Re-transmission.

One important difference between Community radio and Commercial radio is that whereas Community radio lets the public or community speak, Commercial radio speaks to the public or community. Community radio enables sections of the community to express itself whereas Commercial radio targets sections of the community with the goal of profit making.

Among recent entrants into the broadcasting network, licensed for Narrowcasting, have been bodies associated with the horse racing industry. The Totalisator Administration Board (TAB) of Queensland, the Totalisator Agency Board of Western Australia, the Northern Territory Racing Commission and TAB New South Wales, operate stations for the purpose of broadcasting horse racing events and betting details associated with the sport.

In Queensland, Telecom Broadcasting established a network comprising 16 FM transmitting stations with associated program receiving facilities at a number of centres in the State stretching from Thursday Island near the tip of Cape York Peninsula, to Weipa and Normanton near the Gulf of Carpentaria, west to Mt Isa and south to St George and Goondiwindi near the Queensland/NSW border.

A project team comprising Mike Dallimore, Tony O'Brien and Rob Sampson was formed to handle the project work.

The plan was for programs to be relayed using satellite Omnicast service and sourced from 4TAB, the TAB's racing station in Brisbane. The Brisbane station is an AM type employing 141 m high directional aerial system and 5 kW transmitter broadcasting on a frequency of 1008 kHz.

The FM transmitters were installed at sites owned by the National Transmission Agency, at sites with combined NTA/Telecom facilities and in one case, WIN television site.

Transmitters for the network were CTE types supplied by Rohde and Schwarz.

New or upgraded combiners were required at 15 sites and at two sites, aerial systems had to be upgraded to meet the requirements of adding the TAB service to the existing National service.

Satellite receiving facilities employing 3 or 3.7 metre dishes were provided by Acesat Satellite Corporation Pty Ltd.

Equipment racks were assembled in Brisbane for each service to accommodate the transmitter, consisting of 30 watt exciter and 100 watt, 500 watt or 5000 watt PA depending on the service specification. Patching facilities and satellite receiver were also mounted on this rack.

Stations were put to air over a period of several weeks, with the complete network being operational by 9 July 1993.

In the Northern Territory the Racing Commission shared its transmitting facilities with NTA at various sites in the Territory, operating its Darwin racing service on the AM band and in the FM band under an Open Narrowcast Licence at Alice Springs.

In Western Australia, broadcasts for the Perth area began in September 1994 from a site at Belmont with an AM transmitter on 1206 kHz with a Narrowcast licence. The frequency previously had been used by 6KY before it moved to the FM band.

The TAB New South Wales which operates the Racing Radio network examined the feasibility of extending its broadcasts from 2KY Sydney into regional areas in 1993 and installed its first transmitter in Dubbo the following year.

By mid 1997, the network had grown to 116 transmitting sites, and a satellite earth station was constructed in Sydney on the roof top of the 2KY building as part of a plan to assist in the distribution of 2KY racing programs to regional stations. It was initially employed to provide programs to high power AM stations in Newcastle and Wollongong and an FM transmitter at Broken Hill. This enabled the organisation to cancel the landline program circuits to these centres.

The earth station system was supplied and installed by Comsyst (Aust.) Pty Ltd with a 3.7 m dish being used as the main uplink dish fed by an SSE 16 watt Ku-band transceiver. Signal was beamed via PanAmSat PAS2 satellite. At Newcastle, Wollongong and Broken Hill, a 2.4 m Andrew dish was employed at each site for the down link services. Station Chief Engineer who planned and oversighted commissioning of the facilities was Max Carter.

In 1995, the ABA announced plans following amendments to Section 39 of the Broadcasting Services Act 1992, for providing improved programming options to listeners in remote areas from regional Commercial radio stations. The plan allowed for up to 55 new FM regional broadcasting licences to be made available and for upgrading of some AM stations. The aim was to provide for additional broadcasting services in areas where only one service originally existed. Mildura in Victoria was the first centre to benefit under the plan. It enabled the district to have FM station 3MDA on 99.5 MHz in addition to the AM 3MA service. The ABA approved the FM service on 21 September 1995. Both stations employed live shifts, automated shifts and a satellite link broadcast out of Sydney. Chief Engineer for the services was Roger Norris.

Other stations approved by the ABA to mid 1996 included:

- Queensland — 4CG Charters Towers with 4CHT; 4GY Gympie with 4NNN; 4HI Emerald with 4HIT; 4KZ Innisfail with 4ZKZ; 4SS Nambour with 4SEE; 4ZR Roma with 4ROM.
- New South Wales — 2BS Bathurst with 2BXS; 2DU Dubbo with 2ZOO; 2EC Bega with 2EEE; 2GN Goulburn with 2SNO; 2GZ Orange with 2GZF; 2LF Young with 2LFF; 2LT Lithgow with 2ICE; 2MG Mudgee with 2GEE; 2MO Gunnedah with 2GGG; 2PK Parkes with 2ROK and 2RG with 2RGF.
- Victoria — 3BA Ballarat with 3BBA; and 3NE Wangaratta with 3NNN.
- Tasmania — 7XS Queenstown with 7AUS.
- South Australia — 5SE Mt Gambier with 5SEF.
- Western Australia — 6KA Karratha with 6RED; 6KG Kalgoorlie with 6KAR; 6LN Carnarvon with 6CAR; 6MD Merridin with 6MER; 6MM Mandurah with 6CST; 6NW Port Hedland with 6HED; and 6SE Esperance with 6SEA.
- Northern Territory — 8HOT Darwin with 8EZY.

Station 3MA Mildura, the first station to commission an FM station under the new plan, had been providing an AM service to the district since 1933 but efforts had been made as early as 1924 to establish a broadcasting station in Mildura.

An official announcement was made by the Postmaster General to the Melbourne Press during November 1924 that nine new broadcasting stations were to be established in Australia. The plan included three in Sydney, two in Newcastle, two in Adelaide, one in Wangaratta and one in Mildura. Very little information is available on the outcome of the Mildura proposal except that a booklet published in Adelaide in June 1926 listed a B Class station with callsign 3EO as being operational in Mildura on 286 metres with a 100 watt transmitter. The owner/operator of the station was listed as R J Egge, Oliver Avenue, Mildura.

About 1930, the Sunraysia Daily, recognising the value of radio publicity as an adjunct to newspaper advertising applied to the Government for a licence to establish a broadcasting station in Mildura. A licence was granted on 8 November 1932.

On 25 May 1933, 3MA was commissioned by a company registered as Sunraysia Broadcasters Pty Ltd, Zimmers Building, Langtree Avenue, Mildura. The station operated on 333 metres (900 kHz) with a 50 watt transmitter and allowing for a future power increase to 100 watts. The transmitter and studios were located in Zimmers Building. The transmitter was a four stage crystal controlled unit employing high level type modulation. Two studios were provided, with one being large enough to accommodate an orchestra. Studio facilities included two turntables for 78 rpm and 33⅓ rpm transcriptions, three Reisz microphones and one ribbon microphone. The technical facilities were constructed by Chief Engineer Max Folie.

In more recent times, the station has operated on 1467 kHz with a 2 kW transmitter feeding a 53 m high radiator.

With the rapid expansion of FM radio broadcasting services throughout Australia, the ABA follows a number of planning procedures and interference checks to ensure the best possible service is provided to listeners in designated areas.

The VHF FM radio broadcasting spectrum nominally 88 to 108 MHz is divided into 100 channels of 200 kHz spacing starting with frequency 88.1 MHz and extending to 107.9 MHz. Channels serving the same area need to have at least 800 kHz separation because of receiver selectivity limitations.

The technology applicable to the design of VHF FM radio broadcasting services has been around for some time. Engineers of the Postmaster General's Department used the principles in design of VHF Radio Telephone systems from about 1950 when factors taken into consideration included selection of base station site; height of the aerial system; propagation aspects such as free space attenuation, topographical factors and atmospheric conditions; aerial radiation pattern; effective radiated power (ERP); signal polarisation; and noise and power level.

For a radio broadcasting service, the aerial radiation pattern, ERP and signal polarisation are particularly important. The radiation pattern of the aerial has to cater for multiple reception points and minimise signal levels into adjacent licence areas as well as prevention of interference to other operational services. The aerial characteristics also have to contribute to the required ERP to provide a minimum field strength in accordance with ITU recommendations. In the case of a rural service with stereo mode this is 54 dBuV/m. In order to cater for reception of programs in the home and a car, mixed polarisation of the signal is generally employed.

Before firming on an operating frequency for a particular station, a series of interference checks are undertaken to examine possible interference between existing FM radio broadcasting services, TV services and radiocommunication services.

SATELLITE BROADCASTING SERVICES

In October 1979, the Government of the day announced that it was in the national interest to establish a domestic satellite system in Australia.

Plans were for the service to be operational by mid or late 1985 with three satellites, comprising two in orbit (main and active standby) and one spare on ground.

In this first generation system, the satellites were to be positioned in geostationary orbit 36000 km above the equator at 156°E, 160°E and 164°E. The system was to operate in the 14.0–14.5 GHz band in the uplink and 12.25–12.75 GHz in the downlink.

Initially, policy development and co-ordination functions were handled by the Department of Communications, but system planning, design and development were taken over by the Overseas Telecommunications Commission (Australia) following Government announcement in September 1980 that OTC was to be the interim owner and manager of the satellite system.

The Minister for Posts and Communications granted licences to permit OTC to establish radiocommunications services via satellite through earth stations.

On 18 September 1980, the Minister announced that the Government had decided that both Government and private users of the service would be permitted to own earth stations.

The satellite design allowed for the provision of eleven transponders configured in a national beam and four high powered transponders with spot beams covering the Northern Territory and South Australia; Western Australia; Queensland; and New South Wales and Tasmania respectively.

The design catered for a variety of prime services, and for broadcasting, these included:

- The assembly and distribution interstate of ABC TV and radio programs and of Commercial TV programs.
- Transmission of ABC TV and radio programs within States from capital cities by relay to provincial transmitters, and by direct transmission to remote homesteads and communities and to areas of poor reception.
- At least two ABC radio services. In addition, upgraded services were to be available to fringe rural and urban areas of poor reception.

On 6 November 1981, AUSSAT Pty Ltd, the company formed to own and operate the satellite system was incorporated in Canberra. The company Board headed by Mr E S Owens OBE comprised 12 Directors selected by the Government to reflect a cross section of business and community interests.

Tenders were received from a number of organisations for the space segment of the system and shortly after December 1981, AUSSAT entered into contractual negotiations with Hughes Communications International for the supply of three satellites and ground control equipment following a technical report by OTC — the interim system owner. On 6 May 1982, the Minister told Parliament that the Government had approved the major contracts with Hughes. The three satellites, two earth control stations, launch arrangements and launch insurance were to cost $166 million.

The first two AUSSAT satellites were launched in 1985 with design lives of seven years. They were known as the 'A' Series.

The satellites brought a new dimension to broadcasting technology, although the employment of a satellite to carry program from studio to transmitter was not new. Since 1980, the Intelsat satellite had been employed to provide program for the Remote Area Television Service (RATS) stations.

In addition to television, the AUSSAT system introduced radio to more than a quarter of a million people who previously had been outside the coverage of the National, SBS and Commercial services or who received a technically inadequate signal. These people were able to receive high quality programs using appropriate reception equipment which included a receiving dish aerial, typically, 1.5 m in diameter.

The satellite system used the B-MAC (Multiplexed Analog Component-type B) transmission method in the 12 GHz band. Australia was the first country in the world to use the Canadian developed B-MAC standard for TV and radio broadcasting services. The audio channels in the system were designed to be compatible with the best hi-fi equipment available, and included variable pre-emphasis and delta modulation. With variable pre-emphasis, the signal was sampled before it was transmitted and the amount of pre-emphasis set accordingly. The result was surprisingly high quality sound from what was effectively, a low quality channel.

By 1991, the following radio services were available through the various AUSSAT spot beams:

- Western Australia
  ABC radio programs 6ABCFM, 6ABCRN and 6ABCRR through the Homestead and Community Broadcasting Satellite Service (HACBSS) on 12.725 GHz and Commercial radio programs 6FMS and 6SAT through the Remote Commercial Radio Service (RCRS) on 12.661 GHz.
- South Australia and Northern Territory
  ABC radio programs 5ABCFM, 5ABCRN and 5ABCRR through HACBSS on 12.501 GHz and 8ABCFM, 8ABCRN and 8ABCRR through HACBSS on 12.693 GHz.
  Commercial radio program 8AAA and Public radio program 8KIN through RCRS on 12.629 GHz.
- Queensland
  ABC radio programs 4ABCFM, 4ABCRN and 4ABCRR through HACBSS on 12.629 GHz.

- New South Wales, ACT and Tasmania
  ABC radio programs 2ABCFM, 2ABCRN and 2ABCRR through HACBSS on 12.661 GHz.
  SBS radio programs 2EA and 3EA on 12.553 GHz.

All the satellite services operated through satellite transponders with an ERP of 30 watts except for South Australian ABC and the SBS services which operated with an ERP of 12 watts.

By mid 1990, the ABC had 21 regional earth stations in service for radio program distribution and interchange purposes.

In November 1991, the Government announced that Optus Communications would take over the operations of AUSSAT.

With the introduction of carrier competition in Australia, the ABC in particular was able to consider a wider range of options for the delivery of both satellite and terrestrial broadcast and communication services. In 1992, the ABC had two permanent 24 hour a day International satellite links operating. Radio maintained a two way link to London while ABC-TV operated a link to Los Angeles.

In October 1993, Radio Australia began satellite transmission of English language programs into South East Asia, Western Europe and Japan. In May 1994, the USA was added to countries receiving the service.

In late 1995 South East Asia, Radio Australia was available 24 hours a day through the Australian Television signal on Palapa satellite Channel 5H, 3880 MHz C Band. Radio Australia programs could be received by tuning the second channel of the satellite receiver to 7.20 MHz for English and 6.48 MHz for programs in other languages.

In Europe, Radio Australia was available twice daily on the World Radio Network (WRN) service, the ASTRA 113 satellite on channel 22 on the 7.38 MHz audio subcarrier.

In North America, Radio Australia was available twice daily on the Galaxy 5 satellite Channel 6, 3820 MHz with subcarrier 6.8 MHz.

Although the Government funded ABC and SBS services have employed satellite technology for many years, Commercial stations, particularly networks, have also made use of the technology.

As early as 1981, Macquarie Broadcasting Holdings Ltd which had been established as one of Australia's largest broadcasting networks in 1938, prepared a report on the implications of satellite technology on the broadcasting industry. In January 1984, Engineers began planning and implementation of a project to cater for the Macquarie national network which at the time included sites in capital cities in Queensland, New South Wales, Victoria and South Australia as well as distribution networks to radio stations in all States.

It was planned that the project would be implemented in three phases:

- Interconnection of the capital city sites in Brisbane, Sydney, Melbourne and Adelaide.
- Development and expansion of the Regional Radio networks.
- Commissioning of a 3 metre transportable earth station (TES).

However, such was the enthusiasm by all concerned to embrace the satellite technology that implementation proceeded at a pace much faster than originally intended.

All capital city facilities were commissioned in 1986 with Sydney being the first in May, followed by Melbourne in July, Adelaide in October and Brisbane in December. The TES was cut into operation in August 1986.

In the regional areas, 22 receive-only sites were placed in operation by February 1987 with 2BH Broken Hill and 5MU Murray Bridge being the first two commissioned. The Broken Hill site was the first to receive and relay news via satellite. This took place in August 1986.

At the time, the Macquarie Network consisted of an internal audio news information exchange circuit between the fully owned Macquarie stations 4BH Brisbane, 4RR Townsville, 2GB Sydney, 2CA Canberra, 2WL Wollongong, 3AW Melbourne, 5DN Adelaide and 6PR Perth; a news computer data network interconnecting all those sites; Regional Radio news distribution networks to cater for Victoria, New South Wales and Queensland regional stations; and a common program interchange channel.

The Optus 'B' Series satellites like the earlier AUSSAT 'A' Series, had national and zonal beams enabling ABC and SBS programs to be distributed throughout specific areas of the nation. These programs were widely employed for retransmission by NTA terrestrial based stations. Time delay was built into some program material to cater for various time zones.

In August 1997, it was announced that the ABC had contracted with Optus for the use of the Aurora digital satellite service to deliver to remote areas ABC TV, Radio National and ABC Classic FM. The plan was to use both direct-to-home and terrestrial re-transmission methods. The contract was for a five year period and transition to the new digital service was scheduled to start late in 1997.

PARLIAMENTARY BROADCASTING SERVICE

Under the terms of the Parliamentary Proceedings Broadcasting Act 1946, the ABC was required to broadcast the proceedings of the Senate and the House of Representatives of the Federal Parliament. Requirement was that the proceedings were to be broadcast from nominated stations on the Radio 1 network in the State capitals, one station in Canberra, one in Newcastle and on one of the Inland short wave transmitters.

Determination of program material to be broadcast was controlled by the Joint Committee on the Broadcasting of Parliament Proceedings. In a typical year of about 67 sittings, about 530 hours of Parliamentary Proceedings were broadcast.

Today, radio broadcasting of their parliamentary debates is undertaken by more than 70 countries throughout the world but Australia was one of the first to undertake a broadcast of proceedings.

In March 1925, the Directors of Farmer and Co., Ltd operators of 2FC Sydney announced that the Hon. the Speaker had given permission for the proceedings of the Legislative Assembly on the opening day of Parliament to be broadcast over 2FC. The Directors claimed the event was significant in that the NSW Legislative Assembly was the first parliamentary body in the British Empire to have the proceedings of a sitting made available by wireless to the public. The first broadcast in England took place on 26 May 1926 with a broadcast from the House of Lords.

New Zealand had been broadcasting parliamentary proceedings since 1936, and immediately after the Second World War, Richard Boyer and Charles Moses of the ABC visited New Zealand in order to study the procedure. Following on their recommendation, the Commissioners resolved to offer substantial time on one of the ABC's two networks.

The Parliamentary Standing Committee on Broadcasting had been studying the matter for some time, and on receiving the favourable offer from the ABC, unanimously agreed that broadcasting proceedings should take place and they advised the Postmaster General Senator Cameron accordingly. The Committee believed that broadcasting would raise the standard of debate, enhance the prestige of Parliament, and contribute to a better informed judgment throughout the community. The Committee was also of the opinion that the need for broadcasting was even greater in Australia than New Zealand, owing to the greater distances separating the seat of Government in Canberra from the principal centres of population, so making it difficult for most people, from seeing Parliament in action.

Following an allocation of funds by the Government to equip the two chambers with the necessary technical facilities, and the introduction of the Parliamentary Proceedings Broadcasting Bill, broadcasting began at 8 pm on 10 July 1946.

The first speaker to broadcast was the Rt Hon. W M Hughes, who had been in the House of Representatives since 1901 when wireless was in its infancy and only useful for the transmission of Morse Code signals. Mr Hughes was a great supporter of the developing technology for many years, and following a visit to the front line in France during the First World War whilst Prime Minister, he sent the first wireless message to be received in Australia direct from England.

Many Engineers and Technicians were associated with the provision of the initial facilities in Parliament House, Canberra in 1946 and included Jim Hutchinson, Len Harris and Vic Le Pla.

Jim Hutchinson, who eventually rose to the position of Director, Posts and Telegraphs, New South Wales, commenced work in the Postmaster General's Department in 1918 as a Telegraph Messenger. In 1929, he obtained a Free Place at the Sydney University and graduated with Honours in Electrical Engineering in 1933. After graduation, he worked with the Radio Research Board, where he was involved in the controversy at the time, on whether long waves or medium waves should be employed for the Australian broadcasting service. He later joined the PMG's Department Research Laboratories in Melbourne.

In 1938, he transferred to Brisbane as Divisional Engineer Radio and Broadcasting and became involved in the installation of the 4QS Dalby 10 kW water cooled transmitter and the 219 m high radiator with the above ground coaxial transmission line using a rigid tube. Jim transferred to Sydney in 1942 as Assistant Supervising Engineer in the Radio and Telegraphs Division, where he was associated with many projects including 2NC Newcastle studios, Sydney ABC studios and the facilities at Parliament House, Canberra.

Len Harris retired from the Postmaster General's Department in 1973 as First Assistant Director General of the Planning and Research Division following a period of some 24 years on the staff of the Research Laboratories. He joined the Department in 1926 as Cadet Engineer and on qualifying as Engineer joined the Research Laboratories. Len Harris was involved in a number of major telecommunications projects including work for the National Broadcasting Service, in particular studio acoustics and was a leading authority on the subject. At the World Radio Convention held in Sydney in 1938 he presented a paper describing the use of an optical model in conjunction with the criterion of path difference between reflections, in order to determine the correct placing of acoustical absorbent material in a broadcasting studio. His work in this field was an important contribution to a little known art in Broadcast Engineering as it enabled the Engineer to readily determine the best position for placement of the absorbent. In later years he became Chairman of the Radio Research Board — a body that provided grants to support research projects in Australian Universities.

Vic Le Pla began his career in broadcasting on the staff of Commercial station 4GR Toowoomba in 1936 where he was engaged on the operation and maintenance of studio equipment. In 1938, he moved to the Broadcast Section of the PMG's Department in Sydney where he was engaged in the installation and upgrading projects for the 2CY, 2FC, 2BL, 2BH and 2BA transmitters and the installation of the studio facilities for the Parliament House, Canberra. He later worked on the design and installation of mixing consoles for the Sydney ABC studios and on the operation of the first FM transmitter in NSW. Vic left the PMG's Department in 1955 and joined the ABC Television Engineering staff where he held a number of positions, and also lectured at North Sydney Technical College on Film and Television Production Techniques.

The Parliamentary service frequently caused some programming problems for the ABC and in 1979 the Commission wrote to the Minister suggesting a review of arrangements for the broadcasting of Parliament. One major problem was that broadcast proceedings were selected in advance and on an alternating basis between the two chambers by the Joint Committee and the ABC had no authority to vary the format irrespective of the importance of the discussions in Parliament. The Commission was sometimes subjected to criticism by listeners who indicated that they preferred to hear proceedings from the chamber not being broadcast.

As early as 1951, the then Postmaster General had given consideration to the establishment of a separate network for the broadcast of parliamentary proceedings but the plan did not proceed, probably because of the unavailability of suitable transmission frequencies.

During 1988, the Telecom Broadcasting Directorate in conjunction with the ABC, produced a plan to free the National service from the Parliament broadcasting responsibility, by converting standby transmitters at each of the designated stations to operate on separate discrete frequencies. This was implemented for the 1988 Budget Session of Parliament as from 22 August 1988. All of the reallocated Parliamentary broadcasting transmitters carried the callsign 'PB' — that is 2PB, 3PB etc.

The Department of Transport and Communications later produced a National Metropolitan Radio Plan which was designed to lead to two existing Commercial MF transmitters in each capital city being transferred to the FM band. In exchange for FM licences, the selected stations were required to relinquish their MF installations to provide a permanent Parliamentary broadcasting outlet and a Public broadcasting outlet in each area.

By 1991, the transmitting stations in the Parliamentary Broadcast network comprised, 2PB Sydney on 630 kHz, with STC 4SU64 10 kW transmitter; 2PB Newcastle on 1458 kHz with AWA 9J50551 2 kW transmitter; 2PB Canberra on 1440 kHz with AWA 1J50551 2 kW transmitter; 3PB Melbourne on 1593 kHz with STC 4SU64 10 kW transmitter; 4PB Brisbane on 936 kHz with STC 4SU11A 10 kW transmitter; 5PB Adelaide on 1539 kHz with AWA BTM10 10 kW transmitter; 6PB Perth on 585 kHz with STC 4SU64 10 kW transmitter and 7PB Hobart on 729 kHz with AWA 19J50551 2 kW transmitter. The Adelaide station 5PB changed frequency to 972 kHz during September 1992 when transmissions began from a permanent facility at Wingfield using transmitting equipment including Nautel solid state transmitter cut back to 2 kW and 141 m mast radiator previously employed by Commercial station 5DN which had converted to FM operation.

By June 1993, other changes had been implemented and included 3PB Melbourne on 1026 kHz with 5 kW aerial power.

The 3PB service began transmission from 3RN/3LO Sydenham site using the standby 3RN 10 kW STC transmitter type 4-SU-64 and associated aerial, on frequency 1526 kHz.

In 1990, the operators of Commercial station 3TT (formerly 3DB) on 1026 kHz were granted a licence to transfer to the FM band and as part of the licence agreement, the transmitting facility was transferred to the Commonwealth's National Transmission Agency which planned to employ the facility for use with the Parliamentary Broadcast Network. The FM service with callsign 3TTT became operational on 24 June 1990.

Station 3DB began operation on 21 February 1927 as a B Class station with the licence being granted to Druleigh Business and Technical College Pty Ltd, with the callsign 3DB being derived from the business name. The licensee had been granted the licence in 1925. The station occupied two rooms on the 10th floor of Capitol House in Swanston Street, Melbourne, opposite the Town Hall. The transmitter room and aerial system were located on the rooftop area of the building.

The 'Herald and Weekly Times Ltd' made an offer in April 1929 to purchase the station. Following purchase, the new owners acquired land at Ashburton for the installation of a new transmitter and aerial. At the same time, new studios were built at 36 Flinders Street. The transmitter site was 12 km east of Melbourne and the 300 watt transmitter on 1180 kHz, provided a good signal over the city and suburban areas. The facilities were put into operation during December 1929.

When the station kept listeners out of bed until 4 o'clock in the morning to hear the Test cricket scores from England in 1930, it made Australian radio history. The cricket broadcasts did a great deal to popularise radio as a home entertainment medium. People organised Test broadcast parties throughout the State. Immediately following the broadcasts, the studios were gutted by fire which destroyed all plant and records.

Chief Engineer in the early 1930s was Ted Ashwin who had been associated with the establishment of 5CL Adelaide in 1924. In the mid 1930s, Max Hooper was Chief Engineer with Harry Kauper as Consulting Engineer. Harry had also been associated with 5CL, being Chief Engineer from 1926 until 1929.

By 1958, the technical facilities had been upgraded to take into account improvements in Broadcast Engineering Technology, including the installation of a 5 kW transmitter at the site at Viewbank.

In line with many other stations, 3DB began AM stereo transmissions on 1 February 1985. Much of the technical equipment was upgraded to cater for stereo technology, and two new Nautel 10 kW solid state transmitters installed in June 1985 to feed the 134 m high lattice steel radiator linked to the transmitter by a coaxial cable.

In 1988, the station was bought by the Albert family, a music production and publishing group and taken under the wing of the Australian Radio Network.

The new owners decided to relocate the studio facilities from the Herald and Weekly Times Building, Flinders Lane to new premises in Queensbridge Road, Melbourne. They also applied to the Australian Broadcasting Tribunal for a change in station callsign from 3DB to 3TT (3 double T).

In April 1993, the 3PB service began operation from the Viewbank site using one of the 3TT Nautel AMPFET 10 transmitters which were located in a substantial brick building comprising transmitter room, test room and adjacent power generating room. The program input was configured to provide automatic start-up under control of program fed from the studios. Operating frequency was changed from the previous 1526 kHz used at Sydenham to the 3TT frequency of 1026 kHz.

The other 3TT Nautel 10 kW transmitter was set up to provide an alternative standby unit for National station 3LO with a new coupling unit being provided. This added facility was later expanded to provide service for both 3PB and 3LO as required, using a remotely controlled switching system.

In Perth, the service had been provided using a number of NBS transmitters since transmissions began in 1988. Initially, it was proposed to use the 6WN Philips 2 kW 1656 type transmitter but the proposal was changed and an STC 5 kW transmitter type 4-SU-105B, one of a pair destined for 6GN Geraldton was put into operation.

The transmitter operating system was fully automatic, the start-up sequence being initiated when signal was present on the program line and close-down occurring after program ceased.

The 6WF standby aerial, in Alexanderson design installed in 1932, was utilised and retuned to the 6PB operating frequency of 585 kHz. Remote controlled Johnson switches were installed in the three station coupling huts.

In the event of a failure of the main 6WF transmission system, the station logic controller (PLC) would close down the 6PB transmitter, retune the standby aerial to 720 kHz and switch it to the 6WF standby transmitter.

Station 6PB would remain off air until 6WF was restored to the main aerial/main transmitter configuration, whereupon the PLC would reset the standby aerial to 585 kHz and restart the 6PB transmitter.

This system worked fairly well, but in time, the STC 5 kW unit was required at Geraldton, so a Nautel ND5 held for 6BE Broome was put into service in its place. The situation lasted several months, but eventually a decision was made to provide a 2.5 kW Nautel Ampfet transmitter as standby for 6WF and convert the original 6WF 10 kW standby STC transmitter type 4-SU-36C from 720 kHz to 585 kHz as a dedicated 6PB service, still however sharing the 6WF standby aerial with the new 2.5 kW Nautel unit.

This system was installed over several nights during the parliamentary recess in May 1990 and was still operational in this mode at mid 1994.

In Brisbane a 10 kW STC 4SU11A Radio National standby transmitter was retuned for operation on the newly assigned frequency of 936 kHz. The standby aerial required a special switching arrangement and matching unit to allow the Metropolitan Radio and Radio Regional service to utilise the aerial should the main aerial fail.

The transmitter, one of the STC Corio Sand colour models, was delivered to the Bald Hills site in 1948 following factory tests by Vern Kenna then Divisional Engineer Broadcast Installations Brisbane. Original major valves included a push-pull pair of 3J221E triodes in both final RF output stage and the modulator. They were later replaced by TBL 12/25 types. The original 872A mercury vapour diodes for minor HT and the 4078Z mercury vapour diodes for the 12 kV EHT supply were subsequently replaced by silicon diode stacks.

During December 1993, the Government announced that an 'Inquiry into Arrangements Relating to the Televising and Radio Broadcasting of Parliamentary Proceedings' would be held during 1994 by the Joint Committee on the Broadcasting of Parliamentary Proceedings. The Chairman was the Speaker of the House of Representatives the Hon. Stephen Martin MP. Aspects to be covered by the inquiry included:

- The general principles upon which radio broadcast, delayed broadcast and rebroadcast of proceedings of both Houses and their committees occur and the conditions for broadcasting of audio-only excerpts of proceedings.
- Particular matters relating to the televising of proceedings and a review of arrangements for making available to bodies external to Parliament House the signal of proceedings distributed by means of the house monitoring system.
- The establishment of a permanent Australia wide Parliamentary Broadcast Network under parliamentary control.

Because the Parliamentary Broadcast Network had long periods of inactivity, the Australian Broadcasting Corporation submitted a proposal to the Minister of Communications and the Arts to broadcast a 24 hour radio news service utilising the PB transmitters when not required for parliamentary broadcast purposes.

The Managing Director, David Hill outlined details of the proposal to a Joint Parliamentary Committee hearing in early 1994. The service designated ABC News Radio was intended to provide an hourly news service taking in sport, national and international news with headline updating every 10 minutes.

On 28 June 1994, the Minister, Michael Lee announced that he had given approval for the news service to proceed using the network when Parliament was not being broadcast. The news service became operational on 15 August 1994 with broadcasts 6 am to noon seven days a week. The Minister officially launched the service on 20 October 1994.

Programmers were surprised at the popularity of the service. During 1995-96, it was estimated that the network attracted some 274000 listeners, nearly 25% increase over the number of listeners for the first six months of 1995.

The service provided by the transmitters allocated to the facility, is known as the Parliamentary and News Network (PNN).

Just prior to Easter 1997, a transmitting station was provided in Darwin in time for the euthanasia issue being debated in the Federal Parliament. The Darwin service installed at the Deloraine Road site, comprised a temporary transmitter operating in the FM band on 102.5 MHz. All other stations in the PNN operated in the AM band.

RADIO FOR THE PRINT HANDICAPPED

In November 1974, during an upsurge of interest in the likely introduction of Public broadcasting in Australia, a number of blind persons and administrators realised that it was in the interest of the blind community to utilise such services should they be established.

Victorian groups in particular, were very active and an organisation known as Radio for the Blind Committee was constituted. There were 15 members on the Committee and the first broadcast organised by the group was transmitted over 3ZZ in 1975. The program was a half hour segment of information, views, education, talent and interviews relevant to blindness. The program, 'A Blind Affair' went to air each Sunday evening.

When 3CR commenced transmission in 1976, another program known as 'Broadview' went to air.

With the closure of 3ZZ in July 1977, the Committee had only the 3CR program being broadcast, so it began an indepth study of its future requirements. It came to the conclusion that what was needed was some form of broadcasting outlet devoted specifically to the blind community and similar to sub-carrier transmitting stations that had been successfully operated in the USA for the Print Handicapped. However, the Australian Government indicated that it was not prepared to approve a sub-carrier service.

Following representations to the Minister of Posts and Telecommunications, and a study by his Department, the Minister announced on 23 July 1978 that he had approved the granting of radio licences to Radio for Print Handicapped (RPH) groups in Melbourne, Sydney and Hobart. In 1980, a licence was granted to a similar group in Brisbane.

The stations were licensed under the Wireless Telegraphy Act for operation on or near 1,750 kHz. This frequency was off the AM broadcast band and listeners were advised on how they could have their broadcast band receivers modified to tune up to the operating frequency.

In the case of the Victorian station, it began regular test transmissions during 1981 with a 500 watt transmitter operating on 1704 kHz. Official opening of the service took place in December 1982. The studios were located at 7 Donald Street, Prahran in a house made available at peppercorn rental by the Villa Maria Society for the Blind. The station was initially on air from 8 pm to 10.30 pm daily, but later extended the service to daylight hours. The transmitter was later relocated to a site behind the Collingwood Town Hall and frequency changed to 1629 kHz. It shared accommodation with the 3CR transmitter and the two transmitters fed into a common aerial system. Messrs Dale Butler and Ralph Knight provided technical support for operation and maintenance of the station technical facilities.

In Sydney, a Co-operative was formed to establish a station in 1979. A grant from the Federal Government in 1981–82 enabled the group to purchase a 500 watt Harris transmitter for installation at a site at Concord West. Within a short time, the 2RPH studio facilities at 186 Blues Point Road, North Sydney comprised two on-air studios and one production studio with RME consoles; Cuemaster recorders; cart machines and a range of microphones.

By the mid 1980s the Tasmanian station 7RPH facilities comprised Harris MW1A and AWA 19J transmitters with studio equipment including RME and AWA consoles; Technics turntables; Plessey cart machines and Teac tape recorders.

In July 1989, the Australian Broadcasting Tribunal commenced inquiries into the granting of five Special Interest public radio licences for Print Handicapped groups, to serve the cities of Sydney, Melbourne, Brisbane, Adelaide and Perth.

The Tribunal granted licences to the following applicants:

- Radio for the Print Handicapped of NSW Co-operative Ltd, Sydney on 30 March 1990.
- Association for the Blind, Melbourne on 30 March 1990.
- Guide Dogs Association of SA and NT Inc., Adelaide on 19 June 1990.
- Queensland Radio for the Print Handicapped Ltd, Brisbane on 30 March 1990.

At the time, no decision had been reached by the Tribunal in regard to the Perth inquiry.

During 1992, the RPH services in operation included:

- 1RPH Canberra operated by Print Handicapped Radio of ACT using an old 2CN 500 watt AWA transmitter type 2J51316 on 1620 kHz.
- 2RPH Sydney operated by the Print Handicapped (NSW) Co-op Ltd, with a 1000 watt transmitter on 1539 kHz.
  The radiator employed for 2RPH was a former 2UE self-supporting tower erected in 1939. In late 1993 plans were developed for the station to transfer to the original 2WS transmitting station site at Prospect.
- 3RPH Melbourne operated by Print Handicapped (Vic) Co-op Ltd, using a TBC type AM10KD transmitter on 5 kW and frequency 1179 kHz.
- 4RPH Brisbane operated by Queensland Radio for the Print Handicapped with 5 kW on 1296 kHz (previously 500 watts on 1620 kHz).
- 5RPH Adelaide operated by Radio for the Print Handicapped with a 2000 watt transmitter on 1197 kHz.
- 6RPH Perth operated by 6RPH Information Radio with a 2500 watt transmitter on 990 kHz.
- 7RPH Hobart operated by Broadcasting Services for the Print Handicapped with a 500 watt transmitter on 1620 kHz.

For some time the Department of Transport and Communications had planned to move all RPH services to the MF broadcast band as part of the National Metropolitan Radio Plan (NRMP) but by June 1993, not all stations had been allocated frequencies in the band. Station 4RPH Brisbane had changed to 1296 kHz but both 1RPH Canberra and 7RPH Hobart were both operating on 1620 kHz.

In July 1993, the 5RPH service transferred from sharing facilities at Cavan with 5AD to the site at Wingfield vacated by 5DN when that station transferred to FM band operation. It shared the Wingfield site with 5PB but fed into its own 61 m high aerial which had originally been a 5DN standby. The service employed a 5DN standby transmitter with 2 kW output on 1197 kHz, the frequency formerly used by 5KA.

The 3RPH Melbourne service operated with transmitting facility originally built in 1956 for 3KZ when the licensing authority gave permission for Melbourne based transmitters to move to Heidelberg-Lower Plenty area and transmitter powers to be increased to 5 kW.

Commercial station 3KZ began operation on 8 December 1930 with the licence being held by Industrial Printing and Publicity Co. In 1932, the licence was transferred to 3KZ Broadcasting Co., Pty Ltd.

Following the granting of a licence to operate an FM service from 1 January 1990, the 3KZ AM facility was transferred to the Commonwealth's National Transmission Agency which allocated the transmitting facility for use by 3RPH from studios of the Association for the Blind at Kooyong. The transmitter was controlled from the studios using a TFT remote control system.

Transmitters comprised a TBC type AM10KD 10 kW unit derated to 5 kW feeding the main radiator and an STC type 4-SU-55 5 kW transmitter as a hot filament standby feeding a standby radiator.

The main radiator was a 135 m high omnidirectional type erected in 1956, while the standby was a 54 m high type erected in 1971. Both radiators were fed by six conductor open wire transmission lines.

A standby diesel engine power plant installed in 1966 provided emergency power when required.

In Brisbane, 4BK Austereo was the only successful bid during late 1989 when auctions were held for capital city Frequency Modulation licence conversion for Commercial AM radio broadcasters. It released its 1296 kHz transmitter facility at Tingalpa to become FM105.

Radio for the Print Handicapped had been operating for some time using a low power AM transmitter at a disused facility at Murarrie near Tingalpa. With the release of 4BK in April 1990 and the ownership of the facility being transferred to the Commonwealth, the allocation of 1296 kHz was available for the Print Handicapped service. Transmission commenced on 10 September 1990 and was a major boost for the service.

The transmitters were MW10 Harris 10 kW units operating in a main and standby configuration with the transmitters detuned to

5 kW for each unit. The aerial system used a two mast 85 metre directional array with nulls in the pattern directed towards Wellington in New Zealand and Bendigo area in Victoria. Standby power was provided by a Caterpillar 65 kVA motor generator set.

As at the beginning of 1994, 6RPH Perth was operating with ex-6PM facilities on 990 kHz transmitting with a 2 kW transmitter feeding an 85 m radiator while 2RPH Sydney was employing ex-2WS facilities on 1,224 kHz with 5 kW transmitter feeding 129 m high directional aerial system.

In the case of Hobart and Canberra services, the Government allocated $300000 for establishment of their own transmitting facilities employing frequencies 864 kHz for the Hobart service and 1125 kHz for the Canberra service.

In each of the financial years 1994–95 and 1995–96, the Department of Communications and the Arts allocated a transmission subsidy of $100000 to the Australia Council for Radio for the Print Handicapped towards running costs of the services. In the financial year 1996–97 the subsidy was $97000.

DEPARTMENT OF COMMUNICATIONS, THE INFORMATION ECONOMY AND THE ARTS

The Department of Communications, the Information Economy and the Arts has only recently been established, its functions being previously carried out by the Department of Communications and the Arts and before that, by the Department of Transport and Communications.

The Department of Transport and Communications was formed on 24 July 1987 following amalgamation of the Departments of Communications, Transport and Aviation. The Department was responsible for planning, determination and oversighting of the technical standards of broadcasting in Australia and the funding of Government owned broadcasting services.

The Government through various Departments and bodies has controlled broadcasting from the very beginning in 1923. These have included Postmaster General's Department, Postal and Telecommunications Department, Department of Communications, Department of Transport and Communications and Department of Communications and the Arts. Other bodies with involvement at various times include the Department of the Media (radio and television policy), Australian Broadcasting Control Board (technical and planning matters associated with radio broadcasting and television), Australian Broadcasting Tribunal and Australian Broadcasting Authority.

With the reorganisation of the Postmaster General's Department from 1 July 1975, the Australian Telecommunications Commission trading as Telecom Australia, took over responsibility for part of the broadcasting function.

In recent times, the Department of Transport and Communications undertook a number of studies and reviews to keep abreast of technological developments, updating plans for the broadcasting service, development of service quality standards and the technical means of delivery and implementation of various types of services. In particular, a great deal of effort had to be put into reviewing the metropolitan radio services to allow expansion of FM services, establishment of a Parliamentary broadcasting network, requirements for Radio for the Print Handicapped, new FM services in regional areas, the Public radio planning program, remote Commercial radio services, station service areas, Self-help Broadcasting Reception Scheme, Second Regional Radio Network to provide residents in regional areas with access to a second ABC radio service, station site and facility sharing, expansion of the Radio Australia transmission facilities, review of the regulatory structure of broadcasting and broadcasting-like services, work in International forums to provide input and promote Australian views and interests, standards for electromagnetic interference, development of AM and VHF-FM reference receiving specifications, introduction of Ancillary Communications Services to allow the utilisation of spare capacity within the normal signals of radio broadcasting stations to carry separate audio signals, ABC Youth Radio Network, Digital Audio Broadcasting (DAB), TV interference from new FM services, propagation conditions from Radio Australia stations and others.

The Department's activities at June 1991, encompassed a number of functions with those related to radio broadcasting being controlled by Divisions responsible for Broadcasting, Radiocommuncations and Technology Development.

The Broadcasting Policy Division was headed by Bill Ellis, First Assistant Secretary; assisted by Richard Thwaites, Assistant Secretary, Commercial Services Branch and Tony Slatyer, Assistant Secretary, National and Public Broadcasting Branch.

The Communications Policy and Planning Division was headed by Roger Smith, First Assistant Secretary; assisted by Chris North, Assistant Secretary, Planning Branch and David Hartley, Assistant Secretary, Transmission and Spectrum Policy.

The Communications Operations Division was headed by Vic Jones, First Assistant Secretary; assisted by Colin Knowles, Assistant Secretary, Station Planning Branch; Greg McAdoo, Assistant Secretary, National Broadcasting Branch and Graeme Trompf, Assistant Secretary, Radiocommunications Operations Branch.

Other portfolio bodies which reported to the Minister included Australian Broadcasting Corporation, Special Broadcasting Service, Australian Broadcasting Tribunal, Telecom Australia and others.

In July 1991, as part of reorganisation within the Department, the Radiocommunications Operations Branch was moved from the Communications Operations Division, leaving Station Planning Branch, National Broadcasting Branch together with the Policy and Executive Support Unit to form the Broadcasting Operations Division. The move was intended to facilitate the transfer of functions to the proposed National Transmission Agency and the Australian Broadcasting Authority.

Until mid 1992, installation, upgrading, operation and maintenance of the National service, including Radio Australia was carried out under contract to the Department by Telecom Broadcasting under General Manager Leon Sebire. Key services provided to the Department by Telecom Broadcasting included implementation of the Capital Works Program; maintenance and operations services; design of broadcasting network systems and facilities; engineering design of masts, towers aerial systems, transmission lines and feeders; buildings and structures; building and station electrical and mechanical services; project management; supervision of contract project services; material and equipment supply functions; provision of MIC and Lead House repair facilities; specialist rigging services; records management; equipment evaluation; works estimation and others.

The role of the Postmaster General's Department/Telecom in broadcasting in Australia extended to the beginning of broadcasting in this country and in particular from 1929 when the Department took over the A Class stations to form the National Broadcasting Service.

Following the transfer of postal and internal telecommunications operations to independent Commissions on 1 July 1975, the Postal and Telecommunications Department was established on 22 December 1975, assuming those responsibilities of the PMG's Department which had not been transferred to the Commissions. In addition, the Postal and Telecommunications Department took over the radio and television broadcasting policy functions from the former Department of the Media.

On 1 January 1977, the Postal and Telecommunications Department was given the responsibility for technical and planning matters associated with radio broadcasting and television, previously administered by the Australian Broadcasting Control Board, although this did not bring with it any further responsibility for the Radio Australia service. Prior to July 1975, the PMG's Department had total responsibility for the technical policy, construction and operation of the transmitting stations of Radio Australia but following the establishment of Telecom, the policy and technical planning responsibilities were transferred to the new PMG's Department and later to the Postal and Telecommunications Department. Telecom continued installation and operational functions as agent for the Postal and Telecommunications Department.

Since 1939, the responsibility for the content of the programs and for the technical facilities required for the program production studios of Radio Australia has remained with the ABC. Priority of target areas and contents of programs are developed in co-operation with the Department of Foreign Affairs.

For some time, concern had been expressed that the arrangement of a sole supplier may not be the most efficient means of providing and maintaining the Government funded transmission facilities. There were also other aspects of concern, and consequently the Department engaged Consultants to report on the future management of the Commonwealth's transmission facilities.

Following the Consultant's report, and examination of submissions by various organisations, the Government decided on 9 October 1991 to establish a National Transmission Agency to manage the Commonwealth's broadcasting network.

One of the guiding principles was that the NTA would progressively introduce competitive tendering for the services being supplied exclusively by Telecom Broadcasting. It was planned that a review of the NTA would be undertaken after 18 months to consider whether it should be converted to a Government Business Enterprise and whether the ABC and SBS should be funded to pay for transmission services.

As at June 1993, the Broadcasting Program Structure within the Department comprised:

- Broadcasting Policy, with First Assistant Secretary, Tony Shaw; Assistant Secretary Commercial Broadcasting Policy, Peter Field; Assistant Secretary Public Broadcasting Policy, John Neil; Principal Adviser, Chris North.
- National Transmission Agency, General Manager, Vic Jones; Assistant General Manager, Greg McAdoo.
- Communications Selection Team, Assistant Secretary, Chris Dalton.
- Australian Broadcasting Corporation, Managing Director, David Hill.
- Special Broadcasting Service Corporation. Managing Director Malcolm Long.
- Australian Broadcasting Authority, Chairman, Brian Johns AO.

The Broadcasting Policy group provided a policy, regulatory and operational framework for achieving program objectives in all areas of broadcasting, including Commercial, National, Community, Subscription and Narrowcasting. The framework also provided assistance to the ABC, SBS and ABA in meeting their statutory and regulatory obligations, as well as efficient, effective and equitable access to the use of the radio frequency spectrum by broadcasting services.

Cost of providing these services during 1992–93 was approximately $10 million.

The Government made a change to the Communications portfolio when it carried out a reshuffle of ministerial responsibilities during early 1994. A separate and free standing Department of Communications and the Arts was established on 28 January 1994 with Michael Lee as Minister and Neville Stevens as Secretary.

In the first half of 1994–95, a new portfolio program structure was developed to achieve a division of portfolio responsibilities more aligned to a new and evolving environment. Portfolios with a radio broadcasting role included National Transmission Agency; Australian Broadcasting Corporation; Special Broadcasting Service; Australian Broadcasting Authority; Australian Film, Television and Radio School; Spectrum Management Agency; Telstra Corporation; and The National Film and Sound Archive.

In 1997, the Department's Public Broadcasting Branch included National Broadcasting Section, National Transmission Section, and Community Broadcasting Section while the Licensed Broadcasting Branch included Broadcasting Development Section, Digital Broadcasting Section and Broadcasting Industry Section.

As from 1 July 1997, the Spectrum Management Agency merged with the Australian Telecommunications Authority (AUSTEL) to form the Australian Communications Authority.

In 1998, the Department functioned under the name Department of Communications, the Information Economy and the Arts with Hon. Richard Alston as Minister.

NATIONAL TRANSMISSION AGENCY

In October 1991, the Federal Government announced that it intended to establish the National Transmission Agency (NTA) as a separate cost centre within the Department of Transport and Communications to manage the Commonwealth's transmission facilities.

The Agency was established on 1 July 1992, being formed from the National Broadcasting Branch and other administrative elements of the former Broadcasting Operations Division of the Department.

The primary functions of the Agency were to plan, establish, operate and maintain the Commonwealth broadcasting transmission facilities to broadcast the radio and television programs of the ABC and the SBS; to put into effect the Government's policy objectives for the maintenance and extension of the signal coverage of the National broadcasting services; to provide high quality transmission services cost-effectively while maintaining the integrity of the network; and to accommodate the transmission facilities of Commercial, Community Broadcasting and Radiocommunications operators.

The Agency's role was principally one of planning and management. It contracted out installation and construction of broadcasting facilities and infrastructure, and their operation and maintenance. During 1995–96, expenditure involved in the expansion of the network and replacement of equipment and plant was about $40 million while management and operation costs amounted to about $104.4 million.

The Government provided the Agency with the necessary funds by Commonwealth budget appropriation through the Department of Communications and the Arts. However, as from 1 July 1997, the ABC and SBS transmission costs were funded directly by the Government to those organisations.

The network of transmission facilities of the Agency was one of the largest in the world. At 30 June 1996, it included over 1,151 TV and radio broadcast transmitters located at more than 533 sites. Some of the sites were owned by the Agency while others were leased from organisations such as Telstra.

Each transmission facility included the site itself, transmitters and associated technical equipment, towers, masts, aerial systems, buildings and in some cases, the road leading to the site. The total value of these assets as at June 1993, one year after the Agency was established, exceeded $307 million, with the ABC using 114 AM transmitters, 494 FM transmitters, 12 high power HF transmitters located at four sites for the broadcast of Radio Australia programs to the world, and eight HF transmitters located at five sites providing programs to listeners in remote areas of Australia. At the same time, SBS AM radio transmitters were located at four sites. The Agency was also responsible for the TV transmission facilities of the ABC and SBS.

The Government determined where the broadcasting facilities would be established, and it was then the responsibility of the Agency to manage the design, construction, operation and ongoing maintenance of all those facilities.

An important change following establishment of the Agency, was that Telecom Australia no longer had the exclusive right of design, construction, commissioning, operation and maintenance of the NBS transmission facilities. The Agency introduced competition, and for the first time in the history of the National broadcasting service, these activities were put out to public tender on a commercial businesslike manner.

The costs associated with new works and operation of the Government funded transmission services was considerable. In the 1992–93 financial year, capital works amounted to about $51 million while operation and maintenance expenditure was about $76 million. The Agency was based in Canberra with Vic Jones appointed the first General Manager.

Soon after its establishment, the Agency employed a staff of 15 Professional Engineers, six Technical Officers and 47 Administrative Officers.

At mid 1993, the staff included:

- General Manager's Office — Peggy Christopher, Dr John Hall, John Eley.
- Assistant General Manager, Greg McAdoo.
- Implementation Unit — Lyn Mackay, Manager; Angelina Maciejewski; Kelly Pearce.
- Business Development Unit — John Higginbottom, Manager; Linda Andersen; Greg Freeman; Anne-Maree Thomson; Rohan Melhuish.
- Network Management Unit — Brian Foster, Manager; Conrad Shepherd; Dominique Appay; Alex Georgiev; Colin Harman.
- Network Construction Unit — Lou Cossetto, Manager; Bob Pizzato; Warwick Potter.
- Finance and Information Unit — John Griffin, Manager; Danny Clynk; Stacey Pondes; Malcolm Knott; Bob Maslin.
- Transmission Planning Unit — Alan Hayes, Manager; Basil Bilanenko; Peter Pan; Shanthilal Nanayakkara; Alex Beech; Terry Kennedy; Andrew Deans; Darryl Fallow; Steve Farrugia; Weng Kee Tam; James Kirkup; Doug Iles; Premasiri Edirisuriya.
- Property, Environment and Services Unit — Peter Freer, Manager; Kerry Dunstan, Robert Hesterman.

General Manager Vic Jones began his career in the Postmaster General's Department in 1957, transferring to the ABC in 1959 as Technician. In 1969, he graduated from Monash University with Bachelor of Engineering First Class Honours Degree and in the same year was appointed Engineer Class 1 in the ABC where he was engaged on technical operations at the ABC's Ripponlea television studios.

In 1972, he was awarded a Master of Engineering Science Degree by Monash University.

From 1972, Vic spent two years with the Department of Civil Aviation working on the development of digital control and recording equipment before taking up an appointment as Engineer Class 3 with the ABCB. With the ABCB, he was involved in the introduction of VHF-FM radio, early preparations for satellite broadcasting and later, UHF-TV. Following a period of participation in the Public Service Board's Executive Development Scheme, Vic progressed through a number of management appointments in the Department of Communications and Department of Transport and Communications including Assistant Secretary, Station Planning Branch; Assistant Secretary, Broadcasting Planning Task Force; Head, Broadcasting Services Division; Head, Radio Frequency Management Division; Head, Radio Communications and Broadcasting Operations Division; and in 1992, General Manager National Transmission Agency.

Alan Hayes, Transmission Planning Manager began work in radio in 1964 with Radio Corporation Pty Ltd Melbourne wiring and assembling circuit boards and later becoming associated with the design and manufacture of 5 kW UHF TV transmitters. This was followed by field installation work with projects at sites in Western Australia and Tasmania.

In November 1978, Alan joined Postal and Telecommunications Department as Engineer Class 1, Broadcast Engineering Division. He was appointed Director of Engineering with the Department of Communications in 1985 becoming involved in many major activities including planning and implementation of the Second Regional Radio Network, Band II clearance and the Equalisation project.

With the establishment of the National Transmission Agency in 1992, Alan became Transmission Planning Manager including planning of NTA's experimental digital sound broadcasting transmissions for Melbourne, Sydney and Brisbane.

In 1996, Basil Bilanenko was the Transmission Planning Manager. Basil began work in telecommunications in Sydney with Telstra Corporation occupying positions of Technician and Technical Officer before completing a Degree in Electrical Engineering in 1982 when he moved into broadcasting to work for the former Department of Communications in Canberra. He was associated with a range of broadcasting projects with the Broadcasting Planning Task Force before transferring to the Department's Station Planning Branch in Canberra.

With the establishment of the NTA, he became a member of the Transmission Planning Section responsible for extensions and improvements to transmission of the services provided by the National broadcasters and subsequently becoming Manager of the Section.

Highlights of Agency activities during its first year of operation included:

- Staff level increased to 91.
- Project Manager engaged to handle large construction projects.
- Percentage of Government projects completed on time exceeded 48%.
- Percentage of Government projects completed within approved budget exceeded 82%.
- During the period, 189 projects were completed and 173 new projects commenced.
- The number of radio and television transmitters in the network increased by 13% making a total in service of 908. The number of FM transmitters employed to transmit the ABC Radio National and Radio Regional programs increased from 214 to 287 and FM transmitters employed to transmit ABC Class FM increased from 47 to 54.
- Sixty project briefs were completed and 105 technical operating specifications for transmitters to carry National broadcasting services were prepared and approved.
- Fifteen field surveys and test transmissions associated with planning new transmission facilities and extending signal coverage of existing national services were conducted.
- Reliability of the transmission network exceeded 99.6%. Outages resulted from commercial power failure 25%, equipment faults 34%, safety considerations 2%, planned maintenance 37% and external events 2%.
- Total annual cost per kilowatt-hour of the transmission network was $0.43 compared with a target of $0.47 per kW/hr.
- An Asset Management system was developed with asset data derived from a comprehensive valuation of the Agency's assets.
- The Agency operated 529 properties throughout Australia although not all were used for transmission purposes. During the period, 14 transmission sites were added to the network.
- As at 30 June 1993, the number of active Commercial clients was 218.
- The Agency published its first Corporate Plan specifying key performance targets.
- A contract was let for the first major project competitively tendered. The contract worth $7.9 million was awarded in January 1993 to Telecom Australia and covered major works in Northern Tasmania to accommodate Commercial transmitters in new areas and to provide upgraded and new transmission facilities at 11 sites for transmitting National radio and television services to the region.

Important radio highlights during 1993–94 included:

- Additional National service radio transmitter outlets comprised 17 ABC Radio National, 14 ABC Regional Radio, 4 ABC Classic FM, 1 ABC Youth Radio, 7 SBS radio, 1 Radio for the Print Handicapped and two at Radio Australia Cox Peninsula.

- Signal coverage of ABC Regional Radio was extended to about 225000 people, ABC Radio National to about 500000 people and ABC Classic FM to almost 400000 people.
- More than nine million people were provided with access to SBS Radio service.
- The overall availability of the network was 99.71%.
- Total annual cost per kilowatt-hour of the transmission network was $0.38 compared with $0.43 for the previous financial year.
- Tenders were called for provision of a Transmission Operating and Supervisory System (TOSS).
- The NTA commenced publication of a quarterly newsletter 'Contact' to keep clients and others informed about NTA activities.

In June 1992, an NTA Advisory Group was established by the Secretary of the Department to oversee the operations of the Agency. The Group was also intended to assist the Agency in developing its corporate and business plans and strategies to achieve its financial and performance targets. Members of the Group comprised Christine Goode, Deputy Secretary (Broadcasting); Graham Glenn AO and Mike Empson.

In early 1994, the NTA held a briefing with industry to explain plans for the development of a tender and contracting arrangements for maintenance of its National Transmission Network.

Maintenance requirements were to comprise the following functions:

- Site administration.
- First-in maintenance.
- Preventative and routine maintenance.
- Station inspections, including performance assessment and reporting.
- Component and module repair.
- Disaster recovery.
- Spare parts provisioning.
- Station asset management and stocktaking.

Since 1929, the Postmaster General's Department, and in more recent years, Telecom Australia and Telstra Corporation Ltd had maintained all stations transmitting ABC programs.

However, as part of its economic reform process, the Government required NTA to introduce a system of competitive tendering for its Capital Works and Operation and Maintenance Programs. The Capital Works Programs had been subject to the tender system for some time, with private firms figuring prominently on the list of those being awarded contracts for construction projects.

Typical of contracts awarded to private firms was one to Wesgo Communications Pty Ltd in 1994 for refurbishing seven MF/AM transmitting stations to the value of $3.3 million. The work involved replacement of old transmitters and emergency power generation plant and overhead transmission lines with underground cables.

The contract concerned work at 2KP Smithdown, 2NR Grafton, 4QS Dalby, 4AT Atherton, 4MS Mossman, 4TI Thursday Island and 4WP Weipa.

During 1996–97, capital expenditure on the transmission network (TV and radio) was $30 million with works valued at $22.4 million being contracted out to a number of organisations including Telstra, BCL, NEC, Kilpatrick Green and Practel International.

In recent years considerable investment was made in replacing obsolete transmitting equipment which had reached the end of its economic life. By 1997 the average age of transmitters in the network was 7½ years which compared favourably with an expected working life of 15 years.

As part of the tendering arrangement for Operation and Maintenance, NTA divided the nation into five geographic areas comprising Western Australia; South Australia/Northern Territory; Victoria/Tasmania; New South Wales/Australian Capital Territory; and Queensland. Radio Australia installations at Shepparton, Cox Peninsula and Carnarvon were to form a sixth contract.

In late 1995, four companies were invited to submit tenders for three year contracts for the five Operations and Maintenance contracts.

The companies were Telstra Corporation Ltd; Australian Defence Industries Ltd; Broadcast Communications Ltd; and Serco Australia Pty Ltd. Broadcast Communications Ltd is a New Zealand company. The others are Australian companies.

The four were short-listed following response to an Invitation to Register, a five part document each separately bound and supported with 14 floppy disks detailing transmission faults, outages and spare equipment, plus 11 CD ROMs providing technical drawings of facilities at the sites.

Plans were for the successful contractors to assume responsibility across the network from 1 July 1996.

Contracts were subsequently placed with Telstra Corporation Ltd and Broadcast Communications (Australia) Pty Ltd.

Telstra was awarded a Contract for Victoria/Tasmania; New South Wales/Australian Capital Territory and Western Australia regions involving 656 transmitters and 319 sites.

Broadcast Communications (Australia) Pty Ltd was awarded a Contract for Queensland and South Australia/Northern Territory regions involving 467 transmitters at 223 sites. The company whose Managing Director was Nick Powl planned to bring in eleven experts to support the management of its Contract.

The Contracts totalled some $140 million over three years and represented one of the largest contracts of its type awarded in the Australian broadcasting industry.

Each Contract was for a period of three years from 1 July 1996 with allowance being made for extension of each Contract subject to performance criteria. The NTA estimated that the new arrangement would result in ongoing savings to the budget of $26 million.

In order to undertake an effective management role in oversighting the operation of the network and to provide the maintenance contractors with access to a network monitoring system the Agency installed the Transmission Operating and Supervisory System (TOSS). It was an automatic surveillance system enabling monitoring and remote control of transmission facilities at more than 500 sites. The central control facility was located at the NTA Operations Centre Canberra and linked to sites via landline communications circuits. The system began operation in July 1996 at a cost of $1.9 million.

In 1998, NTA placed a contract with Fujitsu Australia Ltd to supply 100 Motorola MOSCAD Remote Terminal Units with supporting software to replace units known as Telstra ACTTS (Automatic Control Testing Telemetry System) which had been in operation for many years and had become outdated technology. The units were to be installed by the two Operation and Maintenance Contractors, Telstra and Broadcast Communications Ltd at selected stations under their control.

As at 30 June 1996, the National radio transmission network comprised transmitters for ABC Radio National, 232; ABC Regional Radio, 210; ABC Metropolitan Radio, 8; ABC Classic FM, 60; ABC Youth Radio, 47; SBS Radio, 13; Parliamentary and News Network, 8; Radio for the Print Handicapped, 5; ABC HF Inland, 3; and Radio Australia, 16. In addition, there were a number of Commercial, Community and Self-help transmitters accommodated with site facilities.

NTA staff employed as at 30 June 1996 comprised 119 people of whom five were employed on fixed term contracts. Agency running costs for the 12 month period July 1995 to 30 June 1996 totalled approximately $9.9 million. At June 1997 staff number had reduced to 106.

For its anticipated final year of operation 1997-98, the Government allocated NTA $22.6 million for capital works and $82.3 million for operations and maintenance.

The largest business group at mid 1998 in the NTA was the Network Management Unit which was responsible for scrutinising network operations and performance, development of major maintenance and equipment programs, formulating network standards, administering Operations and Maintenance contracts and commissioning new works.

During 1997, a major Government policy change in relation to operation of the Government funded National broadcasting services opened the way for control of the transmission facilities to be placed in the hands of the program providers, the Australian Broadcasting Corporation and the Special Broadcasting Service.

In July 1997, the Government announced it had decided to sell the National Transmission Network and commissioned a scoping study to investigate options of achieving a viable sale estimated to be $300-$400 million. It was anticipated that the sale of the transmission facilities managed by the National Transmission Agency would take place by mid 1998. Sale was to be by open tender and the buyer would be required to accept five year transmission contracts with the two National broadcasters.

Potentially the sale of the NTA facilities and the transfer of transmission funds to the broadcasters would enable the ABC and the SBS to exercise greater control over service levels and the planning of new services.

On 29 November 1997, an advertisement in the press called for Registration of Interest for purchase of the network. The sale of the business was to be managed by the Commonwealth Office of Asset Sales with the assistance of Arthur Andersen Corporate Finance. The advertisement indicated that the network included 1197 radio and television transmitters used to broadcast ABC and SBS radio and television services from 547 owned and leased sites and 520 transmitters belonging to 167 licensed broadcasters.

On 6 December 1997, The Senate Environment, Recreation, Communications and the Arts Legislation Committee announced that it proposed to conduct a public inquiry into the National Transmission Network Sale Bill 1997 with the intention of reporting to the Senate by 10 March 1998.

Important factors associated with the sale of the network and included in the National Network Sale Bill 1997 included:

- The Bill provided the ABC and the SBS with a direct commercial relationship with the transmission service providers. The ABC and SBS had been seeking such a relationship for many years.
- Transferring the operational activity to the private sector would produce the scope for greater client focus and responsiveness that flows from normal commercial practice.
- Maintenance of existing ABC and SBS coverage and service quality, particularly in regional and remote communities was a prerequisite.
- Existing Community Service Obligations would be preserved, including those for network users such as Radio for the Print Handicapped, remote commercial satellite broadcasting services and self help retransmission.
- A compact with the ABC and SBS would indicate the Government's transmission coverage and quality expectations.
- The network would be transferred to one or more national transmission companies which would have agreed contracts with the ABC and SBS spelling out transmission requirements. These companies would be sold to the network purchaser or purchasers with the contracts in place.
- The ABC and SBS would be able to establish their own transmission services.
- The ABC and SBS will be responsible for dealing with any complaints from the public about reception quality.
- The process of selling the network was to proceed by way of sale of shares in one or more Commonwealth owned companies (National Transmission Company — NTC).
- The contracts between the ABC, SBS and RPH and NTC would set out core performance obligations for continued supply of transmission services. Contracts would be for 5 years initially, with option for renewal for two further 5 year periods.
- Following sale of the network, the Government would provide funding to the ABC and SBS to enable them to meet contract obligations to purchase transmission services from the NTCs.
- Target date for settlement of the sale was 30 June 1998.

Although passed by the House of Representatives in 1997, the Bill had not been passed by the Senate at the time an election was called in September 1998.

As at late June 1998, staff included:

- General Manager, Vic Jones; Executive Assistant, Helene Tewari.
- Executive, John Hall, Brian Foster, Linda Andersen.
- Development and Review Unit, Jenny Oakes (Manager), Tina Boyd, Kaye Campbell, Elaine Dyason, Michelle Jackson, Lynne James.
- Property, Environment and Services Unit, Peter Freer (Manager), Kerry Dunstan, Phil Russell, Ian Lane, Phill Burns, Simon Dickson.
- Finance and Information Management Unit, John Griffin (Manager), Danny Clynk, Grahame Gerstenberg, David Philip, Barry Walmsley, Mal Knott.
- Business and Development Unit, Angelina Macie (Manager, Client Services), Kevin Payne, Peter Ellet, Anne-Maree Nelmes, Greg Freeman, Vilma Bowers, Debbie Lyons, Chris Gerstenberg, Graeme Barrow, James Foot, Graham Hanna.
- Network Management Unit, John Higginbottom (Manager), Paul Ament, Alex Beech, Craig Hamilton-Smith, Colin Harman, Terry Kennedy, John Postgate, Chris Purnell, Barry Bourke, Pat Conroy, Linda Grieve, Jim Lissaman, Jim Smith, Steve Sollazzo, Aleksandar Georgiev, Norm Chalmers, Rod Fuller, Glenn Howlett, Al Morgan, Ken Williams, Sava Momcilovic, Conrad Shepherd.
- Transmission Design and Development Unit, Alan Hayes (Unit Manager) Stephen Farrugia, Peter Pan, Basil Bilanenko, Andrew Deans, Darryl Fallow, Doug Lles, James Kirkup, Ron McGregor, Michael Payne, Thien Tran, Dennis Wheatley, Bob Pizzato, Matt Betts, Sharron McKay.
- Network Construction Unit, Lou Cossetto (Manager), Dom Appay, Steve Bernasconi, Paul Bray, Patricia Butler, Bill Hatossy, Kelly Pearce, Warwick Potter, Lara Van Nunen, Steve Warner.

BROADCASTING COUNCIL

The Broadcasting Council was an organisation which provided collective consultation between the Minister of Transport and Communications and broadcasters. It was established under the Broadcasting Act, with the Regulations defining its membership, composition and functions, being approved in 1981.

Functions of the Council included:

- To consult with the Minister about planning and development of broadcasting services.
- To consider matters referred to Council by the Minister and
- To consider specific issues relating to the development of broadcasting raised by members of the Council.

Council members were accompanied at meetings by Technical Advisers who assisted with Engineering matters addressed by Council. These advisers were members of a Technical Advisory Group established by Council to advise on Engineering issues concerning broadcasting services in Australia.

The Council comprised a Chairman and representatives from Australian Broadcasting Corporation, Special Broadcasting Service Corporation, Department of Transport and Communications, Federation of Australian Commercial Television Stations, Federation of Australian Radio Broadcasters and Public Broadcasting Association of Australia.

Council considered and dealt with a number of important broadcasting issues in recent times. These included planning guidelines, radio technical performance standards, The National Radio Plan (AM-FM conversion), logging equipment, channel sharing, broadcasts to remote Aboriginal communities, test transmission permits, limited broadcast licences, review of the broadcasting legislation, overseas technical developments in broadcast engineering, sound broadcasting satellite service, Digital Audio Broadcasting (DAB), radio frequency spectrum, rate of introduction of Commercial radio to regional areas, the B-MAC standard, the role of AUSTEL in broadcast technical matters, Broadcasting Services Bill, Frequency Plan for broadcast studio-transmitter links and OB sound links, TAB broadcasts, sixth terrestrial broadcast channel and many others.

The Broadcasting Council was abolished on 5 October 1992 following repeal of the Broadcasting Act and commencement of the Broadcasting Services Act 1992. However, the Council met on several occasions after 5 October with the agreement of the Minister to discuss transitional issues.

At the time the Council was wound up, Members comprised:

- Chairman, Joseph Skrzynski.
- Australian Broadcasting Corporation — Peter Loxton, Director of Radio; John Bigeni, Deputy; Ms Jane Smith, Director Corporate Planning & Policy; Paddy Conroy, Director of Television, Deputy.
- Department of Transport and Communications — Tony Shaw, First Assistant Secretary Broadcasting Policy Division; Peter Field, Deputy.
- Federation of Australian Commercial Television Stations — Tony Branigan, General Manager; Richard Barton, Deputy.
- Federation of Australian Radio Broadcasters — Tony King, Federal Director; Neil McCrae, Deputy.
- Public Broadcasting Association of Australia — Graham Forsaith, Executive Director; Dr Jeff Langdon, President.
- Special Broadcasting Service Corporation — Robert Stokes, Director Policy and Coordination; Bryan Madeley, Technical Advisory Group.

The Technical Advisory Group comprised:

- Bryan Madeley, Chairman to July 1992.
- Neil McCrae, Chairman from July 1992.
- Richard Barton, FACTS.
- Chris Burnat, PBAA.
- Keith Malcolm, DT&C.
- Barry Matson, ABC.
- Neil McCrae, FARB.
- David Soothill, ABC.
- Terry Smith, Secretary, ABC.

The Broadcasting Council was replaced by the Broadcasting Industry Advisory Council as a peak body for consultation between the broadcasting industry and the Minister on high level policy issues and as a body to review regulatory arrangements.

In 1995, the Council comprised representations from Australian Broadcasting Corporation, Special Broadcasting Service Corporation, Federation of Australian Commercial Television Stations, Federation of Australian Radio Broadcasters, Community Broadcasting Association of Australia, Federation of Australian Narrowcast and Subscription Services, Federation of Australian Subscription Television and Australian Broadcasting Authority.

FEDERATION OF AUSTRALIAN RADIO BROADCASTERS

The owners and operators of B Class stations were far from happy when referred to as 'B' Class. They considered this gave the impression of being 'second class' compared with the A Class title given to the Government funded stations.

In 1928, three B Class station owners met and decided to take steps to form an organisation called the Australian Federation of Commercial Broadcasting Stations (AFCBS) which among its top priorities was the discouragement of official and unofficial use of the term 'B Class'.

Emil Voigt, a trained Mechanical Engineer and General Manager of 2KY was elected Chairman of the group which set in motion plans to organise a Convention for the purpose of establishing a permanent organisation.

The Federation was officially established at the Convention held in Sydney in November 1930. The Convention elected Maurice Duffy of 3KZ the first President. Mr Duffy served four periods as President and also, later served as Secretary General. He had been Secretary of the company which owned 3KZ since its establishment and commissioning on 8 December 1930, and was also a member of the Commonwealth Bank Board.

With the formation of the National Broadcasting Service by the Government acquisition of the A Class stations in 1929, the term A Class disappeared and the B Class station owners expected that the term B Class would also disappear. However, the authorities were in no hurry, as the Government was of the opinion that the ABC was the backbone of the Australian broadcasting service and stations which derived their income from advertising provided a supplementary service.

The Federation fought this view vigorously, claiming that their service was an equal partner and pressed the Postmaster General to eliminate the term 'B Class' and to substitute the team 'Commercial'. They were also concerned that the authorities appeared to give preference to the ABC in regard to allocation of frequencies and transmitter powers, spent large amounts of money on the establishment of the stations and studios, and in all matters relating to broadcasting, the first consideration was to ensure that the welfare of the National service was given top priority. It was well into the 1930s before the term 'B Class' disappeared.

In 1962, the Federation changed its name to the Federation of Australian Commercial Broadcasters and in 1975 changed to its present name of the Federation of Australian Radio Broadcasters (FARB).

Following the first interstate convention in 1930, the Federation grew in strength. By 1940, there were 100 members and in 1990 the number had grown to 145.

The FARB has an Engineering Committee appointed by Federal Council to make recommendations to Council regarding Broadcast Engineering matters. In 1990, the Chairman of the Committee was Johannes (Joe) Oost, at the time, Deputy General Manager of Radio 2CH Pty Ltd. Also, each State has its own FARB Engineering Committee, who come together as necessary and consider technical issues of interest or likely to affect local Commercial broadcasting stations. At some meetings, broadcast equipment suppliers are invited to the meetings to present latest products of interest to station Engineering staff.

Joe Oost, the 1990 Chairman of the Engineering Committee began his career in radio as a Wireless Operator serving from 1947 to 1955 with Radio Holland NV, a company with AWA connections at the time. He sailed a converted ship's lifeboat from Tandjong Priok to Townsville where he worked as a Broadcast Technician with 4AY and 4TO for fourteen years on all aspects of studio and transmitter operation and maintenance. Whilst at 4AY Joe became an Associate of The Institution of Radio and Electronics Engineers, Australia.

In 1969, he took up appointment as Assistant Manager of 4TO. From 1974 to 1982 he was North Queensland Regional Manager for 4CA/4TO and then transferred to Sydney as Network Operations Manager of AWA Radio Network. Besides 4CA and 4TO, other stations in the AWA Network included 2AY, 2GN, 3BO, 3MP and 6KY. AWA also operated 2CH for the Combined Churches Council.

After the sale of the AWA Network to Wesgo in 1988, Joe moved to 2CH as Deputy General Manager and when 2CH became Radio 2CH Pty Ltd, in December, he took up the position of Operations Director of the station.

The Federation does not have a permanent in-house Broadcast Engineer, but from time-to-time, it has had the assistance of Engineering Consultants. From the early 1980s, Neil McCrae was the Federation's Consultant for some years and before him, Vern Kenna the ABC's former Controller of Technical Services performed the duties of Consultant.

Vern Kenna joined the Postmaster General's Department in Brisbane as a Junior Mechanic-in-Training in 1924. Following the reorganisation of the Australian broadcasting system in 1929, he was one of the group who took over 4QG from the Queensland Government and then operated the station as a unit of the National Broadcasting Service.

Between 1934 and 1936, Vern worked in the PMG's Department Research Laboratories, Melbourne. He qualified as an Engineer in 1936 and was appointed to the Transmission Section, Brisbane. At about that time, the Department undertook a large program of work for other Departments for the provision of radio-communication and navigation facilities along the Empire and New Guinea air routes. With the commencement of the War in 1939, these activities were extended to other areas, including the British Solomon Islands. Vern participated in much of this work, as well as essential wartime activities for the National Broadcasting Service, including the establishment of 9PA, Port Moresby and the dispersal of 4QG and 4QR from the Brisbane city area to Bald Hills.

In 1954, Vern transferred to Central Office to work on the establishment of Engineering facilities for the National Television Service. In 1961, he was appointed Controller of Technical Services in the Australian Broadcasting Commission and remained in that position until his retirement in 1968.

At its annual Convention in 1990, the Federation decided to marshall its resources to confront the coming difficulties foreseen as a result of the Government's overhaul of the Broadcasting Regulations. Members were of the opinion that planning in particular was totally at odds with the importance and quality of radio broadcasting services in Australia. The Federation however, supported the end of paternalistic over-regulation of Commercial radio broadcasting in some areas, including licence renewals and streamlined allocation processes.

For some years, it was customary for the Engineering Committee to hold its Federal Engineering Committee Meeting to coincide with IREECON Conventions. At the 1991 meeting held in Sydney at the Convention and Exhibition Centre, Darling Harbour, guest speakers were Colin Knowles of DOTAC; Neil McCrae, Engineering Consultant to FARB; Richard Fleming, Chief Engineer 2UE; and Des McCean, General Manager, Engineering, Austerec.

The Chairman, Joe Oost in his address commented that technological changes such as Digital Audio Broadcasting tended to overshadow more routine issues which station Engineers had to deal with, but as a commercially viable mode, DAB was a mid term issue.

In 1995, the Federation's Engineering Consultant was Henk Prins.

When the Federation was established in 1930, it had 33 members. In 1995, there were 156 members throughout Australia operating stations as follows:

- New South Wales
  Sydney, five AM and four FM stations.
  Country, thirty one AM and seventeen FM stations.
- Victoria
  Melbourne, nine AM and four FM stations.
  Country, thirteen AM and three FM stations.
- Queensland
  Brisbane, three AM and three FM stations.
  Country, twenty AM and seven FM stations.
- South Australia
  Adelaide, two AM and three FM stations.
  Country, six AM stations.
- Western Australia
  Perth, three AM and two FM stations.
- Tasmania
  Hobart, three FM stations.
  Country, five AM stations.
- Northern Territory
  Darwin, one FM station.
  Country, one AM and one FM station.

In the break up, there were thirty seven metropolitan and one hundred and nineteen country stations.

The coverage of non-metropolitan Commercial stations generally has a local limitation to one major city or town and the smaller towns and villages in their immediate vicinity.

In the early days of broadcasting, most of the Commercial (B Class) stations struggled to pay for their cost of operations, let alone make a profit. Some ceased operation, many kept operation by frequent injection of funds by the owners while others kept going only by aggressive marketing strategies. In 1933, when stations struggled to attract advertisers due to economic conditions at the time, station 2GB Sydney operated by Theosophical Broadcasting Station Ltd did considerable advertising in the daily and technical press to attract advertisers. It advertised itself as 'The Nation's Station'. One of its publicity leaflets stated '2GB has retained on a permanent basis the finest Radio talent in Australia — new personalities appear on the staff — and American and other Overseas Radio Markets have been combed for the most outstanding program features money can buy. All this has been lined up as a proper introduction to the most far reaching Radio Development in recent years. 2GB is introducing to Australian audiences the newly invented WIDE RANGE PERSPECTIVE SOUND. Thus, to unique programmers and great power, 2GB now adds colour and perspective to Radio Reproduction'.

The station had just completed major upgrading of the studio facilities and equipment under Chief Engineer Len Schultz.

Today, Commercial broadcasting is a profitable business with advertising revenue from 158 Commercial stations for the financial year to 30 June 1994 being about $450 million, an increase of about 6.5 % on the previous financial year. Revenue ten years earlier (1984–85), was about $280 million.

The transfer of AM stations to the FM band resulted in improved revenue income for some of the stations. However, it appeared to be at the expense of the original capital city FM stations whose income fell by 3.5 %.

The FARB has a Secretariat of 13 people located in Sydney and pursues a range of activities on behalf of the members including Government relations, accreditation of advertising agencies, industrial relations, auditioning of recorded advertisements, copyright, education and training, research, radio marketing bureau and others.

One of the many distinguished Presidents with a technical background was Allen (later Sir Allen) Fairhall. He received his technical education at the Newcastle Technical College and served an Apprenticeship as Electrical Fitter at the Newcastle Dockyard during 1925 to 1930. During this period, he became a keen Amateur station operator with his station A2KB which he commissioned in 1927 and began broadcasting programs on the 200 metre bands for local listeners.

He formed Newcastle Broadcasting Co., after obtaining a B Class station licence commissioning station 2KO on 1 August 1931 with a 6 watt transmitter which he assembled using a UX210 valve as power amplifier and a crystal oscillator for generation of the carrier frequency. The aerial was supported by 40 ft (12 m) sawn Oregon timber. The station was located at his residence at Sturdee Street, New Lambton although he had originally intended to establish the station at Kotara — hence the callsign 2KO. The transmitter power was later increased to 25 watts.

In 1932, a new station was established at Sandgate, out from Newcastle, with a transmitter providing 100 watts into the aerial. The power was increased to 200 watts the following year. Chief Engineer was Ken Greenhalgh. Three studios were located in Wolfe Street, Newcastle. In 1935, local staff rebuilt the transmitter, increasing the power to 500 watts.

Allen managed the station until 1947 by which time the business had become a proprietory company. He sold it to the Lamb family who established the United Broadcasting Group.

Allen was a Life Member of the Wireless Institute of Australia, and a Companion of The Institution of Radio and Electronics Engineers, Australia.

In 1939, he was Country Vice President of the Australian Federation of Broadcasting Stations and in 1943 became its President.

During the War years, he served as Supervising Engineer, Radio and Signals Supply, Ministry of Munitions during the period 1941–45.

The story of how the Australian Radio Industry in co-operation with the Radio and Signals Supplies Directorate was transformed to meet the wartime conditions as a matter of extreme urgency represents an inspiring chapter in the history of Australia's home front activities.

In 1949, he was elected a Member of Federal Parliament remaining in Parliament for 20 years. He served as Minister of Works and Interior 1956–58, Minister of Supply 1961–65 and Minister for Defence 1965–69.

In 1970, Sir Allen was made a Knight Commander of the Order of the British Empire.

AUSTRALIAN BROADCASTING CONTROL BOARD

From the commencement of broadcasting in Australia in 1923, the Postmaster General's Department had controlled all aspects related to the service, including allocation of licences, determination of technical standards, inspections of technical equipment and setting program guidelines. Parliament maintained an involvement through the Parliamentary Standing Committee on Broadcasting.

The Commercial broadcasters were not happy with the arrangement, particularly when subjected to frequent criticism by politicians regarding program quality and standard. Also, the role of the Department's Radio Inspector was of some concern in their day-to-day operations.

The Government agreed that the arrangement was, after 25 years operation, due for change, and on 28 September 1948, the Prime Minister announced that legislation would be introduced to take control of broadcasting out of the hands of the Postmaster General's Department officials and to establish a Board to control Radio Broadcasting and the coming Television.

Legislation was introduced into Parliament in October 1948 for amendment of the Broadcasting Act 1942–46 to provide for the establishment of the Board. Following passage through both Houses of Parliament, the Act was assented to on 6 December 1948 and subsequently proclaimed on 15 March 1949.

The Act provided for the Board to consist of three Full-Time Members. The Board constituted on 15 March 1949 consisted of Lawrence (Larry) Fanning ISO, Chairman and Messrs Clive Ogilvy and Robert Osborne. The Act required that the Members were to have no financial interest in broadcasting or in anyway be associated with the broadcasting industry.

The Chairman, Larry Fanning had been Director General, Posts and Telegraphs in the Postmaster General's Department prior to his appointment to the Board. He entered the Department as a Telephone Attendant in Sydney in 1905 and moved to the Central Administration in Melbourne in 1918 where he was later responsible for formation of the Telephone Branch. He became the first Chief Inspector (Telephones) and in 1941 was appointed as Assistant Director General. In 1946 he became Director General.

The Federation of Australian Commercial Broadcasters welcomed the Government move as they assumed that it would remove radio from the political arena because the Parliamentary Standing Committee on Broadcasting, which had kept a close watch on Commercial stations since 1942, was to be abolished. They also saw the move as providing security for the broadcasting industry and impartiality was implied, as no member could have any association with the broadcasting industry.

The Board assumed a number of powers and functions in relation to broadcasting, with those concerning technical matters being:

- To ensure that technical equipment and operating stations were in accordance with standards and practices considered appropriate by the Board.
- To determine the location, transmitting powers and operating frequencies of broadcasting and television stations.
- To detect sources of interference and furnish advice and assistance in connection with the prevention of interference with the transmission or reception of programs of broadcasting and television stations.
- To fix the hours of transmission of stations.

Powers in relation to program matters were extensive, and included such aspects as adequate and comprehensive programs to best serve the interests of the general public, to ensure reasonable variety of programs, to ensure divine worship or other matters of a religious nature was broadcast for adequate periods and at appropriate times, to ensure political and controversial matters were provided on an equitable basis, determination of the extent of broadcasting advertisements and to regulate the establishment of networks of broadcasting stations.

By 1973, the Board had grown considerably in its role of directing broadcasting. It operated with a work force of over 200 people split up among the Secretary's Division, Policy and Licensing Division, Program Services Division, Technical Services Division and State offices in Sydney, Adelaide, Perth, Brisbane and Hobart.

On the technical front, the Board oversighted the expansion of the National service with many new stations being commissioned and some existing transmitters increased in power. The Board also carried out research in relation to a number of important technical matters.

However, the Commercial station operators were of the opinion that much of the Board's involvement in technical aspects of broadcasting were concentrated on problems of the National service, especially in relation to power and frequency allocation. This became evident when Frequency Modulation broadcasting was being planned. Commercial interests including industry made strong representations to be allowed to participate in the planning and development of the service.

By the end of 1976, when the ABCB ceased operation with its functions being taken over by the Australian Broadcasting Tribunal and the Postal and Telecommunications Department, the number of National stations had increased from 37 in 1949 to about 92 by early 1977. These comprised AM medium wave and FM stations.

The Board was responsible for many major technical achievements during its period of office. These included:

- The establishment of many additional National and Commercial radio broadcasting and television stations to meet the demands of an increasing and affluent society.
- Increase in radiated power of broadcasting transmitters up to 50 kW for National stations and up to 5 kW for Commercial stations.
- The introduction of television in Australia in 1956, after protracted investigations and discussions on certain technical matters.
- The introduction of colour television in 1975.
- The introduction of directional aerials to increase the occupancy of medium frequency channels.
- The reduction of broadcasting channel spacing from 10 kHz to 9 kHz.
- Detailed technical investigations into the introduction of FM broadcasting in the VHF band.

The Board had a large staff of Engineers and Technical people during its 28 years of broadcasting control in Australia. The first Director of Technical Services was Bruce Mair, who later became a Board Member. He was succeeded by Don McDonald who also later became a Board Member. Following Directors included Alec McKenzie, Frank Brownless, Jim Wilkinson and Bill Beard.

Other Engineers and Technical staff employed at the Board's Melbourne Headquarters and at State Offices included:

Ray Allsop, Don Anderson, Ross Baker, John Bigini, Tony Brettingham-Moore, Peter Credlin, John Dixon, Peter Dodds, Ian Douglas, Colin Downing, John Drew, Bill Edmunds, Colin

Elworthy, Jim Fisher, Geoff Forrest, Don Graham, Len Grinter, West Hatfield, Ray Herman, Ian Hill, Lance Horvath, Vic Jones, Ray Kelly, Bill Kingwell, Joe Lehman, Arthur MacLachlan, Mike Mazzei, Noel Medlin, Graeme Morley, John Morrisey, Tony Norris, Alan Pierson, Bill Pike, Ian Reid, John Rubin, Keith Sandman, Peter Sas, Frank Sharp, Alec Slamen, Richard Teo, Alan Timmins, Frank Waldron, Neil Warnock, and George Whitfield.

Brief details of Directors of Technical Services are as follows:

- Bruce Mair was educated at Caulfield Grammar School and the University of Melbourne where he graduated with a BEE Degree. He began work at the Engineering School at the University of Melbourne as a Senior Demonstrator in 1924, and in 1925 took up a position as Research Engineer in the PMG's Department Research Laboratories, Radio Section. In 1931, he was appointed Chief Radio Design Engineer occupying this position until 1943. During the period, he was associated with many important Broadcast Engineering projects. With the design, manufacture and installation of a transmitter to replace the original 6WF Perth transmitter, taken over by the Department as part of the National Broadcasting Service, he was responsible for the design of the radio frequency aspects of the transmitter. This was the first time that the Department undertook such a large broadcasting project using its own resources, particularly for the manufacture and assembly. Another project was the establishment of Radio Australia Shepparton during the War years.

  In 1944–48 he was Supervising Engineer, Radio Development and in 1948 became the Australian Delegate to the International Radio Conference, Mexico City.

  On formation of the Australian Broadcasting Control Board in 1949, Bruce became Director of Technical Services, a position he held until 1952 when he became a Member of the Board.

  He became a Senior Member of The Institution of Radio Engineers, Australia in 1952, and in 1959 became a Fellow of The Institution.

- Don McDonald was educated at the Ballarat School of Mines and entered the Postmaster General's Department in 1925, and following part time at University of Melbourne, graduated in 1931 with B.Sc. Degree. He was appointed Engineer in the Department's Research Laboratories in 1936. He was engaged in general radio investigations, propagation studies and development work in connection with ultra high frequency radio telephone systems.

  In the mid 1930s, when plans were being developed for expansion of National Broadcasting Service stations into country areas, Don played a major role in the selection of sites for establishment of transmitting stations. One of the studies was the determination of soil conductivities from measured values of radio field intensity in various parts of Australia. From a knowledge of the soil conductivity in the directions to be served by each station the most suitable site was determined.

  At the World Radio Convention held in Sydney in 1938 by the Institution of Radio Engineers, Australia, he delivered a paper, 'A Resume of Soil Conductivity Measurements in Australia', in which he gave results associated with selection of sites for 3WV Dooen, 2NR Grafton, 3GI Gippsland, 6WA Wagin and 4QN Townsville.

  From 1947 to 1950, he was the Australian Delegate at International Radio Conferences in USA, Sweden and Switzerland.

  In 1950, he left the Department to join the Australian Broadcasting Control Board and in 1952 became Director Technical Services Division. In 1965, he was appointed a Member of the Board.

- Alec McKenzie joined the Research Laboratories of the Postmaster General's Department in 1927 after graduating with Honours in Electrical Engineering from University of Melbourne. He was engaged in general electrical measurements, radio investigations, propagation studies and investigation into radiator design.

  In 1932, Alec worked on the preparation of the specification and the testing of power equipment for the 3.5 kW 6WF Perth transmitter. He transferred to the Radio Section in 1944, and was associated with the design and installation of many facilities which had great impact on the advancement of Broadcast Engineering Technology in Australia. These included high frequency aerial systems for Lyndhurst, the development of a flat top loaded anti-fading radiator for MF transmission, and later, improvement on the design which gave optimum anti-fading properties on two frequencies.

  At the World Radio Convention held by The Institution of Radio Engineers, Australia in Sydney during April 1938, Alec presented a paper 'Loaded Radiators for Broadcasting' in which he outlined developments in loaded radiators and the results obtained for stations 2NR Grafton, 2CR Cumnock, 6WA Wagin and 3WV Dooen which up to that time, had been equipped with loaded radiators employing armatures.

  During the establishment of Radio Australia, Shepparton during the War years, he was engaged on the design of aerials, transmission lines and switching systems.

  Alec joined the Australian Broadcasting Control Board in 1949, subsequently being appointed Director of Technical Services a position he held until his retirement in 1968. During this time he played a major role in the planning and establishment of the Australian television service.

  He attended a number of important overseas Conferences as delegate including ITU conferences in Paris, Stockholm and Los Angeles. He also attended the British Broadcasting Conference in 1954.

- Frank Brownless joined the ABCB as Sectional Engineer Television in 1956, occupying that position until 1965 when he was appointed Assistant Director (Development). In 1969, he was appointed as the Board's Director of Technical Services.

  Frank was educated at London University where he graduated B.Sc. (Hons.) and began work as Engineer with the British Broadcasting Corporation. A highlight of his experience with the BBC was involvement with upgrading of the Daventry HF Broadcasting Centre which was equipped with twelve 100 kW transmitters. Activities included installation and commissioning of high power transmitters, HF feeders, switching systems, aerial design and adjustment, and overhaul of 750 kW diesel generating plant. He also gained experience with demountable valves when he took part in conversion of a surplus Baird TV transmitter for HF operation.

  At the outbreak of the War in 1939, he transferred to the Air Ministry working on Radar development until 1943 before joining the RAF as Flight Lieutenant (Radar) until 1946.

  In 1946, Frank returned to the BBC and became a Senior Research Engineer developing transmitting aerial arrays for forthcoming TV and FM services. In particular, his joint patents for folded slotted-cylinder FM aerial arrays resulted in these aerials being developed below the TV aerials at most of the high power BBC stations. To broaden his exposure, Frank transferred to the Audio Section in 1948 working on distortion problems and listeners' loudness preferences.

  In 1949, he came to Australia to take up a position with the Postmaster General's Department as Engineer with the Central Office Radio Section under Horrie Hyett. In 1951, he was promoted to the position of Divisional Engineer. Project works included pulsed tone testing and selection of monitoring loudspeakers for ABC studios, field tests of synchronised transmitters 4QS and 4QN, synchronised repeater for 3AR at Bendigo and design of a range of easily constructed emergency aerials for the NBS.

  Frank was a member of the RMIT Communications School Advisory Committee for over 20 years; a committee member of the Melbourne Division of The Institution of Radio and Electronics Engineers, Australia for over 30 years; Chairman, Melbourne Division 1967–70, and National Council Member for many years. His contribution to the advancement of Radio

Engineering Technology was recognised by a number of awards including Queen's Jubilee Medal, the IREE Award of Honour 1989 and others.

- Jim Wilkinson. Career details have been covered elsewhere.
- Bill Beard who was Director of Engineering when the Board was abolished in 1976, joined the PMG's Department Research Laboratories in 1946 after graduating from the Melbourne University with a BEE Degree.

  In the Laboratories, he was engaged on a number of projects including Primary Frequency Standards set up for the Australian time service.

  In 1961, just as plans were approved to expand National and Commercial television services into regional areas he transferred to the then Radio Section to head a Division to participate in the Capital Works Program. The Division assumed technical responsibilities for the specification, design analysis and procurement of the aerials, towers and masts and cable systems for some 33 high power television stations established over about 5 years in the early-mid 1960s. Later in the 1960s, the Division was requested to take on board technical responsibilities for the design and procurement of HF aerial systems for the Radio Australia Booster Station being established at Cox Peninsula. Log-periodic aerials were chosen. Thus began a saga — the original design supplied by the contractors proved inadequate and involved his team in the urgent development of a then original computer model to establish the design parameters for a modified aerial system.

  In 1976, he left Telecom to take up the position of Director of Engineering in the ABCB. There, he directed broadcasting system and station technical planning, the setting of technical standards and technical regulation of all domestic broadcasting services. Also, in response to ITU plans, and after appropriate negotiations with the New Zealand authorities, he directed the co-ordination of changes to the MF broadcasting channelling plan from the then 10 kHz spacing to the present 9 kHz spacing. Nearly all Australian stations changed to the new channels on the one day, to an internationally set timetable.

  The ABCB was abolished at the end of 1976, after which its technical responsibilities were assumed by the then Department of Communications. He remained in charge of the Broadcasting Engineering Division. This period saw the beginnings of Public Broadcasting services, the introduction of Commercial FM broadcasting and the establishment of the Government Task Force to enquire into the possibilities of a National Communications Satellite service. He was appointed the Department's representative to the Task Force.

  His last major assignments before retirement in March 1982, were to appear before the Parliamentary Public Works Committee to defend the reestablishment of the Radio Australia station at Cox Peninsula and to lead the Australian delegation to the 1980 CCIR Study Group meetings in Geneva.

At the time the Board was abolished on 31 December 1976, Full-Time Members were Myles Wright and Dr Geoffrey Evans. Part-Time Members included Ernest Kellam and Dr Patricia Edgar.

AUSTRALIAN BROADCASTING TRIBUNAL

The Australian Broadcasting Tribunal was an independent statutory authority established on 1 January 1977.

The Tribunal assumed the powers and functions of the former Australian Broadcasting Control Board which was abolished at the end of 1976. However, its powers did not include the Planning and Engineering functions related to the broadcasting services. These were transferred to the Postal and Telecommunications Department and later, the Department of Transport and Communications.

The Tribunal's role was to regulate certain aspects of Commercial and Public radio, and Commercial television. The powers did not extend to activities of the Australian Broadcasting Corporation or the Special Broadcasting Service.

Briefly, the Tribunal had power to:

- Grant, renew, suspend and revoke licences.
- Formulate standards for programs and advertisements.
- Authorise changes to the ownership and control of licences.
- Collect and make available information about broadcasting in Australia.

The responsibility for planning the development of broadcasting services, the determination of standards and practices for the technical equipment used and its operation, laid with the Minister for Transport and Communications.

The Broadcasting and Television Amendment Act 1976, provided for the appointment of a Chairman, Vice-Chairman and three Members as well as up to six Associate Members to be appointed for the purpose of the Tribunal's functions relating to public inquiries. The three Members comprised Bruce Gyngell, Chairman; James Oswin, Vice-Chairman and Mrs Janet Strickland. Keith Moreman joined the Tribunal later in the year.

At mid 1990, the planning of Commercial and Public broadcasting services allowed the Tribunal to grant eight different types of licences. They included licences for principal and remote services, supplementary services and limited licences. The Tribunal's former responsibility for issuing permits for test transmissions and rebroadcasting and retransmission licences was replaced by a system of temporary permits and retransmission permits administered by the Minister.

Although Members of the Tribunal generally had a background in law, education, economics, broadcast program production or management, at least one Member had a background in Broadcast Engineering. He was Jim Wilkinson who served with the Tribunal as an Associate Member during the Cable and Subscription Television inquiry and later as full-time Engineer Member.

- Jim Wilkinson joined the Postmaster General's Department as Junior Mechanic-in-Training in 1937, following education at University High School, Melbourne.

  On completion of training, Jim began his career in broadcasting at the Melbourne ABC studios working on new Lonsdale Street studios to replace the Russell Street studios. An interesting feature of the new equipment was a program switching facility employing motor uniselectors.

  He continued studies with the intention of passing the Open Engineer's Examination, and having gained passes in Transmission and Natural Science subjects, was posted to the office of the Divisional Engineer, Radio as an assistant to Engineering staff. At the time, work had commenced on the design of the International High Frequency Transmitting Station, Shepparton (later Radio Australia) and Jim became involved in the project. His first task was establishment of cabling diagrams and jumpering schedules for the control circuits associated with the automatic transmitter-to-aerial switching, and for aerial reversing and slewing schemes.

  He moved to the site during 1942, and as he had by then gained passes in the remaining subjects of the Open Engineer's Examination he was advanced as Acting Engineer and assigned to field work concerned with the tuning of the aerials, testing of transmission lines and the commissioning of the external plant facilities.

  On both the Government and Industry sides, the project acted as a magnet for Technical people who wished to become associated with such an exciting and massive Radio Engineering project carried out at a time when the nation was heavily committed to the War effort and the consequent difficulties in obtaining skilled staff and necessary materials, components and equipment.

  Jim later became involved in the provision of VHF radio navigation facilities for the Department of Civil Aviation. This was one of the last activities in which the PMG's Department carried out this type of work before the DCA established its own technical organisation.

With Government decision to begin trials with Frequency Modulation broadcasting, Jim was a member of the group responsible for undertaking a program of tests using a transmitter built in the Melbourne Workshops and installed at Jolimont, on the site occupied by the Central Office Radio Section headed by Horrie Hyett, Supervising Engineer.

Following this work, he transferred from the Victorian administration to Central Office working on AM and FM projects before becoming the first Divisional Engineer Radio-telephone Systems. Beginning with single channel and mobile VHF systems, specifications were then prepared for low capacity systems of 12, 24 and 60 channels followed by 960 channel systems, and planning for the Sydney-Cairns SEACOM microwave system.

Jim made a brief return to the Victorian Administration prior to the Melbourne Olympic Games to assist with upgrading of Radio Australia, Shepparton facilities including provision of air cooled modulator valves to replace water cooled types and new aerial switching facilities.

Back in Central Office, he then became associated with planning of the Radio Australia Booster Station to be installed near Darwin to improve signal strength of Radio Australia transmissions into South East Asia target areas by employing 250 kW transmitters.

About that time, TV was undergoing great expansion throughout the nation and Western Australia was linked with the eastern States by a broadband microwave system, so this was a busy period for Jim in Central Office.

In 1968, he was appointed Assistant Director General, Radio and spectrum management became an important part of his responsibilities.

Three years later, Jim became the Australian Broadcasting Control Board's Director of Engineering and in 1976 transferred to the Postal and Telecommunications Department as First Assistant Secretary Radio Frequency Management. With the P and T Department he became deeply involved in ITU activities as Admin Councillor and Leader of Australian delegations to WARC, CCIR meetings and Plenipotentiary Conferences. It was a great honour when he was the first Australian to be elected Chairman of a CCIR Plenary Assembly. He also became involved with satellite developments, especially BSS.

When the Australian Broadcasting Tribunal began the Cable and Subscription Television Inquiry, Jim was appointed part-time Member and in 1983 transferred from the P and T Department to the ABT to become Engineer Member.

In 1984, he resigned from the ABT to have a last burst as a working Engineer as Program Controller, South Pacific Telecom Development Program based in Suva, Fiji, where a great deal of work was associated with satellite options.

After returning to Australia, he became associated with Imparja TV Pty Ltd, a satellite delivered TV service and with The Republic of Nauru in its planning of telecommunications and broadcasting. Other activities included involvement with AM and FM Commercial stations and representing Consumer Organisations at Standards Committee meetings on telecommunications and broadcasting consumer equipment standards.

In 1978, Jim was awarded the Imperial Service Order, and during 1979–80 served as President of The Institution of Radio and Electronics Engineers, Australia.

In 1996, Jim was admitted to the Degree of Doctor of Engineering Honoris Causa at RMIT Melbourne. Jim had been associated with RMIT for nearly 60 years as a student, lecturer, Professional Engineer, and Member, later Chair, of the Faculty Course Advisory Committee for Communications Engineering.

The Australian Broadcasting Tribunal ceased to exist from 4 October 1992, its functions being taken over by the Australian Broadcasting Authority.

At the time it was abolished, membership of the Tribunal comprised Peter Webb, Acting Chairman; Kim Wilson; Bruce Allen; Susanne Brooks and Tim O'Keefe.

AUSTRALIAN BROADCASTING AUTHORITY

The Australian Broadcasting Authority was created under the Broadcasting Services Act 1992. With the commencement of the Act on 5 October 1992, the Authority took over the role of broadcasting regulator assuming the licensing and program powers and functions of the Australian Broadcasting Tribunal and gaining the broadcast planning function from the Department of Transport and Communications.

The creation of the Authority ushered in a new era of flexibility in broadcasting regulation.

National services which include those services provided by, or for, the Australian Broadcasting Corporation, the Special Broadcasting Service Corporation and the Parliamentary Broadcasting Service are exempt from licensing under the Broadcasting Act. Under the Broadcasting Services Act, National services do not require a service licence but are required to hold a broadcasting service transmitter licence under the Radio-communications Act.

Included among the Authority's primary functions are a number of specific technical matters which include:

- Development of planning priorities.
- Preparation of licence area plans and frequency allotment plans and variation to those plans as necessary.
- Specification of licence areas, operational frequencies, siting and output power of broadcast transmitters.
- Development of technical planning guidelines for broadcasting services.
- Issue of apparatus licences for operation of transmitters for National, Commercial and Community services and for services provided under class licences.
- Allocation of station callsigns.
- To inform itself of technological advances and service trends in the broadcasting industry.

When set up, the Planning Division was one of four Divisions within the Authority and comprised a Planning Administration Branch and an Engineering Branch.

As at June 1993, the Division was headed by Colin Knowles, Director of the Division, with Branch heads being Bob Greeney, Assistant Director, Engineering Branch and Mike Salloom, Assistant Director, Planning Administration Branch.

At that time, the Authority employed 185 staff including Chairman, Deputy Chairman and one Member. Of the total, 124 were located in Sydney, 44 in Canberra, nine in Melbourne four each in Brisbane, Adelaide and Perth, and one in Hobart.

In late 1994, with the establishment of the Planning and Corporate Services Division, Colin Knowles became General Manager of the Division.

The Planning Branch which is located in Canberra plans all broadcasting services using radio frequency spectrum set aside for AM and FM radio and VHF and UHF television.

Director of Planning Branch was Giles Tanner until 18 April 1997 when he resigned and within the Branch, Mike Salloom was Manager, Services Planning Section and Bob Greeney Manager, Planning Engineering Section.

Each Section comprises a number of Subsections. Those forming the Services Planning Section include Branch Support, Implementation Policy, Licence Area Consultation and Licence Area Development Subsections while those associated with Planning Engineering Section include Planning Automation, Spectrum Development, Technology Assessment and Specifications Development Subsections.

On establishment, ABA Members were Brian Johns AO, Chairman; Peter Webb, Deputy Chairman and Tim O'Keefe.

Before joining the ABA, Brian Johns was Managing Director of Special Broadcasting Service Corporation for five years and before that, Publishing Director, Penguin Books Australia. Mr Johns resigned as Chairman of the ABA on 17 March 1995 to take an appointment as Managing Director of the Australian Broadcasting Corporation. He took up duty following the resignation of David Hill.

At June 1995, ABA Members comprised Peter Webb, Chairman; Robert Scott, Deputy Chairman; Tim O'Keefe, Member and Kerrie Henderson, Part-Time Member.

Peter Webb became Chairman in April 1995. He was Acting Chairman of the former Australian Broadcasting Tribunal July-October 1992, following appointment as Vice Chairman of ABT in May 1992.

Mr Webb had many years experience in the legal profession including several positions in the New South Wales Attorney General's Department.

Robert Scott who joined the Authority in June 1995 had been associated with the broadcasting and newspaper industries for some 30 years including General Manager/Managing Director of Commercial stations 2WS, 2DAY-FM and Triple M; President of the Federation of Australian Radio Broadcasters; Chairman of the National Film and Sound Archive and founding Managing Director/Chief Executive of Wesgo.

In July 1995, Christine Goode, Head of the Spectrum Management Agency was appointed Associate Member and John Dickie, Director of the office of Film and Literature Classifications was appointed as Associate Member for the term of the ABA's investigation into the content of on-line services.

On 23 July 1997, the Acting Minister for Communications and the Arts, Warwick Smith announced several new appointments to the ABA.

- Professor David Flint AM was appointed Chairman of the ABA as from 5 October 1997.
  Professor Flint was Chairman of the Australian Press Council and Australian National President of the World Jurists Association.
- Gareth Grainger, ABA General Manager Policy and Programs was appointed Deputy Chairman.
- Michael Gordon-Smith was appointed Full-Time Member.
- Ian Robertson was appointed Part-Time Member.
- John Rimmer was appointed Part-Time Member.

All appointments were for three years.

Ms Kerrie Henderson had been appointed Part-Time Member in February 1995 for a five year period.

On 1 March 1998, the Minister for Communications, Information Economy and the Arts, Senator the Hon. Richard Alston appointed two new part-time Associate Members for the general purposes of the ABA. They were Dr Robert Horton, Deputy Chairman, Australian Communications Authority and Jeffrey Hilton part-time Member of the Australian Competition and Consumer Commission.

In carrying out its technical functions, the Authority has responsibility for managing the broadcasting service bands through the planning process and attempts to ensure that the most efficient use is made of the available broadcasting channels. At the same time, it provides a framework for the introduction of new National, Commercial, Community and Narrowcast services aiming to ensure the services can be received clearly and do not cause interference with other radio services.

The process provides for greater industry certainty and the decisions made must weigh the public interest against technical factors. The three major stages of the planning process include the preparation of planning priorities, frequency allotment plans and licence area plans.

In determining planning priorities, the Authority must balance the merits of many factors including demographic, social and economic characteristics, number of services and demand for new services, technological developments, technical constraints and demand for alternative uses of the radio spectrum.

On December 1992, the Authority sought submissions on broadcasting planning priorities and some 567 were received. In order to assist people to develop their submissions, the Authority published six volumes of planning information entitled, 'Current State of Radio and Television Planning'. The five volumes on radio planning were sent to Local Government authorities for inclusion in local libraries.

On 2 May 1993, the Authority released for public comment its exposure draft of the determination of planning priorities. When submissions on the exposure draft closed on 28 May 1993, some 296 submissions had been received. The Authority also conducted planning priority seminars and technical workshops in all mainland capital cities with a total of 528 people attending.

The planning process has demonstrated the Authority's commitment to public consultation, in contrast to the previous system when planning decisions were made behind closed doors.

In August 1994, the Authority released its Frequency Allotment Plan (FAP) for the Broadcasting Services Bands (BSB). The FAP has three components corresponding to the different types of broadcasting services; MF-AM band radio, VHF-FM band radio and VHF-UHF TV bands. The FAP ensures that planning for individual services in particular areas has proper regard to the potential effect on channel capacity allotted to other parts of the nation.

As at 1 June 1994, licensed MF-AM radio services comprised:

• National services (ABC and SBS)	113
• Community services (previously Public)	14
• Commercial services	134
• Open narrowcasting services	3
Total	264

During the past 10 years, very few submissions were received by the Authority for establishment of new AM services. It is likely that the reason for this was due to the high cost of establishment of such services involving extensive and costly real estate for aerial and earth mat systems; transmission lines; buildings; equipment; studio to transmitter links, and studio facilities. Also, the increasing popularity of FM band services as an alternative radio medium, may have had a major influence on decision makers.

In preparing the FAP for MF-AM band, technical planning criteria were derived from a document 'Technical Planning Parameters and Methods for Terrestrial Broadcasting' (TPP) published in 1992 by the Department of Transport and Communications. They include:

- Channel spacing of 9 kHz providing a total of 120 AM channels.
- Minimum field strength to overcome man-made noise.
- Mimimum channel spacing for services with overlapped coverage.
- Protection ratios to allow for interference from other AM services.
- Skywave propagation assessment to ensure long-range-interference between stations is minimised.
- Employment of directional aerial systems to ensure greater reuse of some channels.

As at 1 June 1994, licensed services using the VHF-FM band comprised:

• National services (ABC and SBS)	416
• Community services (previously Public)	233
• Commercial services	113
• Open narrowcasting services	414
• Retransmission services	82
Total	1258

As from 31 October 1995, a new arrangement was introduced for allocation of licences. It was a price-based allocation system based on an auction style process whereby, subject to certain conditions the licence may be granted to the highest bidder.

The first licence granted under the new arrangement for a radio broadcasting station was allocated to Lookridge Pty Ltd on 10 April 1996 for a service in the Mildura/Sunraysia area. The company bid $10000 for the licence.

Amendments to Section 39 of the Broadcasting Services Act has enabled the Authority to allocate additional Commercial radio broadcasting licences. An allocation fee of $10000 intended to defray ABA costs, is applicable for granting of a licence.

During 1996–97, the ABA allocated 12 Commercial, 5 Community and 53 Open Narrowcasting radio licences. It also approved 132 licences for retransmission of broadcasting services.

Because of its key role in the broadcasting industry, the Authority consults with many parties with an interest in the technical aspects of radio broadcasting. In 1997, these included:

Federation of Australian Radio Broadcasters, National Transmission Agency, Community Broadcasting Association of Australia, Federation of Australian Narrowcasting and Subscription Services, Radiocommunications Consultative Committee, Spectrum Management Agency (now Australian Communications Authority), Broadcasting Industry Advisory Council. Digital Radio Broadcasting Task Force and others.

The ABA has been heavily involved in planning for the introduction of digital radio broadcasting into the Australian broadcasting scene in the near future. The technology is being studied by most countries in the world and during April 1997, the International Telecommunications Union held a series of meeting son the subject. Representatives from United Kingdom, United States, Germany, Sweden, Italy, Austria, France, China, Russia, Brazil, Switzerland, The Netherlands and Australia presented papers at the meeting describing developments in their countries. Bob Greeney, Manager Planning Engineering, represented the ABA.

In Australia, the ABA has been working with a specialist working group to study a digital radio broadcasting system employing both terrestrial and satellite delivery operating in the 1.5 GHz frequency band.

The Minister for Communications and the Arts established a Digital Radio Advisory Committee to consider policy aspects in relation to the introduction of the technology.

The cost of operation of the Australian Broadcasting Authority for the 1996–97 financial year was approximately $12.38 million. Revenue collected for licence fees was over $165 million of which about $10.6 million was associated with radio licence fees.

On 24 February 1997, the ABA convened a Planning Seminar involving 110 people at Rydges Hotel, Canberra, at which the majority of papers were presented by ABA staff. The Seminar was opened by Chairman Peter Webb with Session Moderator being Colin Knowles, General Manager, Corporate and Planning. The inaugural Planning Seminar provided both ABA planners and industry representatives with an opportunity to meet and discuss ideas relating to the broadcasting industry. Papers presented at the seminar included Channel Planning, Teck Lee; As a Client Service, Shanthilal Nanykkara; FM Transmitters and VCRs and Mast Head Amplifiers, Shanthilal Nanaykkara; Interference from FM Radio to Aeronautical Services, Kithsiri Aberasinghe; Attitudinal Research in Broadcasting Planning, Stephen Nugent and Gillian Ramsay; Allocation of Community Broadcasting Licences, Jenny Brigg; Field Strength Prediction Models, Julie Spencer; Elements of the AM Planning Process, Veluppillai Sundaralingam; Licence Area Planning, Mike Salloom; Standards and Guidelines, Bob Greeney; and Broadcasting Satellite Services, Ananda Abeyaratne.

Other technical papers delivered at the Seminar included Innovations in AM Transmission Antennas, John Innes, John S Innes Pty Ltd; Developments in FM Broadcasting Antennas, Glen English, John S Innes Pty Ltd; Practical Filters for Adjacent Channel Operation in Digital Television Broadcasting, Robin Blair, Radio Frequency Systems; and Assignment of Radio-communication Services, by a member of the Spectrum Management Agency.

On 22 August 1997, Colin Knowles, General Manager Planning and Corporate Services resigned from the Authority to take up a position with the ABC as Head of Technology, Strategy and Development.

As at June 1997, the ABA employed 159 staff at its Sydney and Canberra offices, with 106 being located in Sydney.

Early in 1998, the ABA announced that it had identified additional AM and FM channels as being potentially available for the Sydney, Melbourne and Brisbane metropolitan markets, to be followed by studies of the Adelaide and Perth areas. The Authority expected to release draft licence area plans for the Sydney, Melbourne and Brisbane regions in late 1989 and final plans in 1999. Channels were to be made available for Commercial and Open Narrowcasting services under a price-based allocation scheme. Community licences were to be allocated by means of a merit-based system.

The ABA planners identified two AM and four FM radio channels as being potentially available in the Sydney market area. They comprised a 5 kW transmitter located at Homebush operating on 1386 kHz and 1 kW transmitter on a site at Concord West on 1539 kHz, with an additional 500 watt transmitter on 1476 kHz at Emu Plains near Penrith. The four FM services transmitting from aerials on Channel 10 tower at Artarmon would operate with ERP of 150 kW (two) and 15 kW (two).

In Melbourne, three AM and four FM high power channels were identified as being potentially available. Frequencies 1116 kHz, 1422 kHz, and 1593 kHz previously employed by Commercial AM stations which converted to the FM band, were available.

In the Brisbane market area, the Authority identified AM frequencies 1197 kHz and 1593 kHz as being potentially available for use in one of the Brisbane, Gold Coast or Murwillumbah markets.

In Adelaide, one AM and four FM radio channels were identified as being potentially available. The AM frequency 1539 kHz was being used by TAB Radio in Adelaide until 31 December 1998 for open narrowcasting purposes. Nominal site was at Paralowie for a 5 kW transmitter. Nominal sites for FM transmitters were at Mt Lofty, Grenfell Street and South Terrace.

Three high power radio channels comprising one AM and two FM channels had been identified as being potentially available in Perth. The AM frequency 1206 kHz had previously been licensed for 6KY which converted to the FM band and was in use as an open narrowcasting service until 31 December 1998.

As well as metropolitan areas, potentially available channels were identified for other areas including Katoomba, Gosford, Geelong, Colac, Nambour, Gold Coast, Lismore and Gympie markets.

During 17-18 February 1998, the ABA convened a second Seminar employing the theme 'Digital Broadcasting'. ABA staff associated with mounting and assisting with the Seminar proceedings included Bob Greeney, Kathy Evatt, Fred Gengaroli, Dom McKay, Carolyn Smith, Julie Spencer, Sue Van Der Sanden and Nilavan Vonkhorporn.

Papers were presented by Sante Andreoli, Manager ITELCO, Italy; Robin Blair, Consultant RFS Pty Ltd; Peter Kepreotes, Manager Broadcast Communications Development, ABC; Stephen Farrugia, Senior Engineer, NTA; David Soothill, Director Communications and Planning SBS; Peter Gough, Chief Engineer WIN TV; Debra Richards, Chief Executive Officer ASTRA; Colin Knowles, Head Technology Strategy & Development ABC; Richard Barton, Deputy General Manager FACTS; Bruce Robertson, Executive Vice President Nine Network Aust. Ltd; Steve Ahern, Australian Film, Television and Radio School; Rob Nicholls, Manager Aurora OPTUS Communications; Jenny Brigg, Assistant Manager On-Line Services ABA; Phillip Skelton; Geoff Hutchins, Nelson Vithanage; Mike Salloom and Tim Mason. Conference closing remarks were provided by Bob Greeney, Director Planning and Fred Gengaroli, Director Engineering.

AUSTRALIAN BROADCASTING CORPORATION

The letters ABC have been used to identify three different organisations responsible for provision of programs, broadcast by transmitters operated initially by the Postmaster General's

Department and in more recent years by Telecom Australia and the National Transmission Agency as part of the National service.

The National Broadcasting Service was established during 1929 by an Act of Parliament titled the 'Australian Broadcasting Act'. All A Class stations in operation at 1929 were acquired by the Government as their licences expired, and staff of the Postmaster General's Department took over responsibility for operation of the stations from the owners. Some of the Technical staff transferred to the Department.

The Government's plan was that experienced entrepreneurs would produce programs for broadcast under a contract arrangement. A combined tender submitted by Greater Union Theatres Ltd, Fullers Theatres Ltd and J Albert and Sons was accepted. The group formed the Australian Broadcasting Company Ltd following signing of a contract to provide a full program service in all States for a period of three years until June 1932.

On 9 March 1932, Postmaster General James Fenton introduced a Bill in Parliament to establish the Australian Broadcasting Commission. It received Royal Assent on 17 May 1932 and on 1 July 1932 the Commission took over responsibility for provision of programs. Head Office was located at 246 Pitt Street, Sydney. All 250 employees of the Australian Broadcasting Company Ltd were given the opportunity to transfer to the Commission.

The Commission was financed by a proportion of revenue collected from the issue of receiver licences. During the first year of operation about 370000 licences were issued.

The Commissioners comprised Charles Lloyd Jones, Chairman; Mrs Elizabeth Couchman; Professor Robert Wallace; the Honourable Richard Orchard CBE, and Herbert Brookes CBE, Vice Chairman. Although the original term of appointment for Commissioners was three years, Mr Lloyd Jones resigned because of business commitments after only two years in office.

Charles Lloyd Jones had an interest in broadcasting going back to the early days of the establishment of the service in Australia in the early 1920s. At the time of his appointment to the ABC he was Chairman of Directors of David Jones Ltd, a local major retailer which had invested money in 2BL in the period before the station was acquired by the Government as part of the National Broadcasting Service. The company also has its own Radio Department and manufactured in its workshops, a range of receivers under the DJ label. Sets included crystal set and 2,4 and 6 valve battery operated models. For a period the store operated its own radio station on the premises using callsign 4DJ to demonstrate the operation of radio receivers to potential customers.

Herbert Brookes was Vice Chairman 1932-1939, and was a graduate Civil Engineer from Melbourne University. For some years he was engaged in mining pursuits.

The Commission faced many challenges during its initial stage of operation. It had a staff of 265 and provided programs for broadcast by 12 transmitters which were on air for a little over 11 hours daily. Eight separate programs were provided from State capitals with Sydney and Melbourne each providing two programs to meet the requirements for two transmitters in those cities.

Technical staff provided by the PMG's Department for the operation of the studio technical facilities including outside broadcasts and the transmitters, numbered 80.

Funding arrangements for the Commission subsequently changed enabling it to be funded by appropriations from the Commonwealth Government.

In 1964, the Commission took over responsibility for operation and provision of all radio studio technical facilities.

In an endeavour to meet a demand from minority groups who had made submissions to the Priorities Review Staff Inquiry to gain access to the radio broadcasting media, the Government in 1974 invited the ABC to provide a community access program service.

Transmissions using callsign 3ZZ commenced on 12 May 1975 using the 10 kW standby transmitter of 3AR reduced in power to 2 kW and feeding into one of the standby aerials at the 3LO/3AR site at Sydenham.

Transmissions were provided between 6 pm and 11 pm each evening catering for ethnic groups and other organisations seeking broadcast on-air time.

Since the station allowed air time to community groups, it inevitably carried a substantial ethnic program component. Those running the service were allowed a degree of latitude in administration and program content unprecedented in the ABC. In addition, the involvement of community groups was at odds with previous practice in any Government controlled organisation, since they allowed an extraordinary degree of community control of the station and its output.

From 20 September 1976, the transmission hours were extended to 84 hours a week. Broadcast time was heavily booked, particularly for the English service, with program makers having to wait for periods up to three months in order to obtain on-air time.

The station broadcast in 27 languages on a regular basis, plus 18 other languages from time to time. Regular languages broadcast included Albanian, Arabic, Bulgarian, Cantonese, Croatian, French, German, Greek, Hebrew, Hungarian, Italian, Latvian, Lithuanian, Maltese, Mandarin, Polish, Rumanian, Russian, Serbo-Croatian, Spanish, Turkish, Ukranian and Yiddish.

Because of the appearance of 3EA in 1975 providing a similar program format, the Government decided to withdraw funds for the ABC 3ZZ service and the station closed down on 15 July 1977 but not without some drama. Staff locked themselves in the studio and continued to provide program until a Technician operated a circuit breaker to switch off the transmitter.

In 1989, another ethnic access station appeared using callsign 3ZZZ as an FM station but as a Public broadcasting service with a 10 kW ERP transmitting facility.

In 1983, Parliament passed the Australian Broadcasting Corporation Act establishing a new organisation to replace the Commission which had functioned for just over 50 years.

The Corporation became effective from 1 July 1983.

From the very beginning in providing programs for the National service, the Australian Broadcasting Commission saw itself as an organisation dedicated to the cultural uplift and intellectual advancement of the community. This was reflected in its choice of senior Managers and Announcers and the strict rules it applied to ensure the highest standard of professionalism in broadcasting.

However, after the Second World War with staff returning from War service, many changes took place. Not only had Public Service attitudes been adopted by top management, but these attitudes had infiltrated down the line into programs as well. The large number of senior Management staff and Announcers who returned from War service also had considerable influence on policy matters.

With the expansion of National transmitting outlets and local studios into country areas, the ABC made much progress in its 60 years in obtaining a large share of the listening audience. In its 1989–90 Annual Report, the Corporation revealed that in a 1990 survey conducted on public opinion of the ABC, about 17% of people only listened to the ABC, whereas 50% only listened to Commercial radio outlets. The remaining 33% indicated that their listening habits alternated between the ABC and Commercial stations. However, the most significant result showed that in any week, the ABC reached 50% of radio listeners. This showed tremendous support for ABC programs as no single station or network of any Commercial stations could reach anywhere near such number of listeners throughout the population spread of the nation. At the time of the survey, programs were being broadcast through 415 transmitters, 9 Major studio centres, 32 Regional studios and 12 Regional radio outposts.

By mid 1996, programs of the Corporation were being fed to 638 domestic radio transmitters plus 16 Radio Australia outlets. The network comprised Radio National, 21 AM and 224 FM; Metropolitan Radio; 8 AM and 2 FM; Regional Radio, 72 AM and 186 FM; ABC Classic FM, 66 FM; Triple J, 48 FM; Parliamentary and News network, 8 AM; and HF Inland, 3 AM. Three Radio Australia transmitters at Carnarvon were closed down on 31 July 1996.

Corporation staff numbered 5343 which included 1664 associated with operation of radio domestic services and 152 with the Radio Australia service. Net cost of ABC services for 1995–96 was approximately $575 million which included transmission service costs less operating revenue. The operating expenses included 10% to the National Transmission Agency and 6% for communications (satellite and transmission).

As at June 1997, there were 673 transmitters associated with the domestic radio services and staff level was 4887.

Like the PMG's Department/Telecom, the ABC had to support a considerable workforce of Engineers and Technical staff for provision and operation of the studio facilities of the National service. The ABC took on responsibility for television studio facilities at the time of establishment of television, but the radio broadcasting studio responsibility did not take place until 1964. Up to that time, the PMG's Department was responsible for the studio technical facilities.

Liaison on studio technical matters between the ABC and the PMG's Department was first handled by Stanley Darling. He was an Engineer, but initially worked in the Hobart studios of the ABC as an Announcer during the 1930s. He had very little interest in the job until the General Manager, Charles Moses appointed him as Technical Liaison Officer as a member of the staff in the then newly established Head Office in Broadcasting House, Sydney. When he retired from the ABC, he was Head of Building Services.

During the Second World War, Darling was one of the first of about forty ABC staff to enlist. He had been a Lieutenant Commander in the Naval Reserve and was called up for active service on 5 September 1939.

With the establishment of the Engineering Division in the ABC at the time of introduction of television, the first Controller of Technical Services was Vern Kenna, a former senior PMG's Department Engineer who occupied the position from 1961 to 1968. He was followed by Ken Middleton, Controller of Technical Services; Kevin Bourke, Controller of Engineering, and Gerald Moriarty, Assistant Managing Director (Resources). In 1992, senior staff responsible for the Radio Technical facilities included Jim Toogood, Head Technical Services; David Soothill, National Communications Manager Radio and Spencer Lieng, Head Design and Development. David Soothill later transferred to the SBS as Director, Communications and Planning.

When the Commission took over responsibility for the technical facilities for all National Broadcasting Service, including Radio Australia, radio studios throughout the Commonwealth and Papua New Guinea in 1964, almost the entire Technical staff of the PMG's Department Radio Section studio groups in all States elected to transfer to the Commission. The Engineering Division of the ABC doubled to some 1400 as a result. By end of 1980, the strength of the Division had increased by another 200 for the total television and radio commitments and included 64 Engineers, 1 Cadet Engineer, 406 Technical, 32 Broadcasting Engineering Trainees, 749 Operational, 71 Operational Trainees, 103 Trades, 32 Drafting, 42 Training Staff and the balance being Clerical and Administrative Staff.

Training of Technical staff for its radio activities was an ongoing requirement, with courses being conducted for Broadcast Engineering Officers and Technicians in existing and new technology as well as organisational and project management skills.

As a result of a Radio Broadcast Structure Agreement in 1992, a job design process was implemented. The process was designed to link the goals of ABC Radio with the career aspirations of staff.

A range of broadcast and management courses were conducted including Core Broadcasting Skills and Management Skills. Core Skills component was accredited by Charles Sturt University and the University of Western Sydney towards Graduate Certificates and Diplomas in Communications.

During the 1995–96 financial year some 4162 staff members participated in 1,380 training courses covering technical, operational, management and administration, computers and journalism.

During 1992, the Corporation celebrated 60 years of National radio broadcasting and from material in its archives produced a number of programs of particular interest to listeners who had been fans of the ABC for many years. Emphasis was placed on important milestones in its 60 years of operation. These included:

- The ABC began operation on 1 July 1932 broadcasting over 4QG, 2BL, 2FC, 3LO, 3AR, 7ZL, 5CL and 6WF in capital cities and 4RK, 2NC, 2CO and 5CK at regional centres.
- Synthetic test cricket broadcasts in 1934 created a great deal of public interest.
- In 1936 a Technical Supervisor was appointed to coincide with the formation of Federal Departments of Music, Drama, News, Schools Broadcasts and Programs.
- By 1938, the network included two metropolitan transmitters in all capital cities.
- The first mobile studio was commissioned in 1939.
- Short wave service Radio Australia began on 20 December 1939.
- In 1940, an ABC Mobile Reporting Unit went to the Middle East war zone accompanied by a War Correspondent and Engineer Reg Boyle.
- Broadcast of Parliamentary proceedings commenced on 10 July 1946.
- In 1947, the ABC participated in experimental FM broadcasts.
- Radio Australia transmitters Cox Peninsula put off air for extended period following extensive damage by Cyclone Tracy December 1974.
- New studio and administrative complex opened at Collinswood, Adelaide in 1975.
- ABC's first 24 hours-a-day station 2JJ Sydney began operation 19 January 1975. Access radio station 3ZZ Melbourne opened 12 May 1975. The station closed down on 15 July the following year.
- FM Stereo service began 24 January 1976 from the Adelaide Collinswood studios.
- Australian Broadcasting Corporation established 1 July 1983.
- The ABC had grown from a staff of 265 providing programs for 12 transmitters in 1932 to a staff exceeding 5000 and providing programs to 540 transmitters including Radio Australia, 60 years later. In 1997, the number of transmitters had grown to 673.

In celebrating its Sixtieth Anniversary, major radio activities included:

- ABC Symphony Ball.
  Celebration of Orchestras involving Tasmanian Symphony Orchestra, Melbourne Symphony Orchestra and the Sydney Symphony Orchestra presenting concerts in Melbourne, Sydney, Hobart, Launceston and Canberra.
- Special commemorative radio programs.
- Commemorative issue of 24 Hours magazine.
- An exhibition of historic photographs and equipment in Ultimo Centre, Parramatta Town Hall, Parramatta Riverside Theatre and National Library Canberra.
- ABC Picnics in Perth, Adelaide, Brisbane and Sydney.
- Open days at ABC studios in Adelaide, Hobart, Launceston, Newcastle, Wollongong and Melbourne.
- Special program events on Triple J, Regional stations and Radio Australia.
- Radio Coverage of Barcelona Olympics and others.

Because of the diversity of technical and managerial activities, of the ABC, and the location of staff groups at a number of different locations around Melbourne, the Board tackled the problem of acquiring a large property to bring some of the activities to a central point. In Sydney, the position was overcome to a large extent by completion of the Ultimo Centre opened by Prime Minister Bob Hawke on 22 June 1991.

In Melbourne, a project at Southbank was officially launched on 25 May 1992 to accommodate ABC Radio, Radio Australia and Orchestral staff in a specially designed building but the project was temporarily halted because of financing difficulties. However, following discussions with the Victorian and Commonwealth Governments and others, the Board decided in 1992 to reactivate the project by arranging borrowings of up to $50 million over the following three years.

Interesting features of the building design included a 600 square metre Concert Hall to accommodate a 100 piece orchestra with seating for 300 and a production studio of two storey design employing variable acoustics and flexible acoustic spaces.

Cost of providing the technical facilities was estimated to be $8 million and many of the contracts for supply of equipment had been finalised by late 1993. Some of the equipment for the new centre was transferred from the ABC Waverley facility.

By September 1994, apart from Metropolitan and Regional stations, all Victorian ABC networks including Radio Australia were operating from the Southbank building.

The facility was designed to provide five domestic stations and nine foreign language services for Radio Australia transmissions. The building was characterised by its five level glass enclosed atrium. The atrium rose above the lobby and was encircled by studios and offices on each floor.

The complex was officially opened on Saturday morning 5 November 1994 by Prime Minister Paul Keating.

ABC Radio which employed some 1,800 people during 1992–93 provides a number of distinctly targeted services including Local services, National networks and Special Audience services.

The Local services comprise Metropolitan Radio with outlets in all State capitals, including Canberra, Darwin and Newcastle together with Regional Radio with at the time, 32 full-sized studios and 16 smaller studios in regional areas.

The National networks include Radio National — a specialist spoken word network — ABC Classic FM and Triple J a youth service. During May 1993, the 200th Radio National station was commissioned. ABC Classic FM was originally known as ABC FM Stereo but later changed to ABC Fine Music. On 4 April 1994 a further change was made to call the service ABC Classic FM in order to identify the service as a pre-eminent provider of fine music, particularly classical music.

On Australia Day 1995, the Triple J service made broadcasting history with the country's largest single expansion in one day. An additional 17 country transmitters were added to the network making a total of 47 outlets. Special Audience services comprised Parliamentary Broadcasting Service, Aboriginal broadcasting and other services which complement the broadcasting activities such as magazines, program guides, production of tapes and cassettes.

During 1996-97, ABC Radio's domestic weekly audience reached the highest level on record, averaging 6.389 million. For the first time, Triple J listeners exceeded 2.1 million. Radio National's overall national weekly listeners peaked at 0.887 million while ABC Class FM's audience was about 0.990 million. Regional Radio had an audience of some 1.34 million. There were 673 transmitters in operation.

The Radio Australia service which was broadcast in eight languages including a 24 hours a day English program had, like many other international short wave broadcasters, seen a reducing listener audience over the years. During 1991–92 when listening audience was estimated to be of the order of 50 million, more than 94000 letters were received from listeners in the target areas. However, the number was less than half that received during 1987–88. The Thai language program was closed down in September 1995 after 53 years of continuous service. Surveys in Malaysia also indicated there was little interest in international short wave services.

Radio Canada which in 1972 installed three Collins 250 kW transmitters similar to those installed at Radio Australia Cox Peninsula, announced that its international short wave service known as Radio Canada International would close down on 31 March 1997. The service like Radio Australia had been operational since the 1940s.

In July 1996, the Government commissioned Bob Mansfield former head of Optus Communications to review specific aspects of the ABC. The Report titled 'The Challenge of a Better ABC' was released during January 1997. Amongst many other things, he recommended that the ABC should become a purely domestic broadcaster and close down or sell Radio Australia.

On 13 February 1997, the Senate of the Commonwealth Parliament initiated an 'Inquiry into the role and future of Radio Australia and Australian Television'. The inquiry was to be conducted by the Senate Foreign Affairs, Defence and Trade References Committee with the Committee being required to report by 14 May 1997.

Like many other broadcasters throughout the world, the ABC appreciates the opportunities which multimedia presents to extend the role of the Corporation through this new creative form. During 1995–96, the ABC established a Multimedia Unit to investigate and co-ordinate the ABC's involvement in multimedia projects particularly the Internet and CD-ROMs. The Board was of the opinion that multimedia would enhance audience access and interaction with the Corporation's existing programs and services.

In August 1995, the Corporation launched ABC Online, the ABC's Internet publishing service. Sites included radio networks such as Radio National, Classic FM and Triple J; Radio Australia information to an international audience; selected TV programs plus program highlights; and information about ABC Enterprise facilities and ABC services, policies and history.

The sites provided a range of information including program information, audience feedback, fact sheets, guide to further resources and much more.

The Radio Australia presence resulted in considerable activity by listeners. News bulletins were made available in Europe and North America on World Radio Network (WRN) and Internet audio. The WRN was established to provide an alternative means to short wave radio of distributing international broadcasting program material. The ABC is among some 30 major broadcasters involved with WRN with programs being provided via cable, local AM/FM broadcasting stations and direct-to-home satellite.

As at October 1997, the ABC Board of Directors comprised Donald McDonald, Chair; Diana Gribble, Deputy Chair; John Bannon; Russell Bate; Ian Callinan; Kirsten Garrett (staff elected Director); Ian McPhee; and Wendy Silver. Brian Johns AO was Managing Director, having been appointed to the position in March 1995 following the resignation of David Hill.

The main portfolios comprising the ABC structure included News and Current Affairs; Regional Services; National Networks; Program Production; ABC Enterprises; Corporate Management; Human Resources; Finance and Business Services; and Technology and Strategy.

The Technology and Strategy group Head was Colin Knowles with other senior staff including Mgr Tech Strategy (Tech), Dilip Jadeja; Mgr Tech Strategy (Satellites), Dick Winston; National Mgr TV Capital Works, Alex Marhinin; Executive Engineer Trans and New Tech, Brian Bailey; National Mgr Technical Operations TV, Grant Rogers; Executive Engineer, Mike Bridle; Senior Policy Officer, Margaret Cassidy; National Mgr Alpha Tech, Brian Henebery; National Transmission Mgr (R), Brian Hancock; National Mgr Comms (R), Jim Toogood; Mgr Technology Research & Development, Spencer Lieng; Mgr ABC Digital, James Bowden; and Mgr Radio Business Development, Steve Ford. Staff working in the group numbered 83.

Colin Knowles was previously General Manager, Planning and Corporate Services with the Australian Broadcasting Authority and resigned on 22 August 1997 to take up his present position with the ABC. He has over 30 years experience in broadcasting, telecommunications, engineering, policy and management.

While with the ABA, he was Session Moderator at the ABA Planning Seminar in 1997 and also participated in the 1998 Digital Broadcasting Seminar. He has been actively engaged in debates about the development of digital broadcasting technology from both the regulatory and Engineering perspectives since 1983.

Colin chaired the joint ABA/Industry Groups that developed the ABA reports on both digital radio and television systems for

Australia and was Convener of the Australian ITU National Study Group on Radio and Television Broadcasting. He was also Vice Chairman of the ITU International Working Party responsible for terrestrial television planning.

SPECIAL BROADCASTING SERVICE CORPORATION

Prior to the mid 1970s, foreign language broadcasts were restricted to 2.5% of a station's transmission line. All such broadcasts in languages other than English were accompanied by an English translation. These restrictions were part of Government policy which stressed the need for assimilation of migrants into Australia's predominantly Anglo-Saxon society.

Entrepreneurial interests in the Greek and Italian communities in Sydney and Melbourne had been pressing for Commercial radio station licences for some time as their communities were large enough to support such stations from advertising revenue. Other migrant groups, however, wanted broadcasting for ethnic groups to be supported solely by the Government as their communities were too small to support a Commercial station approach.

During July 1974, the Department of the Media, which at that time was responsible for broadcasting policy and licensing, considered applications for a subscriber type service to provide programs to the Greek and Italian communities in Sydney and Melbourne. A number of difficulties were foreseen, particularly in the political field and no approvals were granted.

Early in 1975, the Government accepted a scheme developed by the former Minister for Immigration, the Hon. A Grassby, who had then been appointed Special Consultant on Community Relations. He proposed establishing a three months radio experiment in Sydney and Melbourne to inform ethnic communities of the Government's plans to establish the Medibank scheme. The experiment was seen as a means of providing a test bed for a permanent ethnic radio service.

Stations 3EA Melbourne and 2EA Sydney were established in June 1975 on an experimental basis and a committee was to report to the Government at the conclusion of the experiment. The stations were placed under the control of the Attorney-General's Department and broadcast in seven languages in Sydney, and eight in Melbourne.

In the case of 3EA, studio and recording facilities were provided by Media Sound Pty Ltd, a Melbourne production unit while transmitting facilities were provided by station 3UZ which made available a standby transmitter sited at its offices at 45 Bourke Street. Operating frequency was 1,120 kHz.

Although the licence for operation was issued by the Postmaster General's Department under the Wireless Telegraphy Act, the committee responsible for program material was to ensure that it conformed with the Broadcasting Program Standards issued by the Australian Broadcasting Control Board.

The demand for ethnic broadcasting was demonstrated beyond doubt, and the Government agreed to extend the experiment for a further six months. Responsibility for the stations was transferred to the Department of the Media.

The second experimental period began on 15 September 1975 with the goal of establishing a permanent structure. In Victoria, new studios were leased from Armstrong Video Pty Ltd, and a transmitter was leased from Telecom's National Broadcasting Service facilities.

In September 1976, the Government requested the ABC to establish a permanent ethnic broadcasting service. However, in June 1977, the Government withdrew its offer to the ABC to establish ethnic broadcasting on the grounds that the ABC's estimates to operate the service were unacceptable.

In January 1978, the Special Broadcasting Service was established and assumed responsibility for 2EA and 3EA.

During August 1979, 2EA relay transmitters were established in Newcastle on 29th, and Wollongong on 30th. Both stations employed 150 watt transmitters. The Newcastle transmitter located at Sandgate operated on 1584 kHz and fed a 30 m high omnidirectional aerial while the Wollongong transmitter operated on 1485 kHz and fed a 32 m high omnidirectional aerial. Major changes were made to the Newcastle service in 1996 when the National Transmission Agency acquired the former 2KO Commercial station facilities at nearby Hexham. The 2EA service at Sandgate was closed down in March 1996 and replaced by the Hexham facilities, some of which were upgraded, employing a 112 m directional aerial system fed by a 5 kW transmitter operating on 1413 kHz. Station 2KO had a long history of Commercial broadcasting in the Newcastle area having been established on 1 August 1931 by Allen (later Sir Allen) Fairhall a well-known local Amateur station operator, using a 25 watt transmitter installed at his home. In 1933, new and updated facilities were installed at Sandgate with a transmitter providing 200 watts into the aerial.

The 500 watt 3EA transmitter was replaced by a 5000 watt unit on 26 January 1980. It operated on 1224 kHz and fed a 61 m directional aerial system at Craigieburn.

During July 1980, the 500 watt 2EA transmitter was replaced by a 5 kW unit and a 54 m directional aerial system installed. The station operating frequency was changed from 801 kHz to 1386 kHz with commissioning of the new facilities.

On 9 December 1988, the transmitter and building at Homebush were destroyed by fire when the mast received a direct lightning strike. Co-located station 2KY equipment was also destroyed. The 2EA service was restored within 24 hours by using the standby transmitter and mast of 2SM and later a 3AW transmitter was used until 2EA's replacement transmitter was installed. The replacement transmitter was a 5 kW Nautel solid state model and was placed in service on 8 August 1989.

New studios for 2EA were officially opened in May 1988. They were located at 55 Grafton Street, Bondi Junction and included on-air, program recording and multitrack studios, production suites and a central control room. Two on-air studios were provided to permit the presentation of consecutive live programs. Each studio had capability to handle voice, reel-to-reel tape, cartridge tape, long-playing record, compact disc and outside broadcast program sources. In addition, each studio had an associated news booth for the insertion of news bulletins into programs. One studio could handle telephone talk back programs.

A central control room provided for distribution and monitoring of all program material within the studio complex and for control of program material leaving the complex. Programs were fed to the 2EA transmitters in Sydney, Newcastle and Wollongong and also to the satellite distribution system via SBS television at Milsons Point. The control room was provided with a unique tape automation system for unattended presentation of tape recordings to air. A similar studio was provided for 3EA and officially opened on 9 February 1990. The earlier Bank Street studios had reached the end of their useful life. The new facilities were located at the Australian Ballet Centre in Melbourne.

As from December 1991, the Special Broadcasting Service became the Special Broadcasting Service Corporation.

In mid 1992, SBS announced that as a result of the establishment of new $35 million headquarters in 14 Herbert Street, Artarmon, a northern Sydney suburb, the Sydney radio studio facilities would be transferred from the Bondi Junction site to the new building. The new building was designed to accommodate administration staff and all television and radio technical services.

The new radio studios came into operation on 13 August 1993. During the design of the facilities allowance was made for the future introduction of digital audio broadcasting technology and also for expansion of the radio service as a National network.

Facilities included seven on-air studios designed around five voice-over booths together with a large recording room and production studio. A routing switcher/mixer built by SBS Engineering staff enabled the selection of any studio or voice-over booth, production studio or multitrack to be put to line for transmission.

Program logging was carried out using a Racal VHS logger which catered for 27 hours of four channel recording.

Project Engineer for establishment of the new facilities was Hing Shek.

The building was officially opened on 10 November 1993 by Prime Minister Paul Keating.

Provision of additional facilities and upgrading has been an ongoing exercise. Station switching and program routing was automated resulting in more efficient use of operational staff and a reduction in switching errors.

The provision of digital portable recorders for broadcasting staff, and digital editors and portable mixing consoles ensured production of programs of the highest technical quality.

In October 1993, it was announced that Broadcast Communications Australia Ltd had been awarded a contract to install transmission equipment in Brisbane, Adelaide and Perth as part of SBS's National Radio Network, employing FM band transmitters.

On Australia Day, 26 January 1994, SBS launched its National Radio Network (NRN) extending coverage of programs to Adelaide, Brisbane and Perth. A Darwin transmitter became operational on 4 February 1994. Plans at the time allowed for Canberra and Hobart to be brought into the network at a later date.

The long running 2EA and 3EA stations became Radio Sydney and Radio Melbourne respectively. Sydney and Melbourne were each provided with a second outlet on 30 June 1994.

At that stage, the National Radio Network comprised, Adelaide on 106.3 MHz FM with 20 kW ERP; Brisbane on 93.3 MHz FM with 45 kW ERP; Darwin on 100.9 MHz FM with 10 kW ERP; Newcastle on 1584 kHz AM; Perth on 96.9 MHz FM with 50 kW ERP; and Wollongong on 1485 kHz AM. Radio Melbourne 1 was on 1224 kHz AM; Radio Melbourne 2 on 93.1 MHz FM with 10 kW ERP; Radio Sydney 1 on 1386 kHz AM; and Radio Sydney 2 on 97.7 MHz FM with 20 kW ERP.

The outlets provided SBS radio service to some nine million people.

During January 1995, Radio Sydney 1 had a transmitter frequency shift from 1386 kHz to 1107 kHz using the transmitting facilities previously employed by Commercial station 2UW.

On 30 June 1995, SBS Radio celebrated its 20th Anniversary simultaneously in Sydney and Melbourne.

During 1994-95, terrestrial program links to Wollongong and Newcastle AM stations were closed down and programs fed to the transmitters via satellite circuits.

SBS radio outlets were increased to 13 when FM transmitters were commissioned in February 1996 in Canberra and in April 1996 in Hobart. They were the last capital cities to be provided with SBS Radio service.

In early 1997, the National Transmission Agency announced that a contract had been let to upgrade the 3EA Craigieburn transmitting facilities at a cost of about $273000.

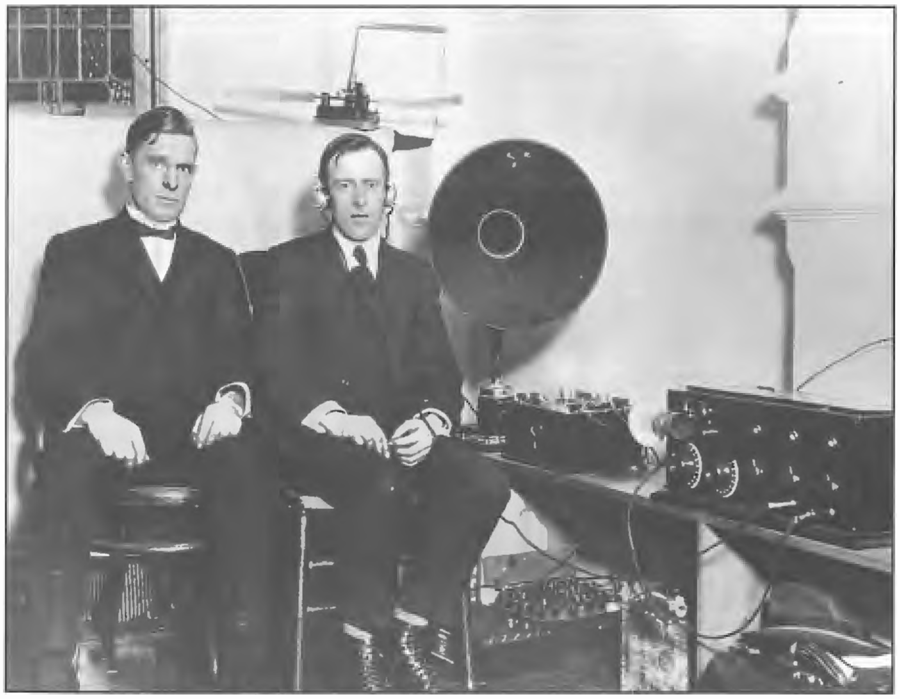
Long-time Director of Engineering, Bryan Madeley retired in 1992. Bryan was heavily involved in extensive expansion of SBS radio and television services, upgrading of facilities, the introduction of new technology to the network and the design and provision of the modern studio complex at Artarmon. After retirement, he conducted a business Bryan Madeley Associates, Broadcasting Consultants.

As at June 1998, Director of Communications and Planning was David Soothill who transferred over from the Australian Broadcasting Corporation in May 1994 after having worked with the ABC for more than 20 years. He is primarily responsible for the management and strategic development of SBS's broadcasting technologies. David's main focus is in the areas of digital technology, transmission, communications and new services. This includes domestic and international satellite services, new transmission technologies, transmitter arrangements, terrestrial communication services and capital planning. He has a special interest in Digital Audio Broadcasting and has been active in this field for several years. At the Broadcasting Planning Seminar organised by the Australian Broadcasting Authority in Canberra 17-18 February 1998, David delivered two papers at the Seminar. They were 'An Introduction to Eureka 147 COFDM and Single Frequency Networks (SFN) Operating in L Band' and 'Service Planning for Eureka 147 DRB'.

With the recent announcement by the Government of the start of digital television and radio in 2001, David and staff are heavily involved in developing strategies for the replacement of studio technology with digital equipment over the next four years. Also, all SBS satellite services are being converted to digital technology. This will result in major works associated with SBS services and will also impact on homes receiving SBS programs.

Delegates at the Broadcasting Conference, Postal Institute Hall, Melbourne 24 May 1923 to discuss establishment of a broadcasting system in Australia. The Government was represented by Postmaster General, the Hon. W G Gibson, MP; Mr J Oxenham, Secretary PMG's Department and Mr J Malone, Chief Manager, Telegraphs and Wireless.

David Sarnoff Head of Radio Corporation of America. His concept in 1915 of 'The Radio Music Box' was an important contribution to the use of radio telephony the emerging off-spring of radio telegraphy at the time, for public information and entertainment. His concept was to bring music and information into the home by wireless. His superiors at RCA considered the proposal hair brained and unreal, referred to it as 'Sarnoff's folly' and filed it away.



Harry Kauper (L) and Lance Jones with receiving and amplifying equipment at First Social and Radio Dance in South Australia 28 June 1923. Kauper later became Chief Engineer of A Class station 5CL while Jones constructed the transmitter for the first B Class station 5DN and was Manager of Adelaide Radio Company.

Sir Harry Brown FIREE former senior officer for 25 years with the British Post Office and first Director General Posts and Telegraphs, PMG's Department. He came to Australia in January 1923 at the time when broadcasting was about to commence in this country. The idea of the dual system of A Class and B Class stations originated in his office and was accepted by the Government of the day. He was also a member of the Radio Research Board from its formation in 1927 until his retirement in 1939.

Sir Ernest Fisk FIREE radio pioneer, businessman, and adviser to Governments. He was appointed General Manager of Amalgamated Wireless (A/Asia) Ltd on formation of the company in 1913. He remained with AWA until 1944 and built the company into the largest commercial Radio Engineering establishment in Australia. He was first President of The Institution of Radio Engineers, Australia when it was formed in 1932 and became The Institution's first Fellow.

Mr A J (Alec) McKenzie, Director of Technical Services, Australian Broadcasting Control Board 1952–68. Prior to joining the ABCB, Alec worked with the PMG's Department Research Laboratories and made major contributions to MF and HF aerial, switching and transmission line technology particularly in the fields of top loaded anti-fading radiators and dual frequency MF radiators.

Mr J R (Jim) Hutchinson, Director Posts and Telegraphs, New South Wales. He had long-time involvement in early establishment of the National Broadcasting Service serving with the Radio Research Board, PMG's Department Research Laboratories and the Department's Radio Sections in Queensland and New South Wales on broadcasting projects.

Mr W E (Bill) Beard, Director of Engineering, Australian Broadcasting Control Board 1976 where he directed broadcasting system and station technical planning, the setting of technical standards and technical regulation of domestic broadcasting services. Before joining the ABCB, he worked in the PMG's Department Research Laboratories and later with Headquarters Broadcasting Branch.

Mr W H (West) Hatfield, Sectional Engineer, Australian Broadcasting Control Board 1949–77. West began his career with the PMG's Department in 1926 and was a member of the team associated with the establishment of Radio Australia, Shepparton during the War years. He also played a major role in early experiments associated with the introduction of the FM broadcasting service.

Mr V F (Vern) Kenna, Controller of Technical Services, Australian Broadcasting Commission 1961–68. Formerly of the PMG's Department, Vern had a distinguished career with the National Broadcasting Service. He was a member of the Department's staff which took over responsibility for operation of 4QG Brisbane in 1930 when the Government acquired the station from the Queensland Government. He was associated with many major projects in Queensland and Papua New Guinea.

Mr J R (Jim) Malone, Chief Officer of the Postmaster General's Department Wireless Branch for 20 years. He played a major role in the determination of policy and administration of the Regulations associated with the establishment and operation of National and Commercial broadcasting services in Australia. He later held positions of Deputy Director Queensland, Deputy Director New South Wales and was first Chairman of the Overseas Telecommunications Commission, a position he held until 1954.

Mr E J (Jim) Wilkinson ISO, Engineer Member Australian Broadcasting Tribunal 1983. Prior to that appointment, Jim held many senior appointments in Broadcast Engineering including Director of Engineering, Australian Broadcasting Control Board; First Assistant Secretary, Radio Frequency Management, Postal and Telecommunications Department; and Assistant Director General Radio, Postmaster General's Department. He played a major role in the installation of Radio Australia, Shepparton during the 1940s, and planning for the Radio Australia Cox Peninsula facility during the 1960s.

In 1996, Jim was admitted to Degree of Doctor of Engineering Honoris Causa at RMIT, Melbourne.

Mr L D (Leon) Sebire AM, General Manager Telecom Broadcasting. For many years he was responsible for design, construction, operation and maintenance of transmitting facilities of the National Broadcasting Service including Radio Australia services. Leon played a major role in design of aerial coupling units associated with sectionalised and dual frequency MF radiators. He was the first Director of the Broadcasting Directorate when it was formed in 1983.

Bust of Guglielmo Marconi 'founder of wireless'. The bust was a gift from the Lions Club of Turin, Italy to the Lions Club, Sydney to mark the Golden Jubilee of Amalgamated Wireless (Australasia) Ltd, the Marconi Company's Australian representative. It was unveiled at AWA's Ashfield site on 14 March 1964. AWA vacated the site in 1990 and the bust was transferred into the care of OTC Limited and installed at their La Perouse station site.

In 1996, the site was Telstra Maritime Communications Station, Sydney.

Mr S H (Sid) Witt FIREE who as Head of the PMG's Department Research Laboratories from its formation in 1924 played a key role in the planning, development and design of technical facilities of the National Broadcasting Service until 1948 when the Australian Broadcasting Control Board took on this function. Staff of the Laboratories were responsible for design and commissioning of Radio Australia during the Second World War years. It was the largest Broadcast Engineering project undertaken up to that time in Australia.

Mr E P (Ted) McGrath MBE, Supervising Engineer Radio, PMG's Department. He played a major role in expansion of the National Broadcasting Service throughout South Australia and Northern Territory over a period of 38 years. Ted was a member of the Departmental staff which took over operation of 5CL Adelaide from Central Broadcasters Ltd in 1930.

Mr W H R (Bill) Robinson Officer-in-Charge of the first Regional National Broadcasting Station 2NC Newcastle commissioned in 1930. Bill later transferred to Commercial station 2UE Sydney where he subsequently became Chief Engineer.

Mr L C (Lance) Jones, Manager Adelaide Radio Company and builder of transmitter for 5DN the first broadcasting station commissioned in South Australia when the station began operation in June 1924. He represented South Australian Interests at the 1923 Conference in Melbourne to discuss the establishment of broadcasting in Australia.

Studio control booth in the Senate of Federal Parliament 1946. Assistant Supervising Engineer-in-Charge of project was Jim Hutchinson PMG's Department.

Administration and studio building 5CL/5CK Hindmarsh Square, Adelaide, originally provided for Central Broadcasters Ltd in 1928 when the company operated 5CL. The ABC operated from buildings in Hindmarsh Square until 1975 when a new complex was erected at Collinswood.

The original transmitter building at Lyndhurst near Melbourne in 1928 when the PMG's Department established an experimental HF transmitter on site. Transmissions were conducted 2-3 hours daily and beamed to Northern Australia. The transmitter provided 600 watts into the aerial on a frequency of 9580 kHz.

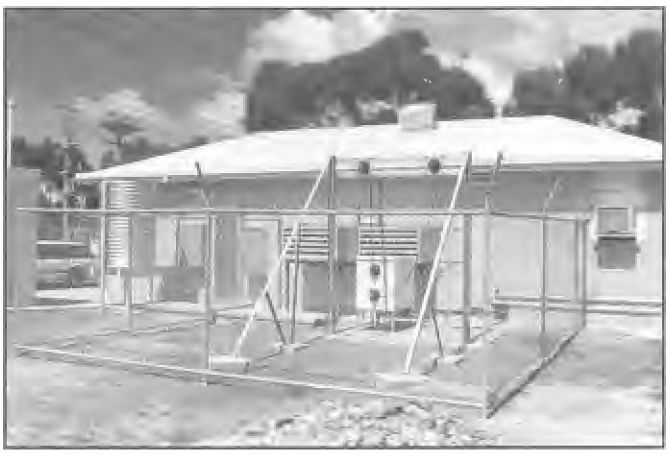
View of 4RK Rockhampton taken 1987 from the station 128 m high radiator showing the original building and aerial provided in 1931. In 1998 the aerial was still in service as a standby. The residence of the station Officer-in-Charge is at the end of the tree lined driveway. The trees were planted by Harry Conway the first OIC.

Station 5CK Crystal Brook began operation on 15 March 1932 with a 7 kW water cooled transmitter feeding a multiple tuned flat top Alexanderson type aerial supported by two 56 m towers. A house was erected on the site for the first Officer–in–Charge Bill Whisson.

Transmitting station building 2CO Corowa. Erected 1931 and demolished in 1997.

Transmitting station building 5CK Crystal Brook, erected 1932.

Transmitting station building 3WV Dooen, erected 1936. First Officer-in-Charge Stan Hosken.



Transmitting station building 3WV Dooen, erected 1988 to replace original 1936 building.

Transmitting station building 2NR Lawrence, erected 1936. First Officer-in-Charge E J Halcrow.

Transmitting station building 2CR Cumnock constructed in 1937. It is typical of the magnificent NBS stations constructed in the mid to late 1930s featuring Art Deco style building with porte–cochere entrance.

Transmitting station building 4QS Dalby, erected 1939. First Officer-in-Charge Harry Conway.

Transmitting station and studios 5DR (later 8DR) Gardens Hills, Darwin 1947. Installation under control of Divisional Engineer Ted McGrath. First Officer-in-Charge of operations and maintenance of technical facilities was Brian Woodrow.

Transmitting station 2NU Manilla, erected 1948.

The 3RPH transmitter building Lower Plenty accommodating TBC type AM10KD 10 kW transmitter derated to 5 kW as main unit and STC type 4–SU–55 5 kW transmitter as standby unit. The station originally belonged to Commercial station 3KZ which established facilities on site and went to air in March 1956 with a 135 m lattice steel radiator. In 1971, a 54 m high standby radiator was erected. A standby diesel engine power plant located in a room on the left side of the building was installed in 1966.

Transmitting station 7ZR/7ZL Ralphs Bay, erected 1958.

Administration and studio building 3WM Horsham, erected 1982. Senior Technician Bruce Lees.

ABC administration and studio building Collinswood, Adelaide. The 5CL/5AN studio facilities were transferred from Hindmarsh Square into the Collinswood building on 13 October 1975. The building became the ABC headquarters for ABC FM Stereo when the service began in 1976.

Transmitting station building 5CL/5AN Pimpala, erected 1961. First Officer-in-Charge Ken Bytheway.

Transmitting station building for HF Broadcasting Service Northern Territory. Identical buildings were erected at Alice Springs, Tennant Creek and Katherine, 1986.

Typical prefabricated Logan type building provided at National Broadcasting Service stations from the late 1980s to house 10 kW Nautel Amphet solid state transmitters. This building housed the 4QL Longreach facilities.

Transmitting station Lyndhurst at time of closure June 1987. The station had been in operation for 59 years. At its peak, the station provided two Radio Australia, two Time Signal, a link to Perth and VLR and VLH Inland services. Officer-in-Charge at time of closure was Max Fowler.

The Australian Broadcasting Corporation Southbank building officially opened on 5 November 1994 by Prime Minister Paul Keating. It caters for ABC Melbourne staff associated with 3LO, Radio National, ABC Classic FM, JJJ, Regional Radio, Radio Australia, Melbourne Symphony Orchestra and technical support services including a range of satellite services.

The Ultimo Sydney studio building of the Australian Broadcasting Corporation opened during June 1991. The entire building is constructed on massive piles socketed into bedrock to render the building as insensitive as possible to vibrations from nearby road and rail traffic. Each studio is a separate box-like construction within the building. Cost of the project was $150 million.

Chapter Two

Broadcast Transmitters

A Class Station Transmitters

The original transmitters for 2FC, 3LO, 5CL, 6WF and 4QG were designed and manufactured by Amalgamated Wireless (A/Asia) Ltd, with AWA Engineer Joe Reed being involved with all the installations while those for 2BL, 3AR and 7ZL were constructed by others. With the exception of components determined by the operating wavelength, the AWA built transmitters were basically of similar design. Stations 3LO, 2FC and 6WF started up on long wavelengths, while 4QG and 5CL used medium wavelengths.

The transmitter provided for 5CL in Adelaide was typical of the equipment provided at the other A Class stations at the time. It had a power rating of 5 kW with the total power consumed by the equipment including modulator, master oscillator and speech amplifier being about 15 kW. The transmitter consisted of six main units:

- Three phase rectifier for high tension supply.
- Power amplifier and modulator.
- Submodulator and line amplifier.
- Master oscillator or independent drive.
- Closed circuit inductor and capacitor.
- Aerial circuit inductor.

Power for operation of the transmitter was obtained direct from the three phase public supply. The filaments were energised by means of step-down transformers connected to 240 volts and to even up the load, the power for the filaments for the various units was drawn from separate phases. Variable control of the secondary output was obtained by means of auto transformers fitted with coarse and fine adjustments to allow for the accurate setting of the terminal voltage for the filaments.

The high tension supply was obtained from a rectifier employing six MR7 valves so connected as to 'double wave rectify' the three phase supply which had been stepped up employing 415 volt primary and two 12000 volt secondary windings.

The output from these valves was passed through a filter system consisting of eight mica capacitors and a large audio frequency choke. The system provided 10 kV DC.

After being smoothed, separate feeds were taken to the main oscillator, master oscillator and sub-modulator. The former supply went through a large speech choke which enabled the modulator valve to control the supply to the oscillator in sympathy with the speech and music frequencies.

In the case where the studio was located some distance from the transmitting station, it was necessary to provide a means of amplifying the line currents, and for this purpose, two small valves, type DE5 located in front of the sub-modulator, were provided. The power to operate these valves — which were connected in parallel — was provided by a six volt storage battery and a dry cell high tension battery of 200 volts. Negative bias to the extent of 20 volts held the anode current within reasonable limits and guarded against grid current distortion.

These valves were choke coupled to the sub-modulator which was specially designed for that purpose, and the latter connected by the same means to the grid circuit of the main modulator which consisted of seven MT7B valves in parallel. The latter, were all mounted in the main oscillator framework with their individual grid bias batteries in the base of the sub-modulator.

The master oscillator or independent drive, which with the exception of its anode current supply, was a self-contained radio frequency generator. This unit consisted of two parallel MT7A valves with its associated filament transformer, meters, capacitors and tuning inductors.

Its function was to generate the exciting energy for the main oscillator and it was connected by means of a coupling coil to the grids of the three main oscillator valves. On its panel were mounted — four Weston meters indicating the filament voltage, radio frequency current, anode current and oscillator grid current respectively.

The operating conditions with a master oscillator were practically similar to those when self-excitation was employed but with the advantage that when the excitation load was removed from the main valves, they were capable of furnishing a greater output in consequence of their higher efficiency.

The main oscillator and modulator panel contained three MT7A and seven MT7B valves as oscillators and modulators respectively. In addition there were the transformers and controls for regulating the filaments and primary voltages to the rectifier filament and anode transformers. Meters indicating the conditions in various parts of the circuit were located in the front of the top panel. At the back were located the valves and associated radio apparatus, such as feed capacitors and grid leak resistors.

The closed circuit radio frequency inductors and power capacitor were mounted on a square table. These items comprised the tuning inductors viz: main inductor, variometer, and aerial coupling inductor.

In space below the inductor, was the closed circuit power capacitor with its radio frequency meter on the front panel.

The aerial inductor was mounted on a similar table with ammeter to match the one on the closed circuit panel.

Other technical points of interest with the design of this, and the other AWA transmitters include:

- The closed circuit of the transmitter consisted of a main inductor and a variometer. At the end of the main inductor were two reaction windings. One was capable of rotary movement and was employed for the self-oscillating condition when the master oscillator was out of circuit. The second winding was fixed in its relationship to the main winding and was used solely when the transmitter was being used in conjunction with the master oscillator. Its function was the reverse of the rotary coil, for it had to neutralise the tendency of the main valves to oscillate of their own accord due to valve interelectrode capacitance.
- Anode feed capacitors to isolate the direct current component of the anode supply from the radio frequency circuits consisted of two glass Leyden jars. They had to be kept free of dust and moisture at all times during operation, otherwise surface leakage could destroy the units.
- There were four grid leaks contained in pairs, in oil filled tanks for cooling purposes. The resistors were provided at the tops of the tanks with the mica capacitors being at the bottom to take advantage of the cooler oil. The resistors were wound on porcelain formers with silk covered Eureka wire.

- Three MT7A valves were provided in the oscillator (magnifier) circuit with a socket being provided for a fourth valve. When acting as a separately excited oscillator, three valves were used but four were brought into operation when self-excited. They required 12.5 volts at 25 amperes for each filament.
- In order to minimise hum problems with those valves whose filaments were powered with 50 Hz power, an equalising potentiometer network was employed. It consisted of two resistors of equal value with a centre connection, with that lead going to the grid circuits.
- A separate Weston DC meter was inserted in the anode supply to each valve, and in order to guard against damage to the moving coil element by radio frequency currents, each meter was shunted by a capacitor of suitable capacity.
- Each group of filaments was supplied by an individual transformer consisting of an auto transformer and a step-down transformer with a ratio of 240 to 20. Fine and coarse control was obtained by change of the output voltage of the auto transformer.
- In the case of rectifier filaments which were at a high potential above earth, the step down filament transformer was oil immersed and insulated for a potential of 15 kV.
- The anode currents for the main and modulator valves passed through two large chokes each of 100 henries. One was the speech choke to enable anode — or what was often called Heising control — to be employed, and the other was the power supply filter choke.
- The modulator MT7B valves required filament voltages of 15 volts at 10 amperes and had a maximum dissipation of 1000 watts. They were all biased using a multi tapped dry cell battery.
- Each major valve was provided with a voltmeter connected across the filament leads. The rectifier valve voltmeter was connected across the primary of the filament transformer using the winding ratio of the latter as a voltage transformer.
- The sub-modulator employed choke coupling between stages with the chokes being contained in heavy iron containers for magnetic shielding purposes.
- The filament consumption of each of the six MR7A rectifier valves was 12.5 volts at 25 amperes and it was necessary to keep the applied voltage at the recommended level because if it was allowed to drop, the impedance would increase, causing a larger ripple content for the smoothing choke circuit to handle. Also, there would be increased heating of the anodes.
- The high voltage for the rectifier valves was provided by three single phase transformers connected with the secondaries in two groups in star fashion with an interphase reactor between them. The function of the interphase reactor was to keep up the voltage of the falling phase and make it overlap with the incoming one thereby enabling the valves to work at a much higher efficiency.
- The primary windings of the high tension transformer were connected in delta fashion. The reason being that if one phase of the rectifiers should fail for any reason, it would still be possible to operate the other two, something that would not be possible for a star connected arrangement.

At 6WF Perth, transmissions began initially with a 600 watt (nominal 0.5 kW) transmitter pending installation of the AWA 5000 watt unit. It was one of eight similar models manufactured by AWA and comprised three major units. These were the modulator rack, the oscillatory circuit rack and rectifier rack.

The top panel of the modulator rack included meters indicating anode voltage of the modulator valves, filament voltage of sub-modulator valves and grid current of the modulator valves. The centre panel contained three Marconi type E9B modulator valves with anode voltage of 2 kV and filament of 12.5 volts at 5.1 amperes. A DC generator provided the anode voltage. The sub-modulator valves were located in front of the modulator valves. The bottom panel of the rack contained grid bias control for the modulator valves, rheostat for sub-modulator valve filaments and a switch which could cut-in a spare sub-modulator valve in the event of failure of one of the working valves.

The top panel of the oscillatory rack contained meters for indication of high tension voltage, anode current, filament voltage and closed circuit current. The centre panel housed two Marconi type E9B oscillator valves. The bottom panel contained control switches for filament supply, motor starter and high tension cut-out relay.

At sites where AC power was not available, a DC generator provided filament power for valves in the modulator and oscillator racks.

Equipment was also mounted on top of both racks. The modulator rack supported the aerial circuit inductance comprising the main winding coupling coil and variometer with wave change plugs. The oscillator rack supported the closed circuit inductances consisting of a main winding variometer and reaction coils with plugs to facilitate setting up of the transmitter on the licensed wavelength.

The installation was under the control of Sid Trim of AWA and the Technical Advisor to Westralian Farmers Ltd was Walter (Wally) Coxon.

Mechanical plant of the completed 5000 watt installation included a motor generator set for providing DC for the transmitter, a motor generator set for charging equipment accumulators and a large blower unit for removing heat from the valves and other heat producing components.

Features of the 6WF design and completed facilities included the following as noted in the Radio Inspector's Report:

- The large valves rested in specially designed anti-vibration holders to minimise movement of valve internal elements.
- The rectifier unit was housed in a panel five feet (1.5 m) square by seven feet six inches (2.2 m) high. The steel frame was enclosed with mesh steel ribbon and access doors were fitted with safety devices.
- The 7 kVA rectifier transformer, valves and filter provided an EHT DC supply with a ripple of less than 1/10th of 1%.
- The filter circuit consisted of a smoothing choke and eight 0.05 MFD capacitors.
- Six MR6 rectifier valves required a supply to provide 16 volts at 10 amperes for each valve. This was provided by a 250/18 volt step down transformer.
- The 6 kW oscillator unit was roughly the same dimensions as the rectifier unit. The front of the panel contained the control levers, switches, regulators and meters for both oscillator and rectifier units.
- A thick sheet of glass was mounted on front of the oscillator unit to allow viewing of the six MT6 type valves. These valves each required a filament supply of 16 volts at 10 amperes and an anode supply of 10000 volts DC.
- Auto transformers provided with rotary regulating switches controlled the filament transformers and the 7 kVA EHT transformer.
- Other items in the oscillator unit included grid damping resistors, grid leak resistors, grid capacitors, grid coupling tuning capacitors, grid meters, radio frequency choke and feed capacitors.
- The closed circuit inductance unit contained the closed circuit inductor which was wound with heavy stranded copper wire and mounted on porcelain insulators. A rotatable reaction coil was mounted inside the closed circuit inductor. A resonance coil was mounted on the same former as the closed circuit inductor.
- A steel frame covered with ribbon mesh of dimensions four feet square (1.2 m) by five feet (1.5 m) high contained the closed circuit air capacitor. The capacitor plates were made of thick metal sheets with rounded edges to minimise corona and flashover.
- The aerial tuning inductor was mounted inside a large enclosure and comprised the main inductor, an aerial tuning variometer and coupling coil. Both coils were mounted on formers and could be rotated at any angle within the main

inductor. Meters were provided to indicate radio frequency currents in the closed circuit and in the aerial feeder.

AWA Engineers who played leading roles in establishing the A Class stations fitted with AWA transmitters included Messrs Arthur McDonald, D Campbell and Joe Reed.

Arthur McDonald was educated at the Melbourne Technical College and worked in General Mechanical Engineering for three years before joining the Postmaster General's Department in 1910 as Junior Instrument Setter in the Engineering Branch, Sydney.

In 1911, he transferred to the Radio Section and was appointed Construction Engineer with the Coast Radio Service. When the Navy took control of the Service, shortly after the outbreak of the First World War, Arthur transferred to the Navy as Assistant Engineer for Equipment. In 1918, he was appointed Radio Engineer.

In 1920, he returned to the PMG's Department but left the Department in 1922 to work for Amalgamated Wireless (A/Asia) Ltd as Radio Engineer when AWA took on responsibility for the Coast Radio Service from the Government.

When Ernest Fisk made an extensive overseas visit in 1922, Arthur accompanied him and spent time in England, France and Germany studying the latest developments in Radio Engineering Technology, particularly broadcasting.

On return, he became heavily involved in the design, construction and commissioning of the AWA transmitters contracted to companies establishing A Class stations.

In 1930, he was appointed Assistant Manager and Chief Engineer of AWA.

At the World Radio Convention in Sydney in 1938, Arthur presented a paper '1913–1939, A Quarter Century of Radio Engineering in Australia'. At the time, he was a Member of The Institution of Radio Engineers (Aust.) and Member of The Institute of Radio Engineers (USA). Arthur was a foundation member of The Institution of Radio Engineers (Aust.) when it was established in 1932, and during 1943–45 served as its President.

In 1945, he became Assistant General Manager (Engineering) of AWA but left the company the following year to take up an appointment as Chief Engineer with the Overseas Telecommunications Commission on formation of the Commission.

Mr D Campbell began his career in wireless in 1898 in HM Navy in England and became Chief Signal Instructor at Portsmouth Signal Schools. His first sea assignment was with HMS Caesar in 1903 when the wireless equipment consisted of coherers, Leyden jars, jiggers, capacitors and magnetic detectors. He later journeyed to Australia in HMS Powerful, and in 1909 left England for Sydney where he joined the Australasian Wireless Company. Two years later, he was engaged in the construction of the Pennant Hills Coast Radio Station. When the Australasian Wireless Company was absorbed by Amalgamated Wireless (A/Asia) Ltd, he was appointed Manager of ship's installations in 1914. With the establishment of broadcasting, he became Construction Engineer for the installation of AWA transmitters for A Class stations 2FC Sydney and 3LO Melbourne. In 1924, Mr Campbell was Equipment Manager for the company.

Joe Reed became interested in wireless when he witnessed a demonstration in the Newcastle School of Arts of wireless telegraphy transmission and reception about 1910 by a local experimenter. He acquired some magazines on the subject, and with the help of local enthusiasts studied electrical and wireless theory and learnt the Morse Code.

By 1914, he had built himself a working installation and conducted a number of experiments with staff of the Newcastle Naval Depot.

In 1915, he was offered a position with the Naval Shipping Examination Service.

He later moved to Sydney, taking up a position as Wireless Telegraphist and Electrical Artificer at Sydney Coast Radio Station, and the Garden Island Station. While at Garden Island, he was Assistant to the Radio Inspector, RAN Radio Service.

About 1918, he joined the Telephone and Telegraph Department of the PMG's Department working on maintenance of equipment at the Sydney GPO until 1921, when he transferred to the Commonwealth Government Radio staff.

During his period with the Radio staff he was involved in a number of projects including radio telephone experiments between Victoria and Tasmania, CW transmissions between Melbourne and Sydney and broadcasts of radio concerts.

When Amalgamated Wireless (A/Asia) Ltd took control of the Coast Radio Service Stations in 1923, he transferred to AWA.

When AWA began the design and manufacture of broadcast transmitters he was appointed Design Engineer and played a leading role in installation and commissioning of the AWA 5000 watt transmitters at A Class stations.

In later years, he became involved in the design of Ultra High Frequency beacons. At the World Radio Convention held in Sydney in 1938 by The Institution of Radio Engineers (Australia), he presented a paper 'Ultra High Frequency Beacons' as part of a general session on Radio Navigation.

When Radio Australia Shepparton was established during the years of the Second World War, two 100 kW transmitters were provided as a joint STC/AWA effort. Joe was responsible for the AWA aspect of the project.

The original 2BL Sydney transmitter with 500 watts into the final stage, was constructed in premises occupied by Electrical Utilities Ltd at 619 George Street, Sydney. The Proprietor of the company, Cecil Stevenson who later established Commercial station 2UE was a qualified Electrical Engineer, had many years experience in experimental wireless activities and opened one of the first All-Radio Shops in Sydney. He provided valuable guidance in the design and construction of the transmitter for the small group of people, including his own staff members, who worked on the project.

One of the willing workers was Ray Allsop an employee of New System Telephones Pty Ltd who acted as a Consultant. After the station began operation, Allsop put a lot of work into improvement of the performance and reliability. He consequently joined the station as Chief Engineer, a position he held until the station was taken over by the PMG's Department as part of the Government's plan to establish the National Broadcasting Service.

One member of the construction and installation staff and later one of the Technical Operators was E Martyn-Jones. He had been interested in wireless from 1914, receiving instruction and practical experience from Frank Leverrier one of the local wireless pioneers who operated spark wireless telegraphy station XEN from his home in Waverley.

In 1925, David Wyles of AWA was appointed Chief Engineer of the transmitter to oversight upgrading of facilities and an increase in transmitter power to 1500 watts at a new site at Coogee. Transmission on the new power level took place from June 1925. A new transmitter was installed at Coogee in 1926 producing an output of 3000 watts. It operated on 353 meters but was later changed to 405 metres (740 kHz).

One of the staff who transferred to the PMG's Department when it took over responsibility for operation of the station was Tom McNeill. He had joined 2BL as a Technician in 1927, having previously worked as a Ship's Wireless Operator since 1918. He was appointed to the position of Supervisor but left the Department in 1931 to become Chief Engineer of Commercial station 2CH where he remained until 1936 before transferring to 2UW as Chief Engineer.

One early 2BL Technician who was already a member of the PMG's Department staff was Ern Crouch. Following education at Sydney Technical Schools he joined the Department in 1924 and worked on the installation and maintenance of magneto, common battery and automatic telephone exchanges and subscribers equipment. He had been interested in radio since 1920 and keenly followed the development of broadcasting in the area. In 1929, when the Department took over A Class station 2BL as part of the National Broadcasting Service he transferred to the Wireless

Branch and worked at 2BL on transmitter and studio installation and maintenance works. In 1931, he left the Department to join 2GB on design and construction activities associated with the transmitter and studio facilities. In 1935, he left 2GB to join Country Broadcasting Services Ltd where he was appointed Chief Engineer. He undertook work as a Consultant on a number of projects including the 2GZ Sydney and Orange facilities. Ern became an Associate Member of The Institution of Radio Engineers (Australia) in 1933, Member in 1944 and Senior Member in 1952.

In Melbourne, station 3AR commenced operation with a 350 watt transmitter designed and installed by Tom Court but about six months later replaced it with a 1500 watt transmitter at another site in the Melbourne suburb of Essendon. Further increases in power took place in later years.

The company had plans to provide a relay station at Ballarat and had selected a suitable site but its share of income from licence fees was so small that it did not even cover the cost of operating 3AR so the plan was shelved. People in Ballarat had to wait until 31 July 1930 before Ballarat Broadcasters Pty Ltd came to the rescue and installed a 50 watt transmitter in Sturt Street opposite the Post Office.

In Tasmania, the Associated Radio Company of Australia Ltd of Melbourne which owned 3AR held the licence for 7ZL which opened in Hobart on 17 December with a 400 watt transmitter temporarily reduced to 250 watts. The company provided programs and technical services until 3 March 1926 when the station was taken over by Tasmanian Broadcasters Pty Ltd. The company fell on hard times owing to the very small number of licences issued to Tasmanians. On 25 June 1928, it was taken over by Dominion Broadcasters Pty Ltd a Melbourne company formed on 1 March 1928 by the amalgamation of the Broadcasting Company of Australia (3LO) and the Associated Radio Company of Australia Ltd (3AR). The Tasmanian station had great difficulty in obtaining suitable people to provide good quality programs and the Postmaster General suggested that 3LO should install a short wave radio link between Melbourne and Hobart in order to relay programs to 7ZL. However, nothing came of the proposal because the Government stepped in and acquired all three stations in 1929.

The original 7ZL transmitter and studio were located in Macquarie Street, Hobart but in 1927 new transmitting facilities were provided at a site on the foot of Mount Wellington, known locally as Radio Hill, and landmarked by an advertisement for Keen's Curry by large white painted stones.

The transmitter building was constructed by Mr Walters, a builder of New Town and completed in February 1927. It was of wood construction comprising one room for the transmitter and another for associated machines with a glass partition separating the rooms.

The aerial system comprised a four wire inverted L type 92 m long including feeder and supported by two 45 metre high sectionalised wooden masts. The earth consisted of a buried copper wire grid of 2 metre squares buried about 900 mm deep.

The transmitter had originally been in service at 3AR Melbourne and installation commenced during April 1927. A number of modifications had been carried out over the years, both during its service in Melbourne and during re-installation at Hobart. These included the provision of a crystal oscillator to replace the Hartley oscillator and some valve changes. At the time of commissioning, the crystal oscillator and the first amplifier were not in service owing to problems in grinding a crystal for the approved operating frequency.

The transmitter was constructed as a number of panel units comprising a sub-modulator with a WE R211D type 50 watt valve, a modulator panel with two Marconi MT7B and two Philips MR10/1000 valves, a master oscillator panel employing a Philips TB2/1250 type valve and power amplifier panel with a Mullard silica OC 2500 watt valve. High power Heising modulation was employed with the transmitter which produced 1 kW into the aerial.

Grid bias supplies were provided by heavy duty B batteries and consisted of 135 V for the power amplifier, 45 V for sub-modulator, and 157 V and 179 V batteries for the modulator panel.

Anode voltage for the modulator was produced by a 15 HP three phase motor coupled to a 350 V 150 Hz alternator. The output of the alternator was stepped up and rectified by two Mullard Silica U4 diode valves to produce 8000 volts DC direct to the modulator and via a series of 16 filament carbon lamps of 25 CP to the power amplifier. The low power stages were powered by a 2000 volt DC generator driven by a 3 HP three phase motor. A two section filter network followed the generator to remove ripple.

The tank circuit comprised a large capacitor in a glass case about one metre cube in size, with the tank coil sitting in the glass case and tuned by an adjustable tap. This was coupled to the aerial tuning coil on the wall near the lead-out feeder to the aerial. Aerial current measured with a hot wire instrument was 13 amperes RF, with operating frequency being 590 kHz.

Studios and administration offices were located in Elizabeth Street, Hobart. Managing Director responsible for management and technical functions was Donald Macdonald who had been Consulting Engineer for 3AR Melbourne.

Donald Macdonald studied Electrical Engineering at the Melbourne Technical College 1900–1903, and following experience with a number of small businesses as Electrical Mechanic, he joined the Postmaster General's Department as an Instrument Fitter in the Melbourne Workshops in 1907. He was later promoted to Engineer in the Telephone Department at a time when there was rapid expansion of the Australian telephone network.

When John Balsille took up the position of 'Engineer for Radiotelegraphy' at the Department's Treasury Gardens Headquarters in September 1911 to take charge of the Commonwealth's wireless activities, Macdonald was appointed to the team as Wireless Engineer, taking up duty in 1912. The major function of the team was the establishment of a network of Coast Radio Stations around the Australian coast and in the New Guinea area. Nineteen stations were put into service between 1912 and 1914.

Shortly after the outbreak of the War, he became a member of the Royal Australian Navy as Lieutenant Commander (Engineer).

On 6 September 1915, the Wireless Telegraphy Act was amended and the Navy took over control of administration of the Act together with the respective staff and all the Coast Radio Stations. Commander Frank Cresswell was in charge of the RAN Radio Services, and Lieutenant Commander Macdonald was in charge of Naval Wireless in the Western Pacific area.

He continued to serve in the Navy after the War, but in 1921 left to take up a career in commercial radio at the time when experimental broadcasting was already in an advanced stage in Holland, USA and UK and the Australian Government was closely following developments.

He made an overseas trip, visiting USA and UK to study the latest technology being employed in those broadcasts.

On his return to Australia, he set up business in Melbourne in 1921 as a Consulting Radio Engineer and was contracted to oversight the design and construction of A Class stations 3AR Melbourne for Associated Radio Company of Australia Ltd, 5CL Adelaide for Central Broadcasters Ltd and 7ZL Hobart when the licence of that station was transferred to Tasmanian Broadcasters Pty Ltd. He also had involvement with the establishment in 1936 with Harry Kauper of the 2000 watt station 3LK Lubeck, a relay station for 3DB Melbourne, and also the 500 watt station 7EX Launceston commissioned on 5 February 1938 with Chris Cullinan as Chief Engineer.

In South Australia, the original 5CL transmitter and studio were located in the Grosvenor Hotel in North Terrace, Adelaide. The transmitter which went to air on 24 November 1924, comprised two equipment racks and assorted components mounted on the floor. One rack housed the four valve speech amplifier which employed a 201A Radiotron, two AP valves and a 5 watt Radiotron valve. A double pole switch on the panel allowed the use of a floor mounted loudspeaker for testing the amplifier.

Many components were front mounted resulting in both front and back of the panel carrying wiring.

The other rack contained the main transmitter with two 250 watt Marconi air cooled valves mounted on the front using clamps. Various meters and switches were also mounted on the bakelite panel. Power for the anodes of the Marconi valves was derived from a 400 watt DC generator driven by a 2 HP motor, while the filaments were powered by two separate floor mounted 12 volt accumulators. The generator normally delivered 1900 volts but controls allowed the output to be varied from 400 volts to 2000 volts if required. Transmitter input power ranged from 175 to 350 watts depending on the generator setting used.

The transmitter fed into a three wire flat top aerial with 5 metre spreaders and insulators 75 cm in length fitted with anti-corona rings. Station operating wavelength was 395 metres (760 kHz).

The transmitter was designed by Archibald Hopton of Melbourne with construction being undertaken by Ern Gunner, Don Gooding and Ted Ashwin, all of whom later became involved in the operation and construction of other stations.

Archibald Hopton began his career during the First World War when he qualified as a Radio Operator with the Royal Australian Navy. He served with the Navy from 1915 and left in 1924 to serve with 3AR as Station Engineer. He remained with 3AR until 1928 and during this period designed the original 5CL transmitter. When the Postmaster General's Department took over 3AR as part of the National Broadcasting Service, he transferred to the Department and became Supervisor of Broadcasting in Victoria until 1930. He left the Department to become Chief Engineer of 3WR Wangaratta, where he remained until 1933. His next move was to 3HS Horsham where he became Manager and Chief Engineer.

Don Gooding began his wireless training with the Royal Australian Navy in 1915, as a Radio Telegraphist. From 1921 to 1924, he served as Ship's Wireless Operator in the Merchant Marine and from 1924 to 1930, worked with Central Broadcasters Ltd, Adelaide on 5CL. Shortly after the station was taken over by the Government as part of the National Broadcasting Service in 1929, he transferred to Commercial station 5AD where he remained as Chief Engineer of the Advertiser Network 5AD-5PI-5MU until 1958 when he left to become Chief Engineer of ADS7 Adelaide.

Ted Ashwin joined 5AD shortly after it was commissioned in 1930, and later served on the technical staff of 3DB. New stations with which he was associated in the design and construction included 6KG Kalgoorlie, 1931, and 7HT Hobart, 1937.

Shortly after the AWA 5000 watt transmitter was commissioned for 5CL at Brooklyn Park on 16 September 1926, Ted Ashwin reconditioned the original low power transmitter and installed it at Brooklyn Park as a standby unit.

Harry Kauper was appointed Chief Engineer of the new 5CL facility and remained at the station until 1929 when it was taken over by the Government. He was one of the leading experimenters in South Australia in the early 1920s. Together with Fred Williamson and Lance Jones he participated in the first speech and music broadcast experiments in the State in 1922. These three experimenters were also instrumental in installing and operating 5DN, the first Commercial broadcasting station in South Australia which went to air in 1924. In 1925, Kauper developed equipment for grinding local quartz crystal to produce crystals for transmitter frequency control. In 1930 he designed the transmitter for Commercial station 5AD and for a short period was its Chief Engineer. He then transferred to Melbourne, where he was Consulting Engineer for the 3DB-3LK Network in Victoria until about 1939.

Operation and maintenance of the technical facilities by owners of the A Class stations did not follow a standard pattern. Also, the staff numbers employed by 1927 varied from 8 for 6WF to 21 for 2BL.

At 3LO, the complete technical support was provided by AWA employees under contract, while 2FC arranged for the main technical duties, particularly those associated with the transmitter to be performed by AWA employees under contract, with its own staff undertaking most of the studio maintenance and OB work.

One member of the AWA 3LO staff was Arnold Lawrence who undertook duties at the transmitter, at the studio and on outside broadcast work. He also maintained the AWA short wave station VK3ME which was on air 7 pm to 10 pm Monday to Saturday. Prior to joining 3LO, he had been employed with the AWA Marine Service as a Ship's Wireless Operator from 1919, and after six years at sea was transferred to 3LO where the company was responsible for operation of the technical facilities for the Broadcasting Company of Australia. He was later appointed Manager of 3BO Bendigo, then 2AY Albury and in 1935, installed and commissioned the 50 watt 4WK Warwick station where he remained as Manager. These three stations were all owned by AWA.

In the case of 2FC, Chief Engineer of the transmitting facilities was Eric Burbury. He joined the AWA Marine Service in 1914, shortly after formation of the company in 1913. In 1922, he went to England where he spent a period in the Marconi Works gaining experience in the latest technological developments in Radio Engineering. Following his service with 2FC, he worked at 2SM, the AWA Laboratory and in the 1930s was Engineer of the AWA Patent Department.

The other broadcasting stations 2BL, 3AR, 4QG, 5CL and 6WF employed their own technical staff using a mixture of full-time and part-time staff.

By 1927, all of the stations except 3LO were operating at a loss. In the case of 6WF, this had a major impact on the staff numbers. When 6WF started operations in 1924, it employed a Technical staff of four full-time and six part-time people but by October 1926 it had to reduce numbers to three full-time and five part-time people because of the shortage of funds. Station 4QG on the other hand which had a similar transmitter and a similar studio arrangement all on one floor, employed a staff of 14.

The operators of 7ZL were in an extremely difficult situation, and were unable to provide a service comparable with that being provided on the mainland. Factors such as sparse population, the difficulty of arranging suitable programs which was aggravated by the absence of voice telephone circuits to the mainland for relay purposes and the shortage of funds all helped to place management in a situation where continued operation was in peril. The technical equipment was below specification for a broadcasting service and had been, up to 1927, badly sited for effective coverage of the major populated areas. The owners of the station received very little revenue, and by 1927 had expended the whole of its share capital. It carried on only by the good grace of the guarantors.

The degree of public acceptance of the 6WF and 7ZL services can be gauged by the number of licences issued. In 1927, out of a total of 225000 issued Australia wide, only 3900 had been issued in Western Australia for the 6WF service, and 2460 in Tasmania for the 7ZL service.

It was in this climate, and following the Report of the Royal Commission of Wireless by Commissioners J H Hammond (Chairman), Sir James Elder, C E Crocker and A J B McMaster in July 1927 that the Government moved to take over the A Class station network throughout Australia and establish a National Broadcasting Service.

At the time the Government took over the A Class stations, the technical facilities of 2FC and 3LO were being operated and maintained under contract by staff of AWA. Owners of the other stations employed their own Technical staff but very few took up the offer to transfer to the Postmaster General's Department to continue work at the stations.

One member who had experience at three of the stations was John Ryan. Before the establishment of broadcasting stations John had been a member of the Royal Australian Navy serving on the 'Sydney' during the First World War. He was on the ship during the famous battle with the 'Emden' at Cocos Islands. In January 1924, at the time 3AR began operation he was on the Engineering staff of the station. In 1927, he went to Adelaide to work on the AWA 5000 watt 5CL transmitter which had been commissioned in September 1925 at Brooklyn Park and in 1929, moved to Hobart where he took up appointment as Chief Engineer 7ZL occupying that position until the station was taken over by PMG's Department staff. In 1932, John became Chief Engineer of 3AW Melbourne when that station was installed and went to air on 22 February 1932 for Vogue Broadcasting Co., Pty Ltd. John was still with the station in the mid 1960s.

COMMERCIAL STATIONS

One of the earliest Commercial, or 'B Class' stations as they were officially designated at the time, to begin regular service was 2BE Sydney, operated by Burgin Electric Co., Ltd, Wireless Engineers and Suppliers located in Kent Street, Sydney. The company was one of the largest trade suppliers in the State of wireless equipment, accessories and components in the early 1920s and produced a large illustrated catalogue listing details of the prices of a wide range of stock. Major stock lines included Kellogg, De Forest, Remler, and Mullard, as well as their own line of Burginphone receivers.

The Proprietor of the Burgin Electric Company was Rowley Burgin and one of his employees was Ossie Mingay — later a successful publisher of radio publications — who convinced Burgin to establish the station. Mingay was Principal of the Burgin Radio College and was the licensed Operator of the company Amateur station A2WV.

The station employed a 100 watt transmitter, operating on a wavelength of 306 metres with regular transmissions commencing on 7 November 1924.

Transmission hours were restricted, and even in 1926 — two years after it began service — it broadcast on only two days a week. On Mondays and Thursdays it provided program between 6 pm and 9 pm. Between 6 pm and 7 pm the program consisted of meal-time music comprising orchestral and vocal selections. From 7 pm to close down at 9 pm the program comprised musical selections and lecturettes.

High costs associated with running the station, and other factors at the time, resulted in the station being closed down on 2 April 1929. The callsign 2BE was later allocated to 2BE Bega in 1937.

The second Sydney B Class station to be commissioned was 2UE which went to air on 26 January 1925 with a transmitter powered with about 250 watts into the final stage and operating on 292 metres (1025 kHz). In 1998, as a result of the first station 2BE having handed in its licence in 1929, 2UE was Australia's longest serving Commercial MF broadcasting station.

The licensee was Electric Utilities Supply Co., with a Provisional Licence being granted on 7 November 1924. The company applied to use callsign 2EU adapted from the company name but at the suggestion of the Chief Inspector Wireless Jim Malone, callsign 2UE was assigned. The Proprietor was Cecil Stevenson an Electrical Engineer who had been educated at the Sydney Technical College and from about 1912 conducted an electrical contracting business with a shop selling electrical goods and appliances. The business Electric Utilities Supply Co., was located at 605 George Street, Sydney.

Cec had been following the development of wireless telegraphy technology in overseas magazines as well as being involved in the activities of the many local wireless telegraphy experimenters. Before the First World War there were more than 100 licensed experimenters in Sydney with many having top class stations.

As a major display item in the shop, Cec had a wireless telegraphy system, complete with large induction coil and coherer receiving unit. At the outbreak of the War, the equipment was placed in a large crate, sealed by Radio Inspector Bill Crawford and the crate placed in a back room for the duration of the War.

Cec and his family lived in the building on floors above the ground floor shop.

Shortly after the War, the business was relocated a few doors away to 619 George Street while the family took up residence at Maroubra. It was evident that there was a great future for wireless, particularly with the development of radio telephony during the War years, so decision was made about 1920 to concentrate the business activities on radio. The building was named Radio House and arrangements made to provide a large stock of radio components and accessories including valves, kit sets and fully assembled crystal sets and multi valve battery receivers.

He also became active as an experimenter operating experimental station 2IY with licence number 815.

With the granting of a licence to Broadcasters (Sydney) Ltd for establishment of a broadcasting station with callsign 2SB (later 2BL), he was one of a number of people with an involvement in radio to support establishment and operation of the station by contributing five pounds per week. He was Treasurer of the company and it was his duty to collect the five pounds each week from the members. The Registered Office of Broadcasters (Sydney) Ltd was located in his building and the premises also used to construct the transmitting facilities to be installed in the Guardian Building.

After 2BL went on air, he sold his interest in Broadcasters (Sydney) Ltd and turned his attention to the establishment of a B Class station as part of his business activities.

On receipt of a licence, Cec and son, Murray began the design and assembly of equipment for the establishment of the station at their Maroubra residence.

The transmitter comprised a number of audio amplification stages and large football shaped air cooled valves employed as modulator and self-excited oscillator. It fed a T type aerial supported by two 24 m high Oregon poles. Microphones used in the studio comprised locally made transverse current types using wooden cases and rubber diaphragms. A city studio was later set up in Radio House to make it easier for people to attend for a broadcast talk or performance. For many years, no income was received to assist in operational costs. The only advertisements broadcast were associated with the Radio House business.

Many major changes were made to facilities of 2UE over the years including in 1930, establishment of a new 1000 watt transmitting station at Lilli Pilli with a pair of STC 4228A water cooled valves in the final stage powered by motor generating equipment; in 1939, a new station at Concord with a shunt fed 60 m high tower; and in 1952, a state-of-the-art studio in the city.

Today, 72 years on, 2UE operates with a 5 kW Harris solid state transmitter from a site at Homebush shared with 2SM and a common 125 m omnidirectional radiator.

Son, Murray who assisted Cec with the establishment of the station became Chief Engineer of 2UE on 1 January 1931 and later a Director of the company. During 1948–49 he served as President of The Institution of Radio Engineers (Australia). When television was introduced in Australia, Murray became Chief Engineer of ATN7 Sydney.

One Cadet Engineer who received training at 2UE was Norm Sawyer who later moved into television. Norm served his Cadetship in the period 1945–56 and obtained a Diploma in Radio Engineering from the University of New South Wales becoming ASTC in 1956. He transferred to ATN for two years where he worked as Operations Engineer. In 1958, he took up a position of Engineer-in-Charge at Jacoby Mitchell & Co., Sydney and the following year, joined ADS7 Adelaide where he was appointed Assistant Engineer. In 1961, he became Chief Engineer of the station.

Norm had a long association with The Institution of Radio and Electronics Engineers, Australia becoming an Associate Member in 1957 and Member in 1963. He was a Committee Member of the Adelaide Division of the IREE and served as Chairman 1964–66 and Honorary Secretary 1968–70.

The first Commercial station to be established in country New South Wales was 2HD Newcastle licensed to Hugh Alexander

Douglas. Known as 'Harry' Douglas, he commenced operation on 27 January 1925.

Harry, an Alderman in the Newcastle City Council from 1919 to 1922 served as an Engineer on the sailing ship 'Venicia' and settled in Newcastle in 1901.

The local newspaper, 'The Newcastle Morning Herald and Miners Advocate' reported widely on the developments of wireless telegraphy by Guglielmo Marconi and others with lengthy articles appearing as early as 1903. The new technology excited many local residents, and Harry was a member of a group which met regularly and conducted experiments using equipment assembled locally.

During the years of the First World War, all experimental work was banned. Harry worked as an Engineer at Gonimans and Commonwealth Steel, Newcastle. He later established a motor car drive-in service station at corner Darby and King Streets, followed by a tyre repair and retread business at Hamilton.

Harry obtained an experimental wireless licence as soon as the PMG's Department began issuing them after the War. With his station using callsign 2XY, he was an active broadcaster on the 200 metre band together with several other local experimenters and provided programs to an increasing number of listeners in the district.

In 1923, a public lecture and demonstration of radio was held in Tyrell Hall, Newcastle under the auspices of the Workers Education Association with at least 400 people packing the Hall. A battery operated three valve receiver with Magnavox loudspeaker was set up in the Hall to receive programs transmitted by N P Olsen using his transmitter 2ZX at Waratah. The demonstration was attended by a Radio Inspector from the PMG's Department Sydney office and by all accounts, the demonstration was an outstanding success.

Harry was a member of the group organising the demonstration and was convinced that residents of Newcastle should have an approved broadcasting station. He applied for a B Class licence and was given approval for establishment of a station using callsign 2HD, with the letters being made up using the initials of his name.

After acquiring all the necessary equipment to enable transmission to commence, he set up a studio in a room above his tyre factory and installed the transmitter in a tin shed. Studio facilities included Edison disc Phonograph with metal horn type loudspeaker, a collection of Edison Diamond Disc records and the family pianola. The discs were bonded types 3/16 inch thick, 10 inch (250 mm) diameter and cut in a vertical mode with 150 grooves per inch. The discs were played to air by placing the carbon granule microphone in front of the horn loudspeaker.

The original studio was too small and it was difficult to keep out noise from passing vehicles so he transferred operations to a building at corner of Darby and King Streets. It enabled the production of improved programs including group performances.

However, the work of providing regular and interesting programs was taking up too much of Harry's time and his businesses were not receiving the attention required, so he sold 2HD. The new licensee was William W Johnston and the transfer became effective from 1 February 1928.

A new transmitter to a Philips design with low level modulation and new studio equipment were constructed by Arthur Dixon and put into service in early 1929. After completion of the work Arthur went to Brisbane to install 4BK where he was appointed Chief Engineer after commissioning of the station.

On 1 October 1930 a further change in ownership was made when Airsales Broadcasting Company Pty Ltd acquired the licence. From that time, the station took on a new role to become one of the major broadcasting stations in the State. The new company set up operations in Maitland Road, Sandgate Hill about 12 km out from Newcastle.

In mid 1931 a new studio was commissioned and the transmitter extensively upgraded. The efficiency and reliability of the transmitter were greatly improved. Six months later, further extensions were made to the building to accommodate another studio. The Architect put a lot of effort into the studio design to ensure incorporation of the latest acoustical practices for studios. The outside walls of the building was brick and the studio walls lined with sound absorbent Celotex material. The air space between outside and inside walls was filled with granulated cork imported from Portugal. No external windows were provided. The only window was a double glazed type interconnecting the studio and the technical control room. The building extension also included a new suite of administration offices.

The building was officially opened by Ernest Fisk, Managing Director AWA who provided most of the technical equipment. Ernest Fink was not present so his speech was relayed over a telephone circuit from his home in Lindfield, Sydney. One of the speakers at the ceremony was Harry Douglas the founder of the station. The designer of the building, Rufus Morris was presented with a miniature radio receiver.

The new group of buildings became a well-known district landmark with the Spanish Mission style buildings lavishingly decorated and crowned with a huge illuminated globe displaying the message '2HD Telling the World'. Located on the Maitland Road which carried a lot of traffic, floodlights and Neon signs made it prominent by day and by night.

Chief Engineer at the time was Tom Kitto assisted by Bob Oakley who later became station Chief Engineer. Other Technical staff included Harvey Heath, Syd Meakins, and F Butt.

An AWA designed transmitter put into service employed Heising type modulation. The power amplifier stage comprised two 600 watt air cooled valves providing 500 watts into the aerial. Extensive shielding was provided throughout the transmitter. Mercury vapour rectifiers were employed for the main DC power supplies. Filament current for all major valves in the transmitter was provided by a special three phase full wave mercury vapour rectifier of 100 ampere capacity.

Studio equipment included the latest RCA velocity microphones for the main studio microphones, with crystal and condenser types being available for other purposes. Pick-ups were RCA types and turntables had capability of 78 RPM and 33-1/3 RPM operation.

Two studios were available for use at the Sandgate building and one at Hunter Street, Newcastle. The Hunter Street studio was 4 m by 6 m while the Sandgate studios were, La Salle studio 9 m by 4.5 m, and Sunshine studio 3 m by 3 m.

The station had a chequered history during the years of the Second World War. On 8 January 1941, it was closed down under National Security Regulations together with three other Australian broadcasting stations. The 2HD licence was revoked on 7 February 1941. Just prior to the close down, a new transmitter building had been erected opposite the main studio building and a 65 m steel radiator erected.

At the time of the closure, 25 staff were employed by the station. The station was reopened on 15 January 1945 after being purchased by the Australian Labor Party and the Trades and Labour Council and licence granted to the new owners.

In September 1968, the brick transmitter building was demolished to permit widening of the road. The building, just off the highway opposite the studios and offices, had been erected in the late 1930s. The transmitter was relocated in a new building erected off the western side of the highway some 200 metres away.

By 1972, the station was operating on a 24 hour schedule with a 2 kW transmitter on 1140 kHz.

To cater for additional office accommodation, plans were drawn up in early 1977 to provide extensions which ultimately cost $250000. The work included the demolition of the western wing of the old brick building which had been erected in 1932, and erection of a new section comprising a steel framed structure with exposed castellated beams, and walls of premoulded panels. It enabled the modernisation and refurbishment of the broadcasting studios, record library and production department. It is believed that the building was modelled on a French perfume factory with port holes installed to match the original stained glass ones in the old building.

The new facility was built by Doran Construction and opened by Premier Neville Wran in October 1977.

The studios operational in 1998 were installed during the 1960s replacing a large studio that featured a grand piano. Two concrete floating floors isolate the studios from ground noise produced by heavy traffic in the area. This part of the building is the only part that remains of the original building.

The present 134 m high omnidirectional radiator was erected in 1983 to replace a bore casing type which survived the 1955 flood in the district but because of the height of the water, the aerial coupling box was under water, resulting in the station being off air for some time. The radiator is a sectionalised type originally manufactured by Good Engineering of South Australia. It is physically half wavelength high but has been modified by the addition of a one eighth wavelength earth stub inside the lower portion of the mast to form a radiator electrically equivalent to a five eighth wavelength anti-fading radiator.

Facilities also include a 30 m mast originally used at 2KM Kempsey and transferred to 2HD in 1976. An AWA 3J transmitter was used with the radiator as a standby facility for some time. It was later replaced by a 1 kW solid state transmitter. When SBS station 2EA began operation in Newcastle on 1584 kHz it used the top loaded standby radiator until the SBS service was established at nearby 2KO site. In 1998, the standby radiator was being used for Hospital Radio with a 100 watt transmitter on 1629 kHz.

During the 1980s, the studios, Control room and transmitter were completely rewired for AM Stereo, a 5 kW Nautel solid state transmitter cut back to 2 kW output installed and a Motorola AM Stereo exciter provided.

Following the purchase of NEWFM by 2HD Broadcasting Pty Ltd, the facilities were transferred from Darby Street to Sandgate six months later with the NEWFM service at Sandgate beginning operation on 5 November 1995. It operates on 105.3 MHz and provides 10 kW ERP.

Technical staff associated with the installation and maintenance of 2HD from establishment in 1925 until close down in 1941 included Arthur Dixon; Tom Kitto, Chief Engineer; Bob Oakley, Chief Engineer; Ambrose Armistead, Chief Engineer; C Maple; Harvey Heath; F Butt; and Robert Henry. From recommissioning in 1945, staff have included P Makin, Technician; H E Edwards, Chief Engineer; Patrick O'Sullivan, Engineer; D Rogers, Technician; Vic Shillcock, Technician; Don Edwards, Technician; Neville Young, Technical Superintendent; A Smith, Technician; G Powell, Technician; Harold Davies, Technician; Bill Irwin, Technical Superintendent; David Suffell, Chief Engineer; Scott Seddon, Technician; Leigh Rogers, Trainee Technician; Paul Suffell, Senior Technician; John Walton, Senior Technician; John Bracken, Senior Technician; and Ian Porteous, Chief Engineer since 17 February 1986.

The second Commercial station to begin transmission in country New South Wales was 2MK Bathurst which commenced service on 11 November 1925. It was owned by Mockler Bros, and at the time, had one of the largest OB networks of country broadcasting stations. Within one month of going on air, there were 35 lines available for outside broadcasts and included lines to public halls, churches, picture theatres and band stands. Microphones were USA Kellogg carbon granule types originally developed by the company for telephone purposes. One microphone was permanently located on the studio desk while two were employed for OB work. The main studio was heavily draped with hessian hung in an artistically pleasing pattern. The hessian was dyed maroon in colour. A second large studio about 22 m by 9 m was used for special occasions such as studio recitals by bands. Musical instruments included a Paling Victor Pianoplayer and a Salonola gramophone. Live broadcasts by local groups and individuals were a feature of broadcasts. The station ceased operation in February 1931.

Another station established in a small New South Wales town was 2MO Gunnedah owned and operated by Marcus Oliver.

Following successful experimental transmissions employing a 10 watt transmitter operated under a Special Licence issued by the PMG's Department, Oliver was granted a licence to establish a permanent broadcasting station. The facilities were designed and constructed by Marcus Oliver in collaboration with Donald Knock, Technical Editor of Radio Monthly and owner of experimental station VK2NO.

Test transmissions on 1320 kHz commenced on 16 January 1931 and full-scale operations commenced on 7 February. The crystal controlled oscillator was housed in a shielded box and fed an intermediate amplifier employing a neutralised Mullard 40 watt valve. The high level modulated stage employed a pair of Mullard 40 watt valves in parallel providing an unmodulated carrier current of 2.8 amperes RF into the aerial system comprising a single wire cage element suspended between wooden masts 75 feet (22.8 m) and 65 feet (19.8 m) high. A multiwire counterpoise system was suspended above ground and immediately beneath the aerial. Transmission hours were weekdays, 7.45 am to 8.45 am and 7 pm to 9 pm, and on Sunday, 7 pm to 9 pm.

By the mid 1930s, service had expanded with increased operating hours and the transmitter output from the five stage transmitter increased to 100 watts. Programs were provided from two studios. One studio was 5.5 m by 3.6 m while the main studio was 7.3 m by 4.3 m. A third studio was added a few years later.

Marcus Oliver had been involved in wireless telegraphy experiments before the First World War and after the War operated Amateur station VK2MO providing experimental broadcast programs for a number of years.

On 15 September 1936, the licence was transferred to 2MO Gunnedah Ltd with Marcus Oliver as Managing Director. However, he left the station soon after. In 1939, station Chief Engineer was E Tibbett.

In 1956, the operating company became 2MO Gunnedah Pty Ltd and still held the licence in 1993 when operating frequency was 1080 kHz and aerial power 2000 watts.

A country station on the south coast which went to air with 50 watts was 2WL at Wollongong licenced to Wollongong Broadcasting Company. The service began on 18 July 1931. It was a vintage year for broadcasting in Australia when 17 stations began transmission. The station was established by Russell Yeldon a qualified Electrical Engineer who served with the Navy during the First World War. He went to Wollongong in 1922 to work with a business installing the town lighting system. He then moved to Kiama which was also being provided with a town lighting system and worked in the capacity as Contracts Engineer.

In 1925, he established his own Electrical Engineering business in Wollongong and while there, applied to the Postmaster General's Department for a licence to establish a Commercial broadcasting station. Approval was granted in 1931 and work began on the design and construction of the technical facilities in his workshops assisted by his staff. The station located at 149 Crown Street, Wollongong provided 50 watts into the aerial at a frequency of 1435 kHz.

The venture was an immediate success, being well received by local listeners and businesses. Within 10 months of going to air, upgraded studio and transmitting facilities were established in new premises with the plant being brought into operation on 20 March 1932. An improved studio mixer was later installed.

Russell, who supervised the entire work was the station Manager, Chief Engineer and Chief Announcer. He was assisted by Assistant Engineer A R Hazelton in operation of the technical equipment.

The station was situated on a hill about 60 metres high and provided good signal coverage of the whole of Illawarra and other areas including Bowral, Mittagong, Bundanoon, Robertson and Moss Vale.

The transmitter was crystal controlled and employed high level anode modulation feeding a cage T type aerial with a counterpoise. Transmission was confirmed to 6.30 pm to 10 pm weekdays and 7 pm to 9 pm on Sundays.

In December 1936, the business became a public company with the licence being transferred to Wollongong Broadcasting Pty Ltd with Russell Yeldon as Director and Managing Director.

By the outbreak of the Second World War in 1939, the station was operating with 500 watts into the aerial with a transmitter of

American design employing high level anode modulation. The aerial was supported by two lattice steel towers at Unanderra. Chief Engineer was P Makin.

When the A Class stations 2FC, 4QG, 3LO, 5CL and 6WF began operations during 1923–25, they operated with powers of 5000 watts into the final stage. The others, 2BL, 3AR and 7ZL initially started up on low powers but later upgraded to high powers. The B Class stations were looked upon by the authorities as more or less of experimental nature as they had irregular hours of transmission, programs were generally of poor quality and the technical facilities were not much better than that in use by Amateur stations.

When the Trades and Labour Council of NSW applied for a licence to operate a B Class station, the General Manager Emil Voigt was determined to take on the A Class stations by employing high power equipment, top quality studio facilities and providing regular programs which would draw a large following of listeners.

Emil Voigt trained as a Mechanical Engineer in England and migrated to Australia to found Voigt and King, an Engineering firm in Melbourne in 1911. He returned to England to found two Engineering firms there before returning to Australia to establish the Labour Research and Information Bureau. He visited the USA during 1923–24 to study Radio Technological developments and operations, and on return, decided to establish a B Class station.

When the station 2KY went to air on 31 October 1925, it employed a transmitter designed and built by Ernest Beard, Chief Engineer of United Distributors Ltd. It provided about 1000 watts into the aerial from about 1500 watts into the final stage. It was located out of town and fed into a top loaded vertical radiator nearly 60 m high. Operating frequency was 1070 kHz.

Programs included a mixture of dance and light music, popular hits of the day, together with a range of sporting events including racing and ringside broadcasts of boxing and wrestling. They also broadcast proceedings of State Parliament and debates from the Trades Hall. The programs proved to be popular with many listeners, particularly working class people and Union members.

Initially, broadcasts took place from 3 pm to 5 pm and from 7 pm to 11 pm Monday to Saturday with no broadcasts on Sundays and Public Holidays. By 1933, broadcast hours had been extended to 6 am to 11.30 pm daily with an extension to 1 am on Saturdays.

During December 1938, the station was closed down by order of the Postmaster General when he was offended by some comments made during a broadcast. However, transmissions resumed a week later.

In that year, the station was operating with a staff of 30 working full-time manning the studios at 428 George Street, Sydney and 1000 watt transmitter at Beacons Hill, French's Forest. Chief Engineer was J H Brown assisted by H E Edwards, Arthur Carlin, Massey Harmer, Leslie Spinner, James White, Thomas Davidson and Jack Pullan.

In 1972, licensed operating body was 2KY Broadcasters Pty Ltd with a transmitter of 5 kW output operating on 1020 kHz from a site at Haslam's Creek, Lidcombe with a 149 m high omnidirectional radiator. Chief Engineer was Leslie Spinner who had been associated with the station for many years. Operating frequency was later changed to 1017 kHz.

A Nautel Model 10S solid state transmitter was installed during 1988 followed by a similar unit the following year.

Another Sydney Commercial station designed by Ernest Beard was 2GB, licensed to Theosophical Broadcasting Station Pty Ltd. It went to air on 23 August 1926. One of the installation team, Len Schultz later became Chief Engineer of the station. The station operated on 316 metres and was licensed to operate with 3000 watts input to final stage but with the type of water cooled valves selected for the transmitter it had capability for ultimate 20000 watts power input to the final stage providing 5 kW to the aerial. Low level type modulation was employed.

The main studio was located on the seventh floor of Adyar House, Bligh Street, Sydney with reception rooms and offices nearby. Adyar Hall itself was used for band items and other group performances. An auxiliary studio was provided at the Manor, Mosman for convenience of broadcasters and guests who may have had difficulty in travelling into the city.

Microphones were WE double button carbon granule types as used at most studios at the time, but a magnetic type was imported from England to enable Engineers to assess its performance with a view to eliminating a high level hiss problem with the carbon granule model.

The transmitting station was situated adjacent to the Manor, the residence of Bishop Arundale at Mosman. The aerial was a cage type 24 m high and supported by two masts 30 m apart.

Initially, carrier frequency was generated by an LC oscillator but later changed to a crystal controlled type.

The modulated amplifier produced an output of five watts and fed three high power amplifier stages before feeding the aerial. The first stage employed a 240 watt valve, the second a 480 watt valve while the final stage was fitted with a pair of 4220C water cooled valves. High tension DC for the low power stages was provided by air cooled rectifier valves while the EHT of 10000 volts for the final stage was provided by a pair of water cooled rectifiers. An elaborate water cooling and circulating system was provided for the water cooled valves and included pump, hoses, radiator, water flow alarm and a supply of distilled water. In 1938, the transmitter was replaced and transferred to 2CA Canberra.

By 1972, the licence was held by Broadcasting Station 2GB Pty Ltd, 136 Philip Street, Sydney. It was the key station in the Macquarie Network and operated on a 24 hour schedule with a 5 kW transmitter located at Homebush. The transmitter operating on 870 kHz fed a 156 m high omnidirectional radiator. Chief Engineer was R J Milne. The frequency was later changed to 873 kHz.

In early 1986, a Nautel Model 10S solid state transmitter was commissioned, followed by an identical unit the following year.

The first broadcasting station commissioned in the Australian Capital Territory was 2CA Canberra. It was designed, constructed and owned by Jack Ryan who held the licence for the station. The station began operation on 14 November 1931 with a transmitter operating on 1050 kHz and producing 50 watts into a 24 m high Marconi type aerial system located at Kingston. The transmitter comprised master oscillator, buffer, modulated amplifier and a linear amplifier. The Heising method of modulation was employed with a pair of TC 2/250 valves in parallel mode in the modulator circuit. The linear amplifier used a Philips TB2/250 valve operating with a filament voltage of 11 volts and 2000 volts on the anode. To keep harmonic distortion to a low level, a grid bias of negative 60 volts was employed. The station provided a reliable daytime signal up to about 60 km from the transmitter.

On 4 July 1932, the licence was transferred to A J Ryan Broadcasters Ltd with Jack being Director and Chief Engineer.

About 1935, facilities were upgraded with 500 watts being fed to the aerial. This was achieved by using a pair of Philips MA4/600 valves with 16 volt filaments and 4000 volts on the anodes. Maximum anode dissipation for this type of valve was 600 watts.

At that time, the studios were located at Giles Street, Kingston while the transmitter was at Symonston, midway between Canberra and Queanbeyan.

In November 1937, the business name was changed to Canberra Broadcasters Ltd and the following year, a 2000 watt water cooled transmitter which had been in service at 2GB Sydney for some years was installed at a site on Yass Road, Belconnen. The 500 watt unit was employed as a standby transmitter until about 1950.

Today, the licensee is Radio Canberra Pty Ltd and the station operates with Nautel solid state Model 10S transmitters on 1053 kHz feeding 5 kW into a 70 m high directional aerial system.

Jack Ryan, who established the station in 1931 began work in the Electrical Engineer's Branch of the Postmaster General's Department as a Mechanic in 1913. In 1918, he served in the AIF Wireless Training School, returning to the Department after the end of the War. In 1922, he took up a position as Electrical

Engineer with the Municipality of Coraki and left in 1924 to become a representative for AGE Ltd marketing Willard storage batteries. These popular batteries were manufactured in USA by The Willard Storage Battery Co., who owned and operated broadcast station WTAM.

Jack left AGE in 1928 to set up business on his own account and it was at this point that he obtained a B Class licence for establishment of a broadcasting station in Canberra, subsequently building the equipment and putting the station on air.

The first Commercial broadcasting station to commence operation in Victoria was 3WR Wangaratta. It was the first B Class (Commercial) station to commence transmission in a country area in Australia, but had a short life.

In the Radiotorial section of the popular magazine RADIO published on 26 November 1924, the Editor announced that nine new broadcasting stations were to be established in Australia, with one of these being in Wangaratta. The local newspaper, 'The Wangaratta Despatch' also announced the good news in its 24 December 1924 issue. It reported, 'An official announcement was made to the Melbourne Press recently by the Director of Wireless, Melbourne that wireless broadcasting stations were to be established in Wangaratta and Mildura and that the Wangaratta station would be operational at an early date'.

The Government granted a licence to Leslie J Hellier owner of the Wangaratta Sports Depot in Murphy Street, on 1 December 1924 for operation of a station with a maximum power of 100 watts into the final stage.

The official opening of the station took place at 8 pm on 25 February 1925 with the broadcasting equipment being located in the owner's house in Rowan Street. The transmitter and associated studio facilities were assembled by Ray Shortell who later became Chief Engineer of 3SR. It was a breadboard construction with ebonite front panel and employed two valves and a standard Post Office hand held carbon granule candlestick microphone. In line with normal practice at the time in the absence of electric pick-ups, gramophone records were played to air by placing the microphone in front of the horn of the spring wound gramophone unit. A local school teacher provided variety to programs by regular performances on a player piano. The transmitter operated with about 40 watts into the final stage and fed an aerial supported by a 22 m high wooden pole.

Les Hellier was not a technically qualified person and did not have a great deal of enthusiasm for wireless but decided to establish the station on the recommendation of Ray Shortell and others, as a business venture. He saw it as adding income to his sporting goods business by the sale of radio receivers and parts. He stocked a range of receivers particularly crystal sets and components to allow locals to assemble their own sets. He named the shop 'Helliers Radio House'.

Unfortunately income from sales of radio equipment was below expectations, and together with cost of running the station, decision was made to close the station as a public broadcasting facility. Transmission ceased on 22 December 1925. However, the equipment was left in situ as an experimental station.

A further attempt to establish a broadcasting station in the town was made on 5 January 1931 when Wangaratta Broadcasting Co., Pty Ltd, Reid Street, Wangaratta commissioned a station employing the original 3WR callsign. Leslie Hellier was appointed Managing Director of the new company.

The transmitter and studio facilities were designed by Les Glew and constructed in the workshops of Oliver J Nilsen, Melbourne. The two cubicle transmitter was crystal controlled and operated on 1260 kHz. Input power to the final stage was 250 watts providing 50 watts into the aerial which was a 30 m high cage configuration supported by two lattice steel towers on Trotmans Building in Reid Street.

The crystal oscillator stage employed a Philips E409 indirectly heated valve and fed an intermediate stage with a Philips TC04/10 valve. The next stage was a pair of TB1/50 valves in push-pull. The final stage RF valves were modulated by the Heising method using Philips MB2/200 valve type. The submodulator employed an F203 valve amplifier. The main anode power was derived from Philips mercury vapour rectifiers with filter network to reduce ripple level.

The studio equipment included Philips manufactured carbon granule microphones. Initially, the station was on air during evening periods only.

In 1932, Chief Engineer was Archie Hopton a former RAN Radio Telegraphist who had worked at 3AR Melbourne from 1924 until 1928 when it was a privately owned station and from 1928 to 1930 when it was taken over by the Government as part of the National Broadcasting Service. He began work with Wangaratta Broadcasting Co., in 1930 and assisted with the establishment of the station. He left 3WR in 1933 to join 3HS Horsham where he became Manager/Chief Engineer.

Geoff Steane took over from Archie Hopton and in addition to duties as Chief Engineer, acted as part-time Announcer. His wife was also an Announcer on the station.

In early 1934, the owners of 3WR considered relocating the station to another area for economic and technical reasons.

Following an application to the Postmaster General's Department for transfer to Shepparton, approval was granted to erect a station in Shepparton using a transmitter of 500 watt output. A new company, Goulburn Valley and North Eastern Broadcasters Pty Ltd was registered and the licence transferred to the new company on 15 January 1935.

The Shepparton transmitting site was alongside the railway line at Congupuna Road. The station site was known as 'Radioville' by those who operated the transmitter there. A residence was provided for the Engineer as well as the transmitter building. A temporary aerial supported by a pair of 150 mm square Oregon poles 30 m high and spaced 45 m apart was erected. Two studios were constructed in Lynette Building, High Street in the town.

The new facilities were commissioned on 5 September 1934 with Geoff Steane as Chief Engineer.

Not long after the station began using the new facilities, the aerial system was badly damaged by a storm. A temporary aerial was erected pending the transfer of the two steel towers previously employed in Wangaratta.

Chief Engineer Geoff Steane left the station in September 1935 to join the family business Steanes Sound Systems in Melbourne. He was replaced by Ray Shortell, with Lindsay Wright acting as Chief Engineer until Ray arrived.

Major changes took place in 1937 when two AWA 2000 watt transmitters employing Marconi CAT6 water cooled valves were employed in the final stages, were installed. The transmitters fed into an aerial supported by two steel masts 45 m high and spaced 120 m apart. New AWA studio equipment was also provided in a building at corner Fraser and Maude Streets. The official opening took place on 1 February 1937 and the station callsign changed from 3WR to 3SR.

Shortly after commissioning of 3SR, Murray Clyne began work at the station. He and Ray Shortell upgraded the equipment formerly employed by 3WR for use as a standby facility. Murray held a Diploma in Electrical Engineering and in 1948 became an Associate Member of The Institution of Radio Engineers (Australia). He had been Chief Engineer at 3UL from 1937 to 1941 and Chief Engineer and Manager from 1941 to 1948. Murray was appointed Manager of 3SR in 1948, ABS Network General Manager in 1966 and a Director in August 1970. He was an active Amateur station operator with his station VK3HZ.

With increase in transmission hours in 1937 from 6 am to midnight, Technical staff numbers were increased with Harry Fuller and Jack Burrage joining the staff. About the same time Richard (Dick) Clayton, a local boy who had just left school, joined 3SR as office boy. Shortly after his 18th birthday Dick joined the RAAF in July 1941. Following discharge in December 1944, he completed a Rehabilitation Course at RMIT and took up a position at 3UL Warragul. While there he obtained his Broadcast Operators Certificate of Proficiency on 21 December 1945. When Harold

Longman left 3SR, Dick took over as Technician-in-Charge (Chief Engineer) but resigned in 1955 to further his career in another area. Ray Jenks returned to 3SR to replace Dick.

After the War, Ray Shortell, Chief Engineer and Jack Marshall left to establish businesses on their own account. Pat Bennett replaced Ray Shortell at Congupna Road transmitter.

In 1956, a new transmitting site was established at Old Dookie Road about 12 km out of town. Two identical AWA 2000 watt BTM2 type transmitters remotely controlled from the studios were installed. The transmitter fed a 130 m high lattice steel radiator.

Keith Smith became Chief Engineer in 1968. Keith was educated at Ballarat Technical College and joined local station 3BA as Control Booth Operator in 1950. In 1956, he transferred to 3UL as Senior Technician and in 1965 became Sales Representative for 3UL. Three years later, he moved to 3SR subsequently becoming Manager of the station.

New studios were commissioned and officially opened on 20 February 1985 in premises in Wyndham Street, South Shepparton adjacent to GMV6 studios. The studios have been in service since December 1984.

In 1986, a Nautel Model 5 solid state transmitter was installed to replace the earlier valve transmitter. Technician-in-Charge was Greg Hately having taken over from Jim Ockenden who left in 1983. Other Technical staff of the 1970–80s included Doug Bell, Ross Taylor, Graeme Stevens, Don McKechnie and Ken Lomax.

The longest serving Commercial station in Melbourne still operational in 1998 is 3UZ. Oliver J Nilsen & Co., were granted a B Class licence on 6 February 1925 for the establishment of a broadcasting station and went to air on 8 March 1925. On 6 February 1934, the licence was transferred to Nilsens Broadcasting Service Pty Ltd.

The transmitter and studio were situated at 45 Bourke Street, Melbourne. The transmitter operated on 319 metres with a power less than 50 watts into the aerial although the licenced power was 100 watts. The transmitter employed crystal oscillator, intermediate stages and power amplifier. High level modulation was employed. Two 5 watt valves were employed in the oscillator and two as modulator. The transmitter was mounted on a self-supporting bakelite panel about 500 mm wide and 750 mm high. All controls and meters were mounted on the bakelite panel. Other technical facilities included a large battery operated receiver with horn loudspeaker, wavemeter, intercom telephone and several accumulators. The aerial was an L type wire cage 30 m high. Reports from listeners indicated that good reception was obtainable with a four valve receiver up to 400 km range.

The studio walls and ceiling were covered with heavyweight velvet material with the ceiling cover forming a drooped doughnut pattern with a large light in the centre. A thick carpet was laid on the floor. The studio facilities included a pianola, a gramophone and a microphone on a pedestal. A report in a technical magazine of the period stated, 'One automatically associates with the callsign 3UZ some of the best piano reproductions that Australia can boast'.

Broadcasts were conducted initially during Monday and Wednesday evenings only.

Within a few months of beginning operations, broadcasts were suspended for several months as a result of financial problems.

The station carried out its first land line broadcast in January 1926 when it broadcast proceedings of the Seventh Day Adventists' Conference at the Melbourne Show Grounds.

When 3DB began operation on 21 February 1927, it became evident to 3UZ management that their broadcasting facilities would need to be upgraded and the hours of transmission increased if they were to complete effectively with 3DB. Up to that point, the only competition was from the A Class stations 3LO and 3AR but they catered for a different class of listener.

Morris Israel was recruited to provide a more powerful transmitter and to upgrade some of the studio facilities. The new facilities were brought into operation in October 1927. The 200 watt transmitter employed a Hartley oscillator and Heising modulation system. Valve types included Philips TB2/250 and UX210 with the modulator using three TB2/250 valves in parallel. Power was provided by motor generator sets with voltage of 2000 for anodes and 14 volts for filaments. The 460 volt DC mains was also used for some anode supplies after being passed through a filter network.

Morris Israel later moved to 3GL where he installed the station. It began operation on 3 December 1930 with Morris as Chief Engineer.

By 1935, two studios were in regular use to cater for the heavy program commitments. Live studio broadcasts were a major feature of the programs of the station. During the year, 5500 hours of program were broadcast.

Under the direction of Chief Engineer Les Glew, a great many improvements had been made to the technical facilities since the station was commissioned. The most modern ideas at the time had been incorporated in program input equipment to enable a high degree of flexibility in handling incoming and outgoing relays, versatile mixing facilities and an elaborate monitoring system throughout the studios and executive offices. The 600 watt transmitter employed forced air cooling of all valves, including the power amplifier. All critical parts of the transmitter such as the Mullard modulating valve, the power amplifier etc, were duplicated in the panels and the spare parts so wired into the circuit that they could be brought into service by operation of a simple change-over switch. In addition, a complete standby transmitter of 300 watts output, together with a small studio and program facilities were located at Oliver J Nilsen & Co., workshops in Fitzroy, approximately 2 km from the main transmitter.

For many years, even up to 1938, there was little change in the Technical staff. They included Les Glew, Chief Engineer; Sydney Riches and William (Bill) Virgona.

By 1939, the number of studios had increased to five with facilities including a Neumann disc recording unit. Also additional Technical staff including L Archibold, H James and E Higgenbotham had taken up duty.

Bill Virgona became Chief Engineer in 1951, and by 1956 had upgraded studio and transmitting facilities including the commissioning of a 5 kW transmitter at Heidelberg.

In 1965, transmission hours were extended to 24 hour operation. Bill Virgona ultimately retired in 1977.

John Goodall who had joined the station in 1957, then became Chief Engineer, and in 1981 was in charge of the transfer to new studio facilities at 200 Berkeley Street, Carlton.

John left 3UZ in 1985 when the station was bought by ENT Ltd, with Vic Duffy becoming Chief Engineer until late 1986.

In June 1987, the station was bought by the Victorian Racing Industry and at that time Neil McCrae was appointed as Technical Director and Nominee for the Victorian Government on the Board.

Neil had an association with 3UZ that extended over several decades. In 1945, when he was a student at what later became known as the Royal Melbourne Institute of Technology doing Applied Science, he was given a tour of 3UZ by Bill Virgona and this inspired him to adopt Broadcast Engineering as a career.

He changed his course to Radio Engineering, and in 1947 joined what was to become the Professional Division of Philips Industries. In the 1950s and 1960s while with Philips, he designed and made several items of broadcasting equipment for 3UZ including a console for their Chadstone studio, OB amplifiers, equalisers, limiters etc, and a stereo record player using ACOS crystal pick-up to play the first stereo records that had just become available.

In a joint venture with 3XY to carry the right channel, and 3UZ transmitting the left channel, in 1958 this was believed to be the first broadcast of stereo records in Melbourne.

In 1978, Neil became a contractor to the SBS and set up and operated their 2EA and 3EA studios. Also, from 1979 to 1986, he was Technical Director of 3EON-FM and responsible for putting the station on the air in July 1980 as one of Australia's first Commercial FM stations.

On joining 3UZ in 1987, he commenced a major upgrade of the technical facilities including maintenance work on the main and standby aerial systems and the replacement of an aging AWA BTM10 transmitter by two Nautel 5 kW solid state units which operated alternately into the main 150 m high omnidirectional radiator.

An existing STC 5 kW transmitter was retained and this normally operated into the standby aerial and used during periods of lightning activity in the area, at which time the main mast was grounded for protection.

Other involvements by Neil included Consulting Engineer to the Federation of Radio Broadcasters, Chairman CCIR Sub-Committee 10 (Sound Broadcasting), a member of several Industry and Standards Association technical committees and Technical Adviser for the development of Radio for the Print Handicapped.

Station 3AK, the fourth Commercial station to begin operation in Melbourne was unusual in that it broadcast at times not normally covered by the other Metropolitan Commercial stations. The station was licenced to Akron Broadcasting Company Pty Ltd and began service on 29 November 1931 with a locally assembled transmitter at 8 Yerrin Street, Balwyn transmitting on a frequency of 1500 kHz with a single wire T type aerial system. The transmitter with 200 watt input produced 50 watts into the aerial.

The station slogan was 'Voice of the night'. In 1932, transmission hours were 5 am to 7 am and 11.30 pm to 2 am on weekdays. On Saturdays, the station was on air until 3 am.

In 1934, the licence was transferred to Melbourne Broadcasters Pty Ltd and midday sessions were introduced on Saturdays and Sundays.

Managing Director was George Palmer who acquired station 7UV Ulverstone in Tasmania about 1933. George was only 22 years old when he took over 3AK and at the time, was one of the youngest broadcast administrators in Australia controlling two Commercial stations when 7UV came under his control.

In the early 1930s, Chief Engineer of 3AK was T Lelliott who also undertook announcing duties as required.

By 1936, aerial power had been increased to 200 watts. The transmitter was a crystal controlled type capable of 100% modulation and equipped with three stages comprising crystal oscillator, buffer and Class C modulated final amplifier. Equipment used in two studios located at 480 Bourke Street included needle type pick-ups and Brush piezo crystal microphones. Each microphone was provided with a separate pre-amplifier. Microphones and pick-ups were fed through the usual mixing arrangements to the main speech amplifier of three stages employing valve types 42 in push-pull in the final stage. The output was fed via a program line to the transmitter some 11 km away at Balwyn. One studio measured 7.6 m by 6.4 m and the other 4.5 m by 3.0 m.

By 1958, a number of major changes had taken place. Studios and offices were located at 17 Grey Street, St Kilda and a 500 watt transmitter was operational at a site at Altona. Chief Engineer was A Henry.

Since its inception, the station operated on restricted hours as a condition of the licence and since 1954, the hours were limited to daytime periods only. The station shared its 1500 kHz operating frequency with 2BS Bathurst and since both stations employed omnidirectional aerials, and having regard to the distance separation of the two stations, operation of 3AK at night-time would have caused objectional mutual interference if both stations were on air at the same time.

The licensing authority subsequently agreed to a proposal that directional aerials be installed at both stations. Installation of 106 m directional aerial system were completed in October 1968 and extension of hours of operation to a continuous service was approved from 8 November 1968 for 3AK.

During 1969, the licence was transferred to General Television Corporation Pty Ltd. At that stage, studios and offices were at 22–46 Bendigo Street, Richmond and a 5 kW transmitter at Lower Plenty. Transmitter frequency was later moved slightly to become 1503 kHz. Tom O'Donohue was Chief Engineer.

Another Victorian station of interest, is 3BA Ballarat which participated in a number of 'firsts' for country stations in that State.

The station was founded by two enterprising local Amateur radio experimenters, Warne Wilson (VK3WA) and Alfred E Kerr (VK3AL). They applied for a Commercial broadcasting station licence in 1929, and a licence was granted subject to financial support being forthcoming from local business people of the city. A company, Ballarat Broadcasters Pty Ltd was registered with office at corner Armstrong and Dara Streets, Ballarat and formed on 12 June 1930.

The station was officially opened at 8.30 pm on 31 July 1930 by Jim Malone, Chief Inspector Wireless Branch representing the Postmaster General. It became the first major Commercial broadcasting station to be commissioned in country Victoria.

The station was located on the second floor of the Commonwealth Bank building on corner Sturt and Lydiard Streets. The studio equipment included locally made Reisz type microphones, double turntable for standard records, 18 inch turntable for transcription discs, piano and a large record library.

Telephone lines from outside broadcast points, the mixing panel for studio microphones, gramophone turntables, studio amplifier and splitting amplifier were arranged along the control table.

The locally constructed transmitter was contained in two cubicles and produced 50 watts carrier power on a frequency of 1300 kHz. It fed a 30 m high cage aerial. The modulator and radio frequency panels were completely AC powered. The modulator housed a 4000 volt transformer, three smoothing chokes, high voltage capacitors and mercury vapour rectifiers. The sub-modulators which comprised two 245 valves in push-pull and their attendant power equipment were located beneath the modulators which were two Philips 200 watt valves in parallel capable of fully modulating the carrier.

The bottom of the RF panel contained a 247 pentode controlled by a quartz crystal hand ground from an old quartz spectacle lens. This drove an RCA 10 watt buffer stage on the middle deck. The final stage of the power amplifier on the top deck was a Philips 75 watt valve with an input of 150 watts.

On 11 April 1936, 3BA moved its studios to 56 Lydiard Street North. Originally, they comprised Studio A of dimensions 9.5 m by 7.6 m by 4 m high and Studio B of dimensions 5.5 m by 4.5 m by 4 m high. At the same time, a 500 watt transmitter manufactured by Transmission Equipment Pty Ltd was commissioned in a new brick building at Cardigan about 7 km from Ballarat on the Adelaide Highway. The total staff numbered 10 at the time.

The new transmitter installed at Cardigan was a low level modulation type employing a 1 kW water cooled valve as the final amplifier. For frequency control, two crystals were used in a shielded and isolated constant temperature oven. Sub-modulators, modulators and modulated amplifier were all push-pull connected, and provision was made in the water cooled linear stage to add another similar valve should it be required to increase power output at a later stage. The aerial system comprised a guyed vertical steel tubular radiator 60 m high which corresponded to approximately a quarter wavelength at the operating frequency of 1320 kHz.

With the provision of the new technical facilities, some rearrangement of staffing took place. Alf Kerr was assigned to the position of Studio Engineer while Warne Wilson took charge of the new transmitting site. Bill Maher, a local lad was appointed Assistant Engineer and worked at studios and transmitter as required. Bert Scetrine later joined the Technical staff.

Just after the Second World War, water cooled transmitting valves were difficult to obtain, as well as being expensive, so decision was made to modify the transmitter to use AWA 833A type air cooled valves in lieu. At the same time, the transmitter circuitry was changed to convert to high level modulation, resulting in increase in overall efficiency and reliability, and improved frequency characteristics.

About that time, Warne Wilson left 3BA to concentrate on Public Address and Recording work. Alf Kerr was appointed Chief Engineer of both studios and transmitting station with Bert Scetrine being Senior Technician at the transmitter with Mart

Chaffer as Assistant Engineer. Keith Ridgeway who joined the staff during the War years undertook work at studios and transmitting station as well as doing much outside broadcast work. Keith later became Chief Engineer of 3BA.

On 18 February 1952, a new AWA transmitter of 1000 watts output was commissioned and 3BA became the first Victorian country broadcasting station to operate a remotely controlled transmitter. The old transmitter was overhauled and installed in the studio building basement with power generating plant for emergency purposes.

During 1955, the studio complex was modernised. New facilities were put into service on 25 July with hours of operation being extended to 118 hours per week. The opening of the new studios had special significance as it was also the occasion of the Silver Jubilee of the station.

On 26 May 1964, 3BA increased its transmitter power to 2000 watts day and night, thus substantially extending the service area. As from 1 January 1967, the station began operating on a 24 hour day schedule. It was the first provincial station in Victoria to provide continuous transmissions. In the same year, satellite studios were opened at Ararat, Maryborough and Daylesford.

A directional aerial system employing 61 m high masts was put into service on 18 August 1976. At the same time, the transmitter power was increased to 5 kW resulting in 3BA being the first Victorian country station to operate on this power level. Operating frequency was 1320 kHz but frequency was later changed to 1314 kHz.

In 1980, the station celebrated its Golden Jubilee. Chief Engineer at the time was Bob Turnbull who first began work at 3BA as a Panel Operator in 1959. He qualified as Technician three years later, and was appointed Chief Engineer in 1974.

In order to improve signal strength of 3BA in the Daylesford area, a transmitter operating in the FM band on 98.7 MHz was installed in late 1997. Maximum ERP of the service was 100 watts.

By March 1926, there were Commercial transmitters licenced in all States except Western Australia. A number of the early Commercial transmitters were units previously owned by Amateur operators. Station 5DN in Adelaide was typical. The original transmitter belonged to 5BQ, a station operated by Lance Jones, Manager of the Adelaide Radio Company. Mr Jones transferred the equipment from his residence to a building which the 5DN licensee had erected at Parkside. It employed five watt Radiotron valves, two being employed as oscillators and two as modulators. The average input power to the oscillator was 23 watts. The power supply was derived from a 200 watt Emerson motor-generator which supplied 540 watts direct current as high tension supply. It fed a five wire cage aerial suspended between two 20 m high wooden poles. The station remained operational until the late 1980s when the licence was surrendered to enable an FM licence to be taken up to operate as 102FM. The AM frequency 972 kHz, was then allocated to the Parliamentary Broadcasting Service for the Adelaide transmitter which began with the old 5DN transmitters in September 1992. The 102FM callsign later became 5AD 102 when AM station 5AD on 1323 kHz surrendered its AM licence, and the 5DN callsign was back on air again using frequency 1323 kHz.

An Amateur station in Queensland used as a Commercial broadcasting station was 4EG Toowoomba. It was the first B Class station in the State and was owned by Ted Gold using callsign 4GR licensed to Gold Radio Electric Service beginning service on Sunday evening 16 August 1925 with input of 40 watts on 294 meters (1020 kHz). The transmitter employed a modified coupled Hartley circuit with high tension being obtained from the town DC mains supply. The transmitter was replaced shortly after with one providing 250 watts input to final stage and employing MOPA configuration with the final valve being driven by one producing five watts. High tension for the new transmitter was provided by a motor generator set with the motor unit being powered from the DC mains.

The aerial was an inverted L four wire cage type 27 m long suspended 15 m above the roof of the building in Margaret Street, Toowoomba. A five wire counterpoise 27 m long and suspended 3 m above the roof, was installed beneath the radiator.

The studio was located in the same building as the transmitter with three rooms being occupied for broadcasting purposes. The studio was about 5 m by 4 m and was provided with drapes for acoustic purposes and fitted out with the best technical facilities available at the time. A second room was used as a Reception Room while the third housed transmitting equipment. The studio facilities included a Beale Player piano and an Edison Diamond Disc phonograph.

Ted had been principal of Gold Radio Supplies for some years, initially operating the business from his residence in Lindsay Street, later transferring it to Kodak Buildings. With establishment of the broadcasting facilities in Margaret Street, he moved the business to a building alongside.

Ted Gold was an Engineer of many talents. He became involved in radio as an experimenter in 1920, obtaining an Amateur licence in 1924. Prior to this, he had trained as an Electrical Fitter Mechanic in 1912 and played an active role in the technical aspects of running theatres. In 1916, he was an Operator-Electrician and in later years, designed and supervised the lighting, power and sound equipment for the Empire Theatre in Toowoomba, the largest provincial theatre in Queensland.

With his Amateur station, he was an active broadcaster on the 250 metre band and had a large following of listeners on the Darling Downs and as far as Ipswich near Brisbane.

When he constructed 4GR, licensed to Gold Radio Service, and commissioned the station, it was the second station to begin service in Queensland. The first station was A Class station 4QG which went to air only three weeks earlier.

In 1936, the transmitter then operating from a site only 200 metres from the Toowoomba Post Office, was closed down and a new station established at Drayton about 8 km from the Post Office. The new station included a 500 watt transmitter which was designed by Ted and fed into a quarter wave tubular steel radiator. The studios were situated at 380 Ruthven Street. Station Engineers at the time included Noel Bishop, Chief Engineer, A H Buzacott and Vic Le Pla.

Ted Gold also designed and constructed 4ZR Roma which went to air on 23 July 1937 with a 300 watt transmitter feeding a single wire T type aerial.

Noel Bishop began his career in broadcasting when he commenced work at 4GR in 1932 as Technician. In 1940, he transferred to 4BC Brisbane as Studio Engineer becoming Chief Engineer of the station in 1946. In 1967, he was appointed Chief Engineer of the Commonwealth Broadcasting Network. Noel was an Associate Member of The Institution of Radio and Electronics Engineers Australia.

A Hardy Buzacott began work with 4BK–AK Brisbane in 1935 as Technician, later transferring to 4GR where he remained over the period 1936 to 1948, subsequently becoming Technician-in-Charge. He took up an appointment as Manager 4ZR Roma 1948–49, and in 1951 became manager 4GY Gympie where he remained for many years.

Vic Le Pla commenced his career in broadcasting when he commenced work at 4GR in 1936. In 1938, he took up a position in the Broadcast Section of the PMG's Department in Sydney where he was engaged on a number of station installation and upgrading projects including 2CY, 2FC, 2BL, 2BH, and others. In 1955, he transferred to the ABC Television Engineering staff.

By 1972, 4GR was a Member of the Commonwealth Broadcasting Network and the Big Q Group with a 2000 watt transmitter on 860 kHz operating from Drayton. Chief Engineer was Royal Henry Hildred who had been appointed to the position in 1960 after commencing work at 4GR in 1956 as Technician.

The valve transmitters were replaced in 1985 by a pair of Nautel Model 2.5 solid state units each capable of providing 2000 watts on 864 kHz and feeding an 85 metre high omnidirectional radiator.

The original licence was granted to Gold Radio Electric Service but in 1931 was transferred to Edward Gold. On 15 February 1932, the licence was granted to Gold Radio Service Pty Ltd which is still the licensee today.

When George Exton put his station 2XN to air on 1 May 1930 following the granting of a B Class licence on 6 January 1930, part of his Amateur station VK2CZ was used to establish the station located at 173 Molesworth Street, Lismore. The transmitter provided 50 watts power to the aerial on 224 metres (1340 kHz). The mast as originally employed, was 36 m high.

The station was licensed to Extons Broadcasting Service with the licence allowing for the transmitter power to be increased to 500 watts. It was the first station to be commissioned in Australia for nearly three years after 5KA Adelaide went to air during 1927. The Depression years had a major influence on the availability of funds for establishing broadcasting stations.

The original equipment employed with 2XN was somewhat unusual for a broadcasting station. Much of it had previously been in service at the Brisbane Coast Radio Station VIB near Pinkenba which had been commissioned as a spark wireless station in 1912 using Balsille designed equipment manufactured in The Maritime Wireless Co., Ltd works under Father Shaw in Sydney.

When the Navy took control of all Coast Radio stations during the First World War and operated them until 1920, they modified the original Pinkenba installation using equipment manufactured by the Navy in Father Shaw's factory which the Navy had taken over and called the Randwick Wireless Works.

Equipment which George had acquired and incorporated in 2XN included 7 kW alternator driven by a 12.5 HP motor powered from the mains supply and three other machines fitted with special control devices. Other equipment included Amplion 50 watt speech amplifier; two 3 kW Mullard rectifier valves; a 5 kW Balsille designed EHT transformer producing 20000 volts originally used to produce the spark; modulation unit; an AWA manufactured 0.5 kW ICW transmitter originally designed for broadcasting purposes using two valve Hartley coupled oscillator with an anode power supply unit producing 8 kV at 400 Hz; oil filled chokes; tuning helix in glass case; Amplion microphones; portable telephones and an assortment of amplifiers.

Although power far in excess of requirements was produced by the installation, it was cut back to 50 watts to meet the initial licence conditions.

The station engine room was 18 feet by 10 feet (5.5 m by 3 m) and the transmitter room 24 feet by 12 feet (7.3 m by 3.6 m).

George Exton was a very busy man in running the service. He held the positions of Managing Director, General Manager, Chief Engineer and Program Manager. During 1935, the station broadcast for a total of 2184 hours.

George saw a great future for broadcasting in the area. He decided to establish a studio in the centre of the town, to erect a transmitter out of town on a site of good soil conductivity and to install a 500 watt transmitter that the licence allowed.

The old 2XN facilities were closed down during 1936 and in its place, a brand new station with a new callsign came into service. Station 2LM was commissioned on 21 September 1936. The new company was Richmond River Broadcasters Pty Ltd and employed a transmitter at Goonellabah about 8 km out of town. Operating frequency was 900 kHz. AWA provided all the technical equipment including a high fidelity studio installation and an AWA transmitter type J2221 producing 500 watts into the folded dipole aerial. The transmitter employed Class B modulation and was one of the first transmitters to employ this type of modulation. Installation was under the control of Tom McNeill. Operational Technical staff included Stan Tonkin, Pat O'Sullivan, B Aked and J Biggins.

In other cases, station Technical staff constructed more elaborate transmitters and this practice continued right up until about the outbreak of the Second World War in 1939. A typical example was 5AD Adelaide which went to air on 2 August 1930. The installation was designed by Harry Kauper, formerly Chief Engineer of 5CL until that station was taken over by the Government as part of the National Broadcasting Service. The transmitter provided 300 watts into the aerial and had a final stage employing two air cooled valves in parallel. These were later replaced by a water cooled STC 4228A type. The rectifiers used for the EHT supply used a single phase bridge scheme for the 2000 volt supply and a three phase full wave scheme for the 5000 volt supply. Rectifier valves were mercury vapour 866 types. The 5000 volt transformer was manufactured by an Adelaide electrical firm.

The number of locally built transmitters in operation was considerable, and in 1938 included 2BH, 100 watts low level Heising modulation and crystal controlled; 2BS, 100 watts Class A output with 203A valves and Class B modulation with 800 type valves in push-pull; 2DU, 200 watts with Class C output stage and high fidelity Class A modulation; 2GB, 1000 watts; 2HD, 500 watts built to Philips design using low level modulation; 2HR, 300 watts; 2KO, 500 watts; 2KY, 1000 watts; 2RG, 100 watts; 2UE, 1000 watts low level Heising modulation; 2WG, 2000 watts with Class B modulation; 3AW, 600 watts high power modulation; 3DB, 2000 watts; 3KZ, 600 watts using low level modulation and type 4228A water cooled output valve; 4GR, 500 watts; 4ZR, 100 watts high level modified Heising modulation; 5AD, 500 watts water cooled 4228A output valve; 5KA, 500 watts; 5MU, 50 watts; 5RM, 1000 watts low level modulation; 5SE, 100 watts; 6AM, 2000 watts low level modulation; 6PM, 100 watts high level modulation; 7HO, 500 watts high level Class B modulation employing push-pull circuits throughout AF and RF stages, and many others.

Commercially constructed transmitters during the 1930s were provided by a number of companies and Consulting Engineers. These included AWA (2AY, 200 watts; 2CH, 1000 watts series modulation; 2CK, 300 watts Class B modulation; 2GF, 200 watts; 2GZ, 2000 watts series modulation; 2KA, 1000 watts; 2LM, 500 watts type J2221; 2SM, 100 watts; 2UV, 750 watts high fidelity; 3BO, 500 watts; 3LK, 2000 watts low power modulation; 3SR, 2000 watts; 3XY, 600 watts high fidelity series modulation; 4AT, 500 watts; 4BC, 1000 watts; 4BK, 500 watts; 4CA, 200 watts; 4SB, 2000 watts series modulation; 4RO, 500 watts; 4TO, 200 watts; 4WK, 100 watts; 5AU, 200 watts; 6GE, 500 watts; 6PR, 500 watts water cooled linear PA; 7LA, 500 watts low power modulation); STC (2AD, 100 watts; 2MG, 100 watts; 2MW, 100 watts; 2PK, 150 watts; 4LG, 500 watts); Philips (2KM, 100 watts model KVFH; 500/116 suppressor modulation; 6IX, 500 watts; 6ML, 500 watts; 6WB, 2000 watts); Transmission Equipment (3BA, 500 watts low level modulation single ended linear; 7HT, 500 watts high level modulation with push-pull final; 7EX, 500 watts; 3CV, 500 watts high level modulation; 3SH, 50 watts high level modulation); and Colville Wireless Equipment Co., who manufactured Philips transmitters under licence (2BE, 100 watts; 2TM, 2000 watts type KVFP2/4; 3CV, 200 watts; 4AY, 500 watts type KVFH 200/2C; 4IP, 100 watts type KVFH 100/2C; and 2KM, 100 watts type KVFHP 500/11b suppressor modulated).

One of the few German manufactured Telefunken transmitters was put into operation at 2CH Sydney in 1932. The unit provided 1000 watts into the aerial and in accordance with usual construction practices of the period, the transmitter was solidly built of angle iron framework with components being shelf mounted. The top, sides and back were covered with wire mesh to allow good circulation for heat removal. The insulated front panel contained all controls and meters. Tom McNeill was station Chief Engineer at the time. The transmitter was later replaced with an AWA model with series modulation.

Consulting Engineers who provided design, manufacturing or installation services included O J Nilsen Pty Ltd (3GL, 100 watts and 3WR, 50 watts); J B Chandler & Co. (4MB, 200 watts); Ted Ashwin Transmission Equip. (7HT, 500 watts); Len Schultz (4BH, 1000 watts, 5DN and others) and Val Sydes in conjunction with Stromberg-Carlson (Aust) Ltd (7QT, 100 watts).

Leonard Schultz as Amateur, Chief Engineer and Broadcast Engineering Consultant was one Engineer who made an outstanding contribution to the advancement of Broadcast Engineering with Commercial stations. He first took up radio as a hobby while still at school and in 1920 at 14 years of age, began employment in the field. He joined the staff of United Distributors Ltd, in 1921 and the following year obtained his Amateur station licence. He was an active experimenter and was one of the first in New South Wales to contact an Amateur in Perth. During 1927, he was employed on the construction of 2KY and 2GB and later made a visit to America, England and Germany to study the latest developments in Broadcast Engineering.

On his return he was appointed Chief Engineer of 2GB in 1928 and held that position until 1961 when he was appointed Director of Technical Services, Broadcasting Associates Pty Ltd.

During his period of association with broadcast stations he undertook design, installation and upgrading of many services including 2GB, 2MW, 2CA, 4BH and 5DN. At 2GB during 1934 he supervised the construction of a new transmitter capable of transmission in line with High Fidelity Standard and during 1937–38 designed and constructed a transmitter for the station with further improvements incorporating the latest in Broadcast Engineering Technology.

Len was a member of The Institution of Radio and Electronics Engineers Australia and served as President 1955 to 1957.

Other organisations with which he was involved include Liaison Officer FACB/Asian Broadcasting Union and Past President of the Royal Flying Doctor Service. For 20 years he was an Honorary Flying Instructor of the Royal Aero Club.

In 1972, he was awarded the MBE for services to the community.

Included on the 2GB staff working under Len Schultz was Ern Crouch who joined 2GB in 1931. He had previously commenced work with the PMG's Department in 1922 and in 1929, transferred to A Class station 2BL when that station was taken over by the Department for the National Broadcasting Service together with 2FC. He left 2BL in 1931 and as part of his duties as Assistant Engineer at 2GB he was responsible for design, installation and commissioning of studio and transmitting facilities. In 1935, he resigned to take up a position of Chief Engineer for the Country Broadcasting Services Ltd with responsibility for station 2GZ.

Another Engineer who made a significant contribution to establishment of Commercial broadcasting stations was Gil Miles. Gil obtained his Amateur licence in 1922 after being a member of the Wireless Institute of Australia since 1919. In 1924, while a member of the RAAF he constructed the Service's first short wave transmitter which operated on 32 metres. In 1927, he joined Television and Radio Laboratories Pty Ltd, Melbourne and carried out experimental work in television and facsimile picture transmission techniques. During the early 1930s he became involved in the construction of a number of broadcasting stations including 3AW Melbourne in 1932 and 7HT Hobart in 1937. After commissioning of 7HT he remained as Chief Engineer until 1940. Operational staff assisting him at the time included Norm Stone, Dave Hildyard, Ern Cooper, Jim Hope, Jim Wilson, Frank Kruptsch and Arthur Burridge.

Although Amalgamated Wireless (A/Asia) Ltd was initially concerned with the design and manufacture of broadcast transmitters and studios, and in some cases provided commissioning, operating and maintenance services, it later became a major owner of, or partner in a broadcasting network.

By 1939, the Broadcasting Division of the company under Vivian Brooker had built up a network of AWA Associates comprising 2AY Albury, on air 17 December 1930 with 100 W; 2CH Sydney, on air 5 February 1932 with 1000 W; 2GF Grafton, on air 12 December 1933 with 200 W; 2GN Goulburn, on air 17 December 1931 with 200 W; 3BO Bendigo, on air 4 June 1931 with 200 W; 4CA Cairns, on air 2 May 1936 with 100 W; 4PM Port Moresby, on air 25 October 1935 with 100 W; 4TO Townsville, on air 5 October 1931 with 200 W; 4WK Warwick, on air 1 March 1935 with 100 W; 7LA Launceston, on air 13 December 1930 with 500 W. Although 2GN and 7LA were not operated under the AWA name, Sir Ernest Fisk was a Director of the Boards.

At the time the company also operated two stations in Fiji and experimental short wave broadcasting stations VK2ME Sydney, VK3ME Melbourne and VK6ME Perth until the outbreak of the War when they were closed down.

The company subsequently acquired 6KY Perth and 3MP Melbourne but in 1988 sold all its broadcasting interests except 2CH Sydney. On 3 July 1992, it added 3EE to the broadcasting arm AWA Media Pty Ltd with Joe Oost being Operations Director. However, by April 1994, AWA had sold both 3EE and 2CH.

Vivan Brooker who headed the Broadcasting Division when it was at its peak just prior to the War, joined AWA in 1917 and following a period in the company marine activities, was Manager and Chief Engineer of 7LA Launceston following commissioning of the station on 13 December 1930. He remained in that position until 1933 when he transferred to AWA headquarters York Street, Sydney to head the Broadcasting Division in July 1933.

When 3BO Bendigo was installed and commissioned by AWA on 4 June 1931, it was one of the most up-to-date country stations installed in Victoria. The building housing the transmitter and studio equipment comprised a studio, a large transmitter and control room, generator room, waiting room, office and a large verandah. The building located about 2½ km from the Bendigo Post Office was lined inside and outside with Celotex to improve acoustic characteristics.

The studio facilities included an AWA carbon type microphone, a dual turntable installation, Marconiphone pick-ups, a mixing panel, modulation level indicator, monitoring loudspeaker and speech amplifiers with gains between 75 and 80 dBm.

The transmitter provided 200 watts carrier power to the aerial and was capable of 100% modulation over a wide bandwidth. The equipment was divided into two units — a base unit and the main linear amplifier. The base unit housed the control circuits for the filament and bias generators, rectifiers for the 1000 and 3000 volt supply circuits, together with the master oscillator, buffer amplifier and modulated amplifier. The base unit produced an output of 50 watts which drove the linear amplifier to produce 200 watts for the aerial. The carrier frequency was normally generated by a crystal, but a valve oscillator was provided with switchover facilities, should the crystal fail. The modulator was a type DET3 which was driven by a push-pull audio frequency amplifier coupled to the studio input equipment. Meters were provided to indicate the main circuit conditions and provision made to give a direct indication of the modulation percentage.

The linear amplifier which was housed in a cabinet of the same size as the base unit, employed three DEM3 type valves.

Power for the filament and bias circuits of the transmitter was provided by a motor generator set producing 17 volts at 45 amps, for the filaments and 600 volts bias. Mercury vapour rectifiers produced a 1000 volt and 3000 volt DC supplies.

The aerial system comprised two tubular steel masts each 52 m high and spaced about 170 m apart. The aerial about 33 m long, was suspended between the two masts and fed by a transmission line some 100 m in length.

The first and second Commercial stations to begin operation in Brisbane also employed AWA designed and manufactured units.

The first station to be commissioned was 4BC licensed to Chandlers Broadcasting Service and owned by J B Chandler and Co. It began operation on 16 August 1930 with studios located in the radio business building of J B Chandler and Co., 45 Adelaide Street, Brisbane.

The transmitter was installed on a site at Oxley about 14 km off the Ipswich Road from the city.

Following receipt of a licence on 7 June 1930 to establish and operate a B Class station, John Chandler proprietor of J B Chandler and Co., contracted with AWA to supply temporary equipment in a bid to head off another company to become the first Commercial station on air in Brisbane. The temporary transmitter and aerial system were installed on the roof top of the Adelaide Street building pending completion of work at the Oxley site. The transmitter was a Master Oscillator Power Amplifier design with low power modulation and provided 200 watts into the aerial.

Chandler invested heavily in the broadcasting facilities to ensure a top class service. He purchased the best technical equipment available at the time and was determined to provide top quality programs. To this end, he arranged with many clubs and organisations to be their official broadcaster. They included Brisbane Repertory Theatre, Fox Movietone Club, Regent Theatre, Trocodero Dansant, Queensland Eisteddfod and many sports clubs. The station made the first major broadcast of an Aboriginal Corroboree which was relayed to interstate stations and also broadcast overseas by AWA station VK2ME. Within three months of going to air, 4BC undertook a major broadcast when it established three separate broadcast points to cover the arrival of Charles Kingsford Smith following the landing of the Southern Cross Junior after a record light aircraft solo flight from England. After arrival in the city, the famous aviator was taken to the 4BC studio where he made a broadcast which was relayed to 2UW, 3DB, 5AD and 6ML and to short wave transmitter VK2ME.

In 1933, Technical staff comprised Fred Stevens, Chief Engineer; Frank Elliott, Chief Studio Engineer; George Sutherland, Assistant Engineer; Patrick Lindsay, Assistant Studio Engineer; Robert Hare, Control Engineer; and E Little, Chief Technician.

Studios comprised Main Studio 9 m by 4.5 m, Drama Studio 4.5 m by 4.4 m and Talks Studio 3.6 m by 3.6 m. They were architecturally designed, incorporating the latest in acoustic technology, even though the design seemed simple compared with studio designs of today.

The permanent AWA 600 watt transmitter installed at Oxley site provided 500 watts into the centre fed T type cage aerial 61 m high. Operating frequency was 1145 kHz. The transmitter was the first broadcasting station in Queensland to employ crystal control of the carrier frequency. The rectifier panel had capability of providing 10 kV DC for the HT supply. Control equipment incorporated the latest in control technology. The press of a single button set in train the necessary stepping and delay functions to bring the transmitter to full power operation. This contrasted with the temporary transmitter which required the manipulation of about a dozen switches to put the transmitter to air.

By 1934, Chandler's radio business and the broadcasting station employed a total of 100 people, being one of the largest employees in the broadcasting industry in Queensland at the time. The station was a member of a group of Interstate stations known as 'The Big 5'. Others included 2UW Sydney, 3DB Melbourne, 5AD Adelaide and 6ML Perth. Station 4BC was the principal station in a group of Queensland stations comprising 4MB Maryborough, 4GR Toowoomba and 4RO Rockhampton.

The station transmitter power had been increased to 1000 watts by 1936 and greatly increased its service area.

The licence was transferred to Commonwealth Broadcasting Corporation (Qld) Pty Ltd as from 28 April 1937.

On 11 March 1938, when 4SB Kingaroy was commissioned with a 3000 watt series modulated transmitter with water cooled output valve, J B Chandler was one of the Directors of the company, and 4SB was coupled to 4BC on permanent relay.

In the same year, 4BC established new studios in the Wintergarden Theatre in Queen Street, Brisbane. Four studios were provided at the new centre and recording equipment included Presto and Neumann units. Supervising Engineer was Frank Elliott with other Technical staff including Stuart Disney Smith, John Wheller, Jack Griffin, Bill Jack and R Smith at the studios and D Dunstan and L Enticknap at the Oxley transmitter.

Noel Bishop who had been Chief Engineer at 4GR Toowoomba transferred to 4BC in 1940 as Studio Engineer. He became Chief Engineer in 1946 and appointed Chief Engineer of the Commonwealth Broadcasting Network in 1967. After Noel retired in 1980, subsequent Chief Engineers included Ron Bland, Jim Ockendon, Dave Griffen and Steve Exton who was Chief Engineer in 1998.

Studios were later shifted from the Wintergarden Theatre to CBC House, corner Wharf and Adelaide Streets.

In 1947, a new transmitting site was commissioned at Indooroopilly with a 1000 watt AWA transmitter. In 1962, the transmitter was severely damaged by a direct lightning strike early one morning. Only sufficient parts could be salvaged to put together a 500 watt transmitter.

A directional aerial system with 106 m lattice steel masts was commissioned in 1976 and a pair of Sparta 5 kW transmitters installed operating on 1116 kHz.

Since February 1988, studio operation and administration functions have been carried out at 30 Macrossan Street.

The second Brisbane station to commence operation was 4BK, licensed to Brisbane Broadcasting Co., Ltd. It began service on 29 September 1930, about six weeks after 4BC.

The company comprised Messrs Edgar V Hudson Ltd, well-known Radio Merchants and Messrs King and King, an old established Music House. A month before the station began operation from the top floor of King House, Queen Street, the local technical press in an exclusive article announced that the station had been licensed to broadcast with a 200 watt transmitter using callsign 4FO. No subsequent explanation was given as to why the callsign 4FO was not used.

The main studio was a large room specially fitted out with echo reducing perforated panels, drapes, carpets and the latest technical facilities to ensure high quality programs. The walls were panelled with 'Ten Test' a new sound absorbent material and finished in buff and cream colours with dark walnut finish on borderings. The curtains and hangings were in chocolate brown with putty lines. The main decorating feature was a bannerette in brown and gold colouring, carrying the station motto '4BK Our Best Always'.

The studio technical equipment was designed and constructed by Chief Engineer Arthur Dixon assisted by Bob Browne, a well-known Consulting Engineer with a practice in Brisbane. The microphone amplifier employed two valves coupled with Ferranti AF5 transformer, and output transformer to match the line impedance. The main speech amplifier mounted in a wooden box table type cabinet featured three meters, six faders, monitoring jacks and switches. Studio equipment included two microphones, two turntables and an Announcer's control panel.

The aerial system was mounted on the roof of the building and supported by a pole on the tank stand and a second pole fastened in steel gallows to the Elizabeth Street side of the building. The radiator was a cage type employing hoops as spacers for the wires, with the feeder dropping down to the transmitter via a porcelain lead-through insulator. The 600 watt transmitter designed and built by AWA had been originally installed at 4QG's temporary site at Executive Buildings in George Street in 1925 pending the installation of the 4QG 5000 watt transmitter on the roof of the Queensland State Insurance Building.

The company establishing 4BK purchased the transmitter from 4QG and carried out a number of modifications to the unit. The transmitter a 600 watt series modulated type comprised three separate units. The rectifier unit supplying the main high tension was fed from the 240 volt AC mains. Originally, it had been equipped with two MR6 type valves, but staff under Arthur Dixon changed it to employ four MR6 valves to increase the output to feed the larger demands of the modulator valves. All transformers, chokes, valves, meters and switches associated with the rectifying system were accommodated in the unit. The oscillator unit had inductance coils of the variometer type on top of the unit while capacitors, valves, transformers, chokes, meters and controls were mounted within the main frame. Frequency was generated by an LC circuit arrangement. Two T250 type valves absorbed an input of 600 watts. The modulator unit was similar in layout and appearance to the oscillator unit with aerial tuning inductance being superimposed on the main frame. In the original factory design, six T250 type valves were used as the series modulating bank but these were replaced by two Mullard MC5 types, each producing 750 watts. Tests showed the new arrangement gave vastly improved modulation depth and reduced distortion. As installed, the transmitter provided 200 watts into the aerial on 1290 kHz.

The transmitter was later transferred to 4AK Oakey, a relay station of 4BK as a standby unit. In 1994, it was housed in a museum in Oakey. In mid 1934, the company became a public company with licence being transferred to Brisbane Broadcasting Co., Pty Ltd. About this time plans were developed to relocate the station to the business address site of the owners. About 1936, new facilities were commissioned in the new Courier Mail Building, Queen Street, where an AWA 600 watt series modulated transmitter type J2728 was installed to feed an aerial system installed on the roof of the building using lattice steel tower and counterpoise system. Three studios were provided and equipped with AWA equipment including AWA manufactured disc recording facilities.

Arthur Dixon the station Chief Engineer, came to Australia from England in 1912 and worked in the Drafting Office of Metropolitan Water and Sewerage Board, Brisbane before joining Toowoomba Foundry Co., Ltd in 1913. He later moved to Sydney and began work with AWA in 1914 as a Ship's Wireless Operator performing sea going duties for some 8½ years. He then spent a period as Instructor at the Marconi School of Wireless.

After a time in the School, he left AWA to take up a position as Manager of Burndept (Aust) Ltd followed by Manager of A Beal Pritchett (Aust) Ltd and Engineer with Mullard Valve Co., and Ferranti Ltd, both English companies in Australia. While with Mullard and Ferranti, he operated experimental broadcast station 2AD. In early 1930, he constructed and commissioned the 500 watt station 2HD Newcastle and following completion of this work, took up appointment as Chief Engineer of 4BK.

Another of the AWA Queensland installations of interest in 1930s was 4SB Kingaroy operated by South Burnett Broadcasting Co., Ltd with the transmitter located at Wooroolin and coupled to 4BC Brisbane as a relay service. The station comprised a 3 kW series modulated transmitter employing CAT water cooled valves and was commissioned on 11 March 1938, transmitting on its licensed power of 2 kW into a folded back T type aerial supported by two 67 m high masts.

The transmitter was the only one of its design in country Queensland at the time and 4SB together with 4AK Oakey on the Darling Downs were the only Commercial transmitters operating on a radiated power of 2 kW. In fact, there were only five throughout Australia operated on this power level by Commercial station operators at the time.

Chief Engineer of 4SB was Norman Cruickshank with Bernard Harte being Technician/Announcer who served in this position 1938 to 1940. Bernard had previously been a Technician at 4BH Brisbane 1935–38. Following a period of 5½ years War service with the RAAF, he resumed duty with 4SB serving as Station Engineer 1946–48. He then transferred to 2UW Sydney as Technician until 1950 when he was appointed Engineer/Manager 2KM 1950–66. In September 1966 he became General Manager/Director of 2KA/2KM.

Another type of AWA transmitter installed in the late 1930s was the 500 W unit installed at 4AT Atherton in 1938 and commissioned early 1939. It was a type J4825 and operated on 680 kHz. It employed anode modulation of the modulated amplifier. The RF chain employed valve types 42 oscillator, 807 oscillator amplifier, 807 RF amplifier, 805 buffer, and four 805 valves in parallel push-pull for the modulated amplifier. In the audio chain which employed push-pull throughout, valve types were 6A6 first audio, two 6A6 in parallel push-pull second audio, four 2A3 parallel push-pull submodulator and four 805 in parallel push-pull for the modulator. Six 866A mercury vapour rectifiers provided 1250 volts for EHT.

One of the original Directors of 4AT was Edward Dahl, who also occupied the position of Secretary of the company licensed to operate the station, Atherton Tablelands Broadcasters. At the same time, he was General Manager and Secretary of 4AY Ayr licensed to Ayr Broadcasting Pty Ltd. He served an apprenticeship with F J Walker Ltd, as Fitter and Turner and later attended Sydney University where he graduated with a Degree in Mechanical and Electrical Engineering. He possessed a Commercial Broadcast Operators Certificate and joined 4AY in February 1938 and 4AT in February 1939.

Western Australia was the last of the mainland States to have a B Class station service. It was not until 19 March 1930 after Westralian Farmers Ltd, had ceased to exist and transferred its 6WF A Class station to the Government that B Class station 6ML was commissioned by Musgroves Ltd. A further eighteen months elapsed before 6KG, a Kalgoorlie station went to air and a second metropolitan station 6PR owned by Nicholsons Ltd, began service. When 6BY opened at Bunbury on 16 April 1933, the Western Australian people considered they had a reasonable service, but unfortunately the Bunbury station had to close down on 31 July 1935.

Station 6ML was licensed on 2 December 1929 and began operation on 19 March of the following year with an aerial power of 300 watts on 1135 kHz. Both studios and transmitter were located at Lyric House, Murray Street, Perth. Chief Engineer was Harry Simmons, a former Ship's Wireless Operator. The station power was later increased to 500 watts in accordance with its licensed power. The transmitter was a Philips design and fed into a T type aerial. Three studios catered for the needs of the station's operations. The station ceased operation on 30 May 1943 mainly as a result of the shortage of Technical and Announcing staff during the War.

The Kalgoorlie station 6KG operated by Goldfields Broadcasters Ltd, began service on 16 September 1931 with 100 watts aerial power on 1220 kHz. The STC built transmitter was located at Parkeston with the studios being in Kalgoorlie. The Station Manager and Chief Engineer was Norman Simmons, previously Engineer at 7ZL. The power of the high level modulated transmitter was later increased to produce 500 watts into the Marconi quarterwave aerial. The transmitter was installed by STC Engineer Bert Wood.

Another Manager of 6KG who had a Technical background was Henry Taylor. He was an early Amateur station operator and in 1935 founded the Goldfields Radio Society. From 1937 to 1947, he was Technical Advisor on radio communications to the Royal Flying Doctor Service in Western Australia. He was associated with the design of four broadcasting stations in Western Australia and from 1947 became Chief Engineer of Whitford's Broadcasting Network comprising 6PM Perth, 6AM Northam, 6GE Geraldton and 6KG Kalgoorlie.

Nicholson's station 6PR, began transmission on 880 kHz on 14 October 1931 with 200 watts into the aerial. Within a few months, the power was raised to 500 watts from the transmitter at Applecross Radio Centre. The studios were located at Barrack Street, Perth and comprised an Announcer's studio 10 m by 9 m and a Concert Hall 26 m by 16 m. The equipment was designed, installed and maintained by AWA. Sid Trim of AWA, who installed the station remained as its Chief Engineer. The transmitter was housed in four separately and fully enclosed cabinets. It operated with a Class B modulator with a final linear water cooled stage. The cage aerial was an inverted L type. Two studios were provided and facilities included Marguerite 3 speed recording equipment made in England for acetates or pressings.

The 6BY station began service on 16 April 1933 and was situated in the heart of Bunbury in what was known as Bedford Hall, a specious brick building. The studio, transmitter and offices occupied the rear half of the building, leaving a large hall for community singing, dancing etc The quartz crystal controlled transmitter was the first broadcast transmitter to be fully designed and constructed in Western Australia. The aerial was supported by two 27 m high steel lattice towers, situated in grounds adjoining the studio. Chief Engineer was Clarence Sirl who had previously worked at 3TR, 5KA and 6ML.

In the early 1930s, Northam Broadcasters Ltd commissioned Walter Coxon formerly Chief Engineer/Manager of A Class station 6WF Perth to design and construct a broadcasting station to cover the Northam area. The station 6AM went to air on 1 June 1934 with 1000 watts and operating frequency 980 kHz, about 6 km west of the Northam Post Office. Programs were provided from studios located at Princess Chambers, 23 William Street, Perth with a small emergency studio being provided at the transmitter.

On 1 April 1937, the licence was transferred to 6AM Broadcasters Ltd and about this time, facilities were expanded, and comprised a two studio and office complex at St Georges House, St Georges Terrace, Perth and a 2000 watt transmitter employing low level type modulation. The transmitter fed a quarter wave Marconi aerial. The transmitter was constructed by station staff comprising F Tredrea, Chief Engineer A L Read and Ralph Henwood. The studio equipment was manufactured by Colville Wireless Equipment Co., Pty Ltd of Smail Street, Sydney.

In 1948, the company became a public company and the licence transferred to 6AM Broadcasters Pty Ltd. The station was a member of Whitford's Broadcasting Network with the other stations being 6PM Perth, 6GE Geraldton and 6KG Kalgoorlie.

One man who played a major role in the expansion of broadcasting in Western Australia was Fred Kingston. Fred came to Australia from England and at the outbreak of the First World War joined the AIF Signals unit. After discharge from the army, he entered the music trade, a career he had been following before joining the AIF. In 1923, he joined with Mr D O Musgrove and others to form Musgroves Ltd, a Perth music warehouse business. In 1929, he became associated with the distribution of radio products in Perth. Major products included Stromberg-Carlson receivers and components, and Magnavox loudspeakers.

Fred was keen to see the establishment of a B Class station in Perth and was a driving force in the formation of WA Broadcasters Ltd who were given a licence for the establishment of a station, 6ML in Perth. He was a Director of the company and because of the popularity of the station he was keen to see a second Perth B Class station put into operation. Popular programs of 6ML included broadcasts of ringside wrestling and boxing and the 1930 Cricket Tests.

WA Broadcasters Ltd established a second station, with callsign 6IX on 27 November 1933 and Fred was a Director of the station. Studios for both 6ML and 6IX were located in Lyric House, Murray Street, Perth. The 500 watt 6ML transmitter was located at Lyric House but the 6IX 500 watt transmitter was installed at Newspaper House, St Georges Terrace. Harry Simmons was Chief Engineer for both stations.

Besides being a Director of 6ML and 6IX, Fred was in control of the Radio, Record and Phonograph Departments of Musgroves Ltd.

The Commercial station AM network in Western Australia expanded considerably over the years and by 1995 there were 19 metropolitan and country stations in operation, although in 1986 there were 21 stations.

In Tasmania, although the population was small compared with mainland States, some business people saw potential in Commercial broadcasting.

Messrs Findlays Pty Ltd, Tasmania's leading music warehouse for some 50 years, and retailers of radio receivers soon after commissioning of A Class station 7ZL Hobart in 1924, commissioned 7HO Hobart on 13 August 1930, although preliminary testing had began much earlier. The station was licensed to Commercial Broadcasters Pty Ltd and was located in the building owned by Findlay Bros Pty Ltd, 80–82 Elizabeth Street, Hobart. Operating frequency was 890 kHz and power into the L Type aerial mounted on top of the building was 50 watts. Chief Engineer was Ron Hope who designed and built the station. Bill Nicholas was Junior Technician.

The service soon became popular with the increasing number of local listeners as the company was able to provide high quality programs using the extensive resources of the owner's musical business. The company also enlarged its Radio Department, and by 1933 was Tasmanian distributors for a wide range of receivers made on the mainland. These included Stromberg-Carlson, Audiola and Radiola models.

In 1937, the 7HO transmitter was replaced by a 500 watt unit designed and constructed by Bill Nicholas and installed on a site at Mt Nelson. The installation comprised four self-contained cubicles. It employed high level modulation using Philips TL250 valves. After the War, an AWA 2 kW transmitter was installed followed by an AWA hybrid solid state/valve model and later by a Harris 3 kW solid state transmitter. In more recent times, the station changed to the FM band employing a transmitter located on Mt Wellington.

One of the Assistant Engineers at 7HO in the mid 1930s was John Dodds who previous to joining the station had been with United Distributors Ltd and Service Engineer with Findlay Bros Pty Ltd, Elizabeth Street, Hobart. Findlays were Tasmanian distributors of Stromberg-Carlson, Audiola and Radiola receivers. He was later associated with the Commonwealth Electronics Pty Ltd facility at Derwent Park, near Hobart producing high quality turntables for broadcast studios.

Although Launceston was the second largest town in Tasmania influential business people could not convince the authorities that an A Class or B Class station should be established to serve northern Tasmania from studios in Launceston. The residents had a long wait before a local station became a reality. However, there were a number of radio Experimenters who provided local residents with receivers with some entertaining programs. Active Experiments in 1926 included OA7AB, A C Smith; OA7AS, A S Gill; OA7BC, N Cave; OA7BH, E C Sheldrick; OA7BQ, J A Crooks; OA7CS, A C Scott; OA7LA, O A Hope; OA7PF, P O Fysh; OA7WI operated by the Tasmanian Division of the Wireless Institute of Australia and OA7BN, licensed to Tasmanian Radio Company. Station OA7BN was located in Findlay's Building, Launceston and carried out regular transmissions until 7LA began operation as a B Class station.

Findlay Bros, in collaboration with Wills and Co., Pty Ltd, a major Launceston firm, established a station four months after 7HO, in Launceston. The station with callsign 7LA and licensed to Findlay and Wills Broadcasters Pty Ltd went to air on 13 December 1930 using an all-AWA installation with a 300 watt transmitter feeding a flat top T type aerial on a high site overlooking the Tamar River. The studio was located in Findlays Building in Brisbane Street, Launceston. The studio was very large, and employed the latest in studio technical equipment with amplifiers providing gains of 75 to 80 dB. A lot of thought was given to providing the best acoustic properties of the studio room using a combination of Celotex and drapings. Chief Engineer was Val Sydes who was subsequently succeeded by Rex McLean. Rex started work at 7LA in 1937 and retired in 1985.

About 1987, a Nautel Model 10S solid state transmitter was installed to replace the valve transmitter and the licensed transmitter power increased to 5 kW. The transmitter fed a 120 m high directional aerial system which replaced a 55 m omnidirectional radiator.

In 1993, the old 7LA transmitter which had been located at a site on the West Tamar Highway and used until the 1960s had to be removed from the transmitter building after standing idle for some 30 years to enable the building to be demolished to make way for a new highway. The transmitter was donated to the Queen Victoria Museum and Art Gallery for restoration by the Curator of Physical Sciences Martin George. The transmitter had been originally installed at Prospect in 1937 by Rex McLean and other staff, and moved to the West Tamar site in the 1950s as a standby unit. It carried out this function until the 1960s. The current transmitting facilities are located at Rocherlea.

During 1997, 7LA upgraded its production studio facilities by installing a Spectral audio production system supplied by Australian Audio Supplies. The system comprises a 16 track PC based work station featuring multitrack hard disk recording and editing, networking digital signal processing and many other functions.

In 1998, an AVC Duet BM200 was installed at 7LA by Frank Wilcox from Perfectly Frank. He modified the console to allow telephone interviews to be recorded offline while normal programs were being broadcast.

So popular were the two Commercial stations 7HO and 7LA that within three years of them beginning transmissions the number of listener's licences in Tasmania more than doubled from about 6000 to about 12500. It took five years for the number to reach 6000 when only A Class station 7ZL operated in Hobart.

A second Hobart station was commissioned on 19 April 1937 when 7HT licensed to Metropolitan Broadcasters Pty Ltd went to air with studio in Murray Street, Hobart and a transmitter made by Transmission Equipment Pty Ltd, located on Rosny Hill. Chief Engineer was Gill Miles who was assisted by Norm Stone on the installation and operation.

The Murray Street studio situated in Cleburn House contained equipment provided by Ashwin Transmission Co., Ltd, Melbourne and included rack mounted patch panels, line amplifier, studio amplifiers, monitoring amplifiers, equaliser panel, attenuator, and power units. Microphones comprised an RCA Model 44B ribbon microphone with built-in coupling transformer and a GE dynamic microphone. Turntables comprised Garrard 78 RPM type and a 33⅓ RPM Green Flyer for transcription records. The studio was linked to the transmitter on Rosny Hill by PMG's Department circuit via submarine cable across the Derwent River.

The transmitter licensed for 500 watt output was manufactured in Melbourne by Transmission Equipment Pty Ltd and supplied and installed by Ashwin Transmission Co., Ltd. Ted Ashwin had been associated with the first 5CL Adelaide transmitter in 1924.

The transmitter fed a quarter wave radiator supported by a pair of 40 m high wooden guyed masts. Transmission line was a balanced open wire 600 ohm type. Operating frequency was 1080 kHz.

In 1940, Gil Miles left and Bill Nicholas from 7HT became Chief Engineer. About that time, the studios were transferred to McCann's Building, Melville Street. Other Technical staff at the time included Norm Stone, E Cooper, Dave Hildyard and J Wilson. Bill Nicholas left in 1957 to form Commonwealth Electronics Branch in Hobart and Bruce Klein became Chief Engineer. Bruce had began work in New South Wales with the PMG's Department as Technician in 1942 becoming Senior Technician in 1950. He joined 7HT in 1953 and was appointed Chief Engineer when Bill Nicholas left. He later became Assistant Manager, Technical.

A new transmitting station was installed at Droughty Point with an AWA 2 kW transmitter on site and an emergency unit in the studios. The emergency transmitter received more than its fair share of work and a new transmitting site was established at Sandford.

On 25 May 1998, the then licensee Tasradio Pty Ltd closed down 7HT when it transferred to the FM band. The new service on 107.3 MHz began operation on 27 April 1998. The MF and FM services ran parallel transmissions for one month.

By the outbreak of the Second World War, Tasmania was well served with Commercial broadcasting stations. In addition to 7HO, 7LA and 7HT others were 7UV Ulverstone (later 7AD Devonport) on 6 August 1932; 7BU Burnie on 19 October 1935; 7QT Queenstown on 29 May 1937; 7DY Derby (later 7SD Scottsdale) on 26 February 1938 and 7EX Launceston on 5 February 1938.

The years of the Second World War saw very little increase in the number of Commercial stations in Australia. Only five stations were commissioned during the period of the War. They were 3CS Colac on 7 October 1939; 6TZ Bunbury on 11 October 1939; 6MD Merredin on 5 July 1941; 6KY Perth on 23 October 1941; and 4GY Gympie on 3 November 1941. No more Commercial stations were put to air until May 1947 when 4KQ in Brisbane began operation.

The first of the wartime stations was commissioned by Colac Broadcasting Co., Pty Ltd on 7 October 1939, employing a 200 watt transmitter operating on 1130 kHz. The station provided wide coverage of the surrounding rural area and the coast from Geelong to Warrnambool.

The licence for operating the station was obtained by Mr M B Duffy who formed a company with Messrs Sellwood, Mayor of Colac; Williams; Anderson and Wallace. Mr Wallace owned a block of land in Murray Street on which he built the studio and office and rented the building to the company. The building comprised a talks studio, a large auditorium with attached kitchen and a control room which housed the transmitter and the program input equipment.

The original staff comprised one male Announcer, one female Announcer, one Announcer/Technician and Chief Engineer. The Announcer/Technician split his time between the two jobs of program and technical work.

The studio equipment comprised one operating table with control panel, two Garrard turntables and two microphones. The control panel comprised a four channel mixer with operational controls, a motor, keys and jacks. The Garrard turntables were later replaced with Byer models.

The transmitter was constructed by Transmission Equipment Pty Ltd, Melbourne and employed modified Heising modulation with Class B modulators. The studio facilities and program input equipment were locally assembled by Chief Engineer Roy Streeter with components and equipment made available from station 3KZ. The Chief Engineer of 3KZ, 'Snow' Grace acted as a Consultant during the design and commissioning of the facilities.

The aerial was 72 m high but the earth mat was restricted in size because of the small area of the site. About six months after the transmitter went on air, the structure collapsed during guy tensioning operations. A temporary facility was erected to maintain transmissions. The new radiator was shorter than the original owing to the difficulty of obtaining steel structures during the War years. The new aerial was 57 m high and fed by a 75 ohm buried coaxial feeder.

In November 1952, a new transmitting facility was installed at a site of Cororooke Road, West Colac. The transmitter was an AWA model employing 833 type valves and capable of 2000 watt output but was cut back to 1000 watts to meet licensing conditions. It was provided with remote control facilities and controlled from the studios. Operating frequency was 1000 kHz. The original transmitter was retained at the studios with makeshift aerial for emergency purposes.

During the transfer, a temporary aerial was erected while the main aerial was being dismantled and re-erected at the new site. A large earth mat was provided, with 100 copper radial wires being placed in the ground. This resulted in considerable signal improvement in the service area.

Chief Engineer of 3CS from commissioning in 1939 until 1957 was Roy Streeter. As a 16 year old with a keen interest in radio, Roy enrolled at the Melbourne Technical College in 1933 and in 1936 obtained a Diploma in Radio Engineering. He attended the classes during the evenings and during the daytime worked at 3KZ under Chief Engineer 'Snow' Grace as a Junior Technical Assistant, mainly on outside broadcast work. Roy obtained a Broadcast Operators Certificate in 1936 and continued at 3KZ until 1938 when he joined 3CS as its Chief Engineer undertaking the installation and commissioning of the transmitter and the studio and program input equipment.

In 1941, Roy joined the Royal Australian Air Force as Radar Mechanic working on Catalina aircraft. He was discharged in 1946 and returned to 3CS where he remained until 1957 when he joined the Postmaster General's Department working on radio telephone equipment in Victoria and later on television at Mt Burr in South Australia, before retiring in 1982.

Chris Cullinan became Chief Engineer of 3CS when Roy left. During 1960, the radiated power was increased to 2 kW during daylight hours but remained at 1 kW during night-time transmissions. Further changes took place in August 1963 when a directional aerial system was installed using 73 m high structures allowing 2 kW power to be maintained throughout the day and night-time transmissions. In December 1977, the transmitter power was increased to 5 kW using an operating frequency of 1134 kHz.

For many years 2000 watts was the maximum authorised power allowed for Commercial broadcast transmitters in Australia. By the end of 1938, there were five in New South Wales ,and Australian Capital Territory (2GZ Orange, 2CA Canberra, 2WG Wagga, 2NZ Inverell and 2TM Tamworth); two in Victoria (3LK Lubeck and 3SR Shepparton); two in Queensland (4SB Kingaroy and 4AK Oakey); one in South Australia (5PI Crystal Brook); two in Western Australia (6AM Northam and 6WB Katanning) and none in Tasmania.

After the War, the authorities were more liberal in granting approval for powers up to 2 kW. Many station Engineers were hopeful of seeing the day when the power would be extended to 5 kW and built their transmitters accordingly so that it would be a simple matter to upgrade to this power at short notice. They were, of course, disappointed and their transmitters ran at low efficiency for years until replaced. However, in more recent years, selected stations were given approval to operate at 5 kW and together with the introduction of directional aerials and 24 hour operation. Commercial broadcast stations now provide a service which provides good continuous signal strength over a specified area with minimum interference from other stations during night-time periods. In mid 1994, there were 59 Commercial transmitters licensed for 5 kW operation.

Transmitters operating at 5 kW today comprise a pair of 2.5 kW models with combined output, a pair of 5 kW operating in main and standby mode or a single 5 kW unit. Like their counterparts in the 1930s, some Engineers with an eye to the future have installed 10 kW transmitters cut back to 5 kW.

Typical of twin 2.5 kW transmitters installed in the 1960s before the solid state era was the STC 4SU-55A/S model. It could be operated as a main/standby configuration or operated with an STC combiner type 792SU-3B to produce close to 5 kW to line. The valve types used with these transmitters comprised 807 oscillator, 807 buffer, QB3/300 driver and 3X2500F3 modulated amplifier in the RF chain. In the audio chain which employed push-pull throughout, valve types were EF37A first audio, 807 second audio, 807 driver and 4/1000A modulator. All high tension supply units were fitted with silicon diode rectifiers.

With the exception of one or two transmitters imported from overseas, local manufacturers fully supplied the Australian need for broadcast transmitters for about 50 years. However, with a few exceptions, manufacture in Australia of MF and HF broadcast transmitters has virtually come to a stand-still and most new requirements are being brought in from overseas sources.

In early 1991, there were 144 Commercial AM stations serving the Australian listening public. Additionally, there were 11 Public AM broadcasting stations in operation. However, there has been a reduction in the number of Commercial AM stations due to some broadcasters transferring operations to the FM band.

According to figures published by the Australian Broadcasting Authority as at 20 March 1997, the number of Commercial AM stations totalled 217 with 21 stations being located in capital cities. Stations operating in the FM band numbered 107 with 21 being in capital cities. At the same time, Community (previously Public) stations numbered 210 comprising 15 AM and 195 FM stations. The FM licence total included former BRACS (Broadcasting for Remote Aboriginal Communities Scheme) services now categorised as Community.

In 1997, the largest Commercial radio network in Australia was Sky Radio which distributed programs to some 140 Commercial stations. Facilities included a digital audio satellite distribution system manufactured by International Datacasting Corporation and supplied by Comsyst. The service was uplinked via Optus satellite after being transmitted to the Nine Network from Sky Radio operational centre in a Sydney suburb employing a 2 Mbit digital microwave link.

In the development of Commercial Broadcast Engineering in Australia, many Engineers involved in the design, construction and maintenance made major contributions to the technology. Chief Engineers often found it difficult to obtain adequate funding to provide or maintain the technical facilities to acceptable standards and reliability, and innovation became an important factor. In Museums and private vintage radio collections today, there are excellent examples of equipment and components which station Engineering staff made with the limited resources available to them. However, from photographs in existence of studio and Artist waiting room furnishings, it is evident that many Managers were able to find funds to provide expensive drapes, carpets and seating, even during the years of the Depression when business thought twice about advertising on the radio. At several stations, the Manager was also the Chief Engineer and he was able to ensure an equitable distribution of the small budget between the demands of Administrative, Announcing, Record Library and Engineering groups.

Skilled Chief Engineers were difficult to find, particularly during the Golden Decade of the 1930s when an average of about nine new Commercial stations were commissioned every year. This meant considerable movement in the Technical staff between stations. Some held the position of Chief Engineer for more than one station, particularly where a Network was involved such as 5AD, 5PI and 5MU, while there were also instances where the station technical facilities were operated and maintained by staff of an outside organisation such as AWA.

The first broadcasting station to go to 24 hour operation was Commercial station 2UW Sydney. The station originally established by music house W H Paling and Co., Ltd was purchased in 1933 by the Australian Broadcasting Company Ltd which from 1930 to 1932 provided programs for the Government's National Broadcasting Service stations. Prior to switching to 24 hour operation, the station operated from 7 am to midnight. Technical staff comprised Harry Kauper, Consulting Engineer; H Marshall, Chief Engineer; Roy Allen; H Buzacott and N Bonnington. When the 750 watt transmitter was on air continuously without shut down from 22 February 1935, the Technical staff was increased by two.

There was no mad rush for other broadcasters to follow suit. By 1956, 21 years after 2UW began continuous transmission, stations 2KO, 3XY, 4BC and 5KA were also on 24 hour operating schedules.

Accurate station staff records are not readily available today for any particular date or period, but near the end of the 1930 decade ,just as the Second World War started, records indicate that the following Chief Engineers were in charge at various Commercial stations: Ambrose Armistead, 4AT; Robert Beatson, 4MB; Noel Bishop, 4GR; H W Brown, 2BH; J H Brown, 2KY; N Buzacott, 3LK; Lloyd Chappell, 7QT; G Chisholm, 4VL; Murray Clyne, 3UL; T C Croke, 2BS; Eric Crouch, 2GZ/2NZ; Norm Cruickshank, 4SB; Chris Cullinan, 7EX; Arthur Dixon, 4BK/4AK; Frank Elliott, 4BC; Eric Evans, 3SH; W Fager, 4AY; Keith Fairweather, 4IP; Max Folie, 3MA; Albert Fox, 2GF; W Frewin, 2MG; Harold Fuller, 3YB; Les Glew, 3UZ; Don Gooding, 5AD/5PI/5MU; A (Snow) Grace, 3KZ; W T Grant, 2KA/2KM; Hector Green, 4BU; Ken Greenhalgh, 2KO; D E Holmes, 2DU; Edgar Hooper, 3DB; Arch Hopton, 3CV; Ern Hume, 5DN/5RM; V Jarvis, 2RG; Alf Kerr, 3BA; Tom Kitto, 7UV; Arnold Lawrence, 4TO; Tom Ling, 2BE; E C Littler, 4BH; Tasman Lord, 7BU/7DY; John Lowe, 2GN/4WK; P Makin, 2WL; Alex Mather, 2HR; Jack Mattlicios, 3GL; Tom McNeill, 2UW; Gil Miles, 7HT; C Morrison, 6GE; J Murphy, 3HA; Bill Nicholas, 7HO; Russell Nicholson, 4LG; George Nolte, 3TR; G F Nutley, 5AU; Bob Oakley, 2HD; John Parris, 2PK/2QN; Fred Pearce, 4CA; John Proust, 2AY; P Roberts, 2WG; Jack Ryan, 2CA; John Ryan, 3AW; Len Schultz, 2GB; E Semfel, 4RO; Lindsay Shepherd, 3XY; Ray Shortell, 3SR; Harry Simmons, 6IX/6ML/6WD; T A Small, 2MW; Fred Stevens, 2CH; Murray Stevenson, 2UE; Val Sydes, 7LA; Charlie Tareha, 5KA; H V L Taylor, 2AD; Thomas Taylor, 2CK; Ernest Tibbett, 2MO; Stan Tonkin, 2LM; F Tredrea, 6PM/6AM/6KG; R K Try, 2XL; J Walker, 4ZR; Tom Welling, 5SE; Tom Whitcomb, 2TM; Warne Wilson, 3BA; and L Wright, 3AK.

The designation 'Chief Engineer' as head of the Engineering group in the broadcasting industry was used from the start of broadcasting. Australian broadcasters followed the BBC practice in UK where the first head of the Engineering Department was P P

Eckersley who was appointed Chief Engineer in February 1923. The head of the Australian Post Office Engineering Department was also designated Chief Engineer in early days. However, both these positions required Professional Engineering qualifications whereas the Officer-in-Charge of a single broadcasting station with title 'Chief Engineer' had qualifications of a much lower standard, in comparison. The title 'Chief Engineer' was never used for station Officer-in-Charge by the Postmaster General's Department when it established the National Broadcasting Service in 1929. Designations followed those used with staff working on other Engineering facilities such as telephony, telegraphy etc

In the late 1940s, some Commercial station networks changed the designation of the station Officer-in-Charge from Chief Engineer to Technician-in-Charge, but the practice was not universally adopted throughout the industry.

Today, the titles Technical Director, Engineering Manager, Broadcast Services Manager or Executive Vice President Engineering have become common with the head of the Engineering Group being accepted as part of the station or network management team. For many years, the Award designation for an Officer-in-Charge was Technical Superintendent.

In recent times, Awards and Conditions for Technical staff at Commercial Broadcasting stations were handled by the Technical, Communications and Aviation Division of the Public Service Union (PSU–TCA Division).

The first attempt to cater for the needs of Radio Technical staff was taken in 1916 when the Radio Telegraphists (Marine) Institute was formed by Wireless Operators in the Mercantile Marine. The organisation was very active on behalf of its members and greatly improved the conditions and pay of the Operators, and established definitely, their status as responsible officers. In 1920, Radio Telegraphists working at Coast Radio Stations were admitted as members, and the word 'Marine' dropped from the Institute name.

When the AWA Beam Radio Service was put into operation in 1927, Telegraphists and Technicians employed on the system were admitted to the Institute.

When the Commonwealth Government acquired the A Class broadcasting stations in 1929 to form the National Broadcasting Service, records show that the studio and transmitter Technical staff of 5CL owned by Central Broadcasters Ltd, were members of the Radio Telegraphist Institute of Australia. Staff of the Postmaster General's Department who took over responsibility of the operation functions were members of a different organisation.

In 1935, the name and constitution were changed and it became the Professional Radio Employees' Institute (PREI), an industry organisation rather than a craft organisation.

Since that time, transmitter and studio Technicians of broadcasting stations were enrolled, although some appear to have become members much earlier. There were some 60 Commercial broadcasting stations on air at the time. The Institute was divided into autonomous sections under a governing council.

In March 1937, the Institute secured an Award for broadcasting Technical staff with wages being determined by a station's grading. There were four Grades comprising:

- Grade A – 8 or more Technical staff.
- Grade B — more than 4 but less than 8.
- Grade C — with 3 or more staff.
- Grade D — with 1 or 2 staff.

Juvenile members of the staff were not taken into account.

The Award set down different wage levels for Technician-in-Charge, Technician and Control Room Operator. A Technician was classified as a person who 'attends transmitting plant and performs all duties incidental to the running of the plant'. Control Room Operator was classified as a person who 'operates the control amplifier and sets up connections for studio and outside pick-ups'.

There were two Awards, one for the city stations and one for country stations. In 1939, both Awards were incorporated into one Award, and some alterations made to station gradings. The General Secretary at the time was Alex Sheppard who had previously worked with AWA on administrative duties and later became an Announcer at the AWA short wave station VK3ME.

Technical staff of Commercial broadcasting stations in Tasmania saw the Institute as a means of improving liaison and co-operation between stations and about 1943, a group of members met to discuss the possibility of forming a Tasmanian Division of the Institute. A Steering Committee was elected to pursue the matter. The Committee comprised Val Sydes, 7LA; Norm Stone, 7HT; Chris Cullinan, 7EX; John Dodds, 7HO; Cliff Parish, 7SD; Bill Nicholas, 7HT; Ern Cooper, 7LA; and Keith Burbury, Radio Inspector Postmaster General's Department.

A minor change in the name of the organisation was later made to include the word 'Australasia' to accommodate staff employed off the mainland, particularly New Guinea.

About the mid 1970s, staff designations were Senior Technician, Technician and Panel Operator.

In 1975, a further change in name was made, giving the organisation the name Professional Radio and Electronics Institute (A/Asia). In October 1992, the Institute amalgamated with the Public Service Union and by mid 1993 membership included about 100 staff of Commercial broadcasting stations. The Award under which the members were covered was the Commercial Broadcasting Station Radio Technical Staff Award, with designations being Technical Superintendent, Technician and Broadcast Operator.

In recent times, with the greater decision making powers vested in Accountants in the management of broadcasting stations and networks, the role of the Chief Engineer/Technical Director in the management of broadcasting services has been under close scrutiny.

This has arisen as a result of a number of factors including:

- Developments in automation and other broadcasting technical facilities.
- Increased reliability of technical equipment.
- The transfer of the operation of certain technical facilities previously the responsibility of Technical staff to Presenters, Producers, Journalists and others.
- The availability of Consultants specialising in the planning, installation, operation and maintenance of broadcasting technical services.

The impact of the national economic situation on station advertising revenue has resulted in cutbacks in Engineering budgets with demands for:

- Ongoing productivity improvements.
- Reduction in Technical staff levels.
- Deferment of equipment replacement programs.
- Modification and upgrading of equipment to extend service life.

Although Consultants can provide management with answers to any technical problems, management is often more confident in decision making processes when it can call upon somebody close to the day-to-day operational scene and who has a vested interest in the immediate and future welfare of the business.

This aspect is well recognised by most station administrations. However, in some instances there is reluctance to involve the Chief Engineer in important strategic planning decisions and in the allocation of financial and manpower resources.

Where management does recognise the important role of the Technical Department, the departmental head is often designated Technical Director or Executive Engineer and is a member of the Board of Management with responsibilities comparable to those vested in other Directors.

Over more than 66 years of operation, the various Commonwealth Governments have never appointed a Professional Broadcast Engineer to the Board of Directors of the Australian Broadcasting Commission/Corporation.

According to figures released by the Australian Broadcasting Authority for 1996–97, the Commercial radio broadcasting industry showed a modest profit for the financial year. For free-to-air stations, profit increased by 5.6% to $74.7 million. Revenue increased by 0.3% to $556.2 million, while operating expenses which included costs associated with the studio and transmitting technical facilities decreased by 0.5% to $481.4 million. Sixteen of the 20 capital city FM services showed a profit compared with six of the 19 capital city AM services. It is of interest that services with transmitters located in areas serving the larger regional market such as Gold Coast, Toowoomba, Gosford, Newcastle and Canberra showed a decrease in total revenue by 7.5% whereas stations located in medium regional market areas such as Mackay, Kempsey, Dubbo, Tamworth, Wangaratta and Bunbury showed an increase in total revenue by 1.1% and stations located in smaller market areas such as Armidale, Cooma, Mt Isa, Renmark and Geraldton also showed an increased revenue. In this case, it was 2.4% over the previous year.

NATIONAL BROADCASTING SERVICE

The system of A Class and B Class stations proved to be successful with licences increasing from 38000 in December 1924 to 85000 twelve months later, with programs being supplied by 17 stations. However, only three of the transmitters were located in country areas. These were 4GR Toowoomba, 2MK Bathurst and 2HD Newcastle. All were B Class stations. The Government and country people were far from happy with the rate of progress in bringing broadcasting to the Australian people.

Although the owners of 3LO, Broadcasting Company of Australia, developed plans as early as late 1926 to construct relay stations at Bendigo, Maffra, Wangaratta and Hamilton to serve Victorian country residents, no action was taken to establish the stations. In Queensland the Queensland Government, owners through the Queensland Radio Service of 4QG planned a broadcasting station at Rockhampton but although a licence had been granted, the station was not built by that Government. In 1928, the owners of 2FC Sydney planned the establishment of a number of relay stations in country New South Wales with the first to serve the mid north coast region. The company wrote to the PMG's Department seeking rental of a program line but the Department advised that no program lines were available for rental on a permanent basis and suggested the company erect a self-contained station in the Newcastle-Maitland area to broadcast locally generated programs. The company took no action on the suggestion preferring to wait the outcome of the Royal Commission into Broadcasting which was about to submit its Report.

This, and other factors relating to broadcasting led the Commonwealth Government to appoint a Royal Commission in January 1926 to enquire into a number of broadcasting issues and to make recommendations as to any alterations deemed desirable in the policy and practices then in force.

On 25 July 1928, the Government announced its intention of establishing a National Broadcasting Service whereby one organisation would cater for the National programs of all States. The Engineering services of all stations would be owned and operated by the Government, while the provision of programs would be left to entrepreneurs under contract. No change was proposed in respect of the B Class stations.

Under the plan agreed upon, arrangements were made for the Postmaster General's Department to take over the A Class station technical facilities as their licences expired between July 1929 and January 1930. The date of expiry of the licences were: 2FC, 16 July 1929; 2BL, 21 July 1929; 3LO, 21 July 1929; 6WF, 12 July 1929; 3AR, 7 August 1929; 5CL, 13 January 1930; 4QG, 29 January 1930; and 7ZL, 13 December 1930. Although 6WF Perth was not due for takeover until 21 July 1929 the company was in such financial difficulty that it advised the Government that it could not continue operations until the licence expiry date. The Department purchased the transmitter and other facilities, and took responsibility for the service from 20 December 1928 although the official transfer did not take place until 1 September 1929.

Tenders were called on 9 May 1929 for the provision of programs, and following a detailed examination of eight bids received, the PMG's Department awarded a three year contract to end on 30 June 1932, to the Australian Broadcasting Company Ltd formed by a group comprising Greater Union Theatres Ltd, Fullers Theatres Ltd and J Albert and Sons. Apparently the broadcasting policy makers of the time, having been impressed by the considerable success of the 3LO program format which had been closely associated with theatrical and musical industries since it was established in 1924, decided to follow suit.

The Albert family subsequently became major players in Commercial station broadcasting. In 1988, R O Albert, E F Albert and A A Albert each held a third share of Albert Investments Pty Ltd which in turn was a major shareholder of The Australian Broadcasting Company Pty Ltd which controlled a large network of stations including 2CC, 2KIK, 4SB, 4BC, 4RO, 4MB, 4ZR, 4GR, 2UW and 3TT.

The Australian Broadcasting Company Ltd quickly took control of program matters and began operation at 2FC Sydney from 16 July 1929, 2BL Sydney from 21 July 1929, 3LO Melbourne from 21 July 1929, 3AR Melbourne from 8 August 1929, 4QG Brisbane from 1 February 1930, 5CL Adelaide from 13 January 1930, 6WF Perth from 21 July 1929 and 7ZL Hobart from 13 December 1930.

At the same time, the PMG's Department Engineering staff set about the major task of upgrading and replacing the studio and transmitting facilities, and extending the service to country or regional areas.

In August 1929, the Postmaster General announced that the Government had approved an expenditure of £750000 for the provision of four relay stations over the next 3-4 years with the first station to be erected in Newcastle.

The Specifications issued by the PMG's Department on 7 February 1929 called for the transmitter proposed for Newcastle to have capability of providing 3 kW power into the aerial and employing low level type modulation capable of at least 70% modulation of the carrier. Tenders for the work closed on 12 March 1929 with some prospective tenderers claiming they had insufficient time to prepare a tender. Contracts were subsequently let to Standard Telephones and Cables (A/Asia) Ltd for all four stations including transmitters, aerial systems and services of a company Engineer.

Following selection of a site at Beresfield about 19 km from Newcastle, construction of the transmitting station began in early April 1930. The plan included provision of a local studio in the Strand Theatre, Hunter Street, Newcastle for broadcast of local church services, news, stock and station reports and shipping information when not relaying Sydney programs.

Commercial station 2HD had been serving the district since 1925, and many local listeners were concerned that the new National station on 241 metres (1245 kHz) would cause interference with 2HD programs then being broadcast on 212 meters (1415 kHz).

By November, listeners who had looked forward to the new 2NC station were critical of the Department of ongoing delays in bringing the station to operation. There had been postponement after postponement since April, but in November the Director General, Posts and Telegraphs, Harry Brown assured the residents that the station would be operational by the end of the year. It was expected that there were some 200000 prospective listeners in the service area of the station.

There had been comments in the local press that the delays had been caused by the fact that the work was being undertaken by Postal Electricians who were unaccustomed to the specialised work of Radio Engineers. There was also reference to problems with adjustment of the crystal control system which controlled the station carrier frequency.

The station was commissioned at 8 pm on 19 December 1930 with 2 kW into the aerial to become the first Regional broadcasting station of the National Broadcasting Service.

The 2NC station was followed by 4RK Rockhampton on 29 July 1931 with a 2 kW transmitter, 2CO Corowa on 16 December 1931 with a 7 kW transmitter and 5CK Crystal Brook on 15 March 1932 also with a 7 kW transmitter. The 7 kW carrier power for 2CO and 5CK was available from the transmitter when modulated at 90 % modulation depth. For 95% modulation depth, the available carrier power produced was 6.25 kW.

These stations were rated in terms of power into the aerial. Prior to decision of the CCIR at The Hague in 1929, transmitters had been rated in terms of anode power input to the final amplifier. This earlier approach was misleading because it did not indicate the real power radiated, as the power into the aerial was only of the order of 25 % to 35 % of the anode input, with the actual proportion depending upon the power conversion efficiency of the final amplifier.

Facilities including program input equipment were provided by STC, Sydney, with the 2NC and 4RK 2 kW transmitters and building layouts being identical and the 2CO and 5CK 7 kW transmitters and building layouts also being identical.

Although the 2NC and 4RK transmitters were of similar design and installed under the supervision of Claude McQuillan, STC representative, modifications were soon carried out by local staff to improve performance. At 2NC for example, early improvements included:

- Installation of a new master oscillator unit giving very accurate carrier frequency control.
- Changes to the method of modulation to give improved transmission quality and to minimise variations in output due to the somewhat severe commercial power fluctuations encountered.
- Neutralisation of radio frequency stages not provided in the original design.

The original station equipment included a Transmission Measuring Set for measurement of gains, levels and losses; an Audio Frequency Oscillator with a range 35-50000 Hz; line terminating equipment; telephone equipment; line equaliser and speech input control equipment.

The control equipment was mounted on a desk panel and contained volume indicator panel, power amplifier for operating a Western Electric 540-AW double cone monitoring loudspeaker which sat on top of the desk panel, a fader mixer panel and a four stage resistance capacitance coupled amplifier with a gain of 100 dB, and meters for reading filament and anode currents of valves. A WE carbon granule studio type microphone sat on the desk to the left of the operator.

Within a few years of 4RK going to air, some major changes had been made to the program input and control equipment and facilities were provided for generation of an emergency program from the transmitter.

The emergency studio facilities included a desk with control panel, two WE 4A gramophone reproducers, and a type 633 microphone.

A control desk was installed in front of the transmitter and included a control panel and a General Radio Modulation Monitor type 731A consisting of three elements — a linear diode rectifier which gave an instantaneous output voltage proportional to the carrier envelope, a peak voltmeter which provided continuous indication of the peak modulation, and a trigger circuit which flashed a light whenever the modulation momentarily exceeded a value previously set by the Operator. A floor mounted monitoring loudspeaker was placed to the right of the desk.

The transmitter incorporated a crystal controlled master oscillator with automatic temperature control, 100 % modulation capability at low power, automatic push button starting control of the rotating machines and facilities for tuning the transmitter from a 'dead front' panel with the transmitter operating under maximum output power.

The output of the crystal oscillator which employed a 4102D valve was successively amplified up to the final power amplifier which had an anode input of about 6 kW giving an output into the aerial of a little over 2 kW unmodulated carrier power.

Three quartz crystals were provided, with two being spare. Frequency shift was maintained within ± 100 Hz. The master oscillator which was modified to improve frequency stability was housed together with two subsequent stages in a brass lined box to ensure good screening from external fields. The unit was mounted externally to the transmitter proper with interconnection being made by a concentric transmission line. The line which was terminated by a potentiometer, formed the input to the separator stage. The 50 watt separator stage function was to, not only carry out further amplification of the carrier, but also to isolate the master oscillator from changes in load impedance due to modulation.

A 250 watt modulated amplifier valve type 4212D worked as a Class C amplifier and was modulated by a similar valve working as a Class A amplifier in a variation of the Heising method of modulation. Two 80 henry chokes were employed, and being so wound as to keep distributed capacity to a minimum to ensure reasonably flat response of audio frequencies up to 10 kHz.

After passing through the station speech input equipment, the program was fed to a 50 watt amplifying stage using a 4211D valve, resistance coupled to the modulator valve. The modulated carrier was amplified through two successive linear Class B stages before being fed to the aerial.

The first stage known as the first RF amplifier used to 4212D valves in parallel operating in a neutralised circuit configuration. The circuit included carrier harmonic reduction features. The second and final RF amplifying stage used two 4228A water cooled valves operating as a Class B amplifier. This stage was also neutralised. Output was fed to the aerial via a loading inductance with a sliding contact. For 2 kW RF into the aerial, about 4 kW was dissipated as heat at the valve anodes. A water cooling system kept the water temperature below 60°C.

The filament, grid bias and anode supply voltages were obtained from duplicate sets of motor-generators. The filament and bias generators were driven from a single motor while three high tension anode generators were arranged in tandem. The first of the anode generators had two sets of windings on the armature each with its own commutator with the two commutators being connected in series providing 750 V and 1250 V for air cooled valve anodes while the other two generators of 1250 V enabled 4000 V DC to be supplied to the final water cooled amplifier stage.

A number of automatic protective devices were provided to ensure safety of Operators and the equipment. These included removal of filament and HT voltages in event of water circulation failure, removal of all HT voltages should grid bias fail, prevention of application of HT should the door giving access to the rear of the transmitter not be fully closed, and removal of HT in case of an overload. All controls for starting, operating, tuning and closing down the transmitter were mounted on the front of the transmitter panel.

Procedure for adjustment of the input signal to the transmitter is of interest. The equipment manufacturer recommended the following procedure where the studio was located remote from the transmitter:

'At the studio.

Set the volume indicator on the speech input equipment for an output of 2 TU or to the highest output level permitted by the Telephone Administration owning the line.

Supply a continuous steady tone to the speech input amplifier. Adjust the amplitude of the tone by means of the Gain Control Potentiometer to obtain a standard deflection of 30 divisions (up to the red zero position on the scale) on the galvanometer. Throw the Broadcast Key to the "on" position so as to transmit the tone to the transmitter.

At the transmitter.

Perform the necessary switching to connect the output of the speech input equipment at the studio via the line amplifier at the transmitting station to the transmitter.

Adjust the Gain Control Potentiometers (Input pot and Inter pot) until the transmitter receiving the steady tone is just on the point of overloading, as indicated by the modulator valve beginning to show grid current. Adjust the volume indicator by means of the key and dial switch to obtain the standard deflection of 30 divisions on the galvanometer.

Note:

The tone may be obtained from any convenient source, e.g., via the microphone from a musical instrument or from a low frequency oscillator directly coupled to the speech input amplifier.'

The installation and commissioning of the 2NC Newcastle facility was under the control of Engineer Harry Weir. Foreman Mechanic of the installation team and first Officer-in-Charge of the station was Bill Robinson.

Bill Robinson had learnt visual signalling while a student at Crown Street Superior Public School during 1915, and was taught the Morse Code and elements of telegraphy by an enterprising Aunt. In 1918, he became Patrol Leader (Signals) in the Scouts and in the same year passed the Qualifying Certificate Examination at school.

As part of the National Service Scheme at the time, Bill was inducted into the Royal Australian Navy Reserve in 1919 and was allotted to the Signals Branch (Visual).

One of his relatives was a Mechanic in the Postmaster General's Department and encouraged Bill to take the examination for Junior Mechanic-in-Training. In January 1920, he joined the Department's Engineering Branch as a temporary employee pending the results of the examination. On appointment to the permanent staff in 1921, he was attached to Workshops for training and simultaneous part-time attendance at Sydney Technical College.

Continuing his duties with the Navy, he transferred from Signals to the Wireless Branch of the Service and later became a Petty Officer Telegraphist as a Senior Cadet. From 1921 to 1923, his training with both the Department and the Navy resulted in experience being gained in a wide range of technical areas.

By 1925, he had completed his Junior Mechanic-in-Training course and was promoted to Mechanic on the Relieving Staff.

In March 1926, Bill was sent to Canberra to work on the wiring and equipment for the Parliament House telecommunications facilities.

Although by this stage he had fulfilled his obligation of service with the Navy and was discharged, he rejoined the Navy on a voluntary basis as a Petty Officer Telegraphist.

In May 1928, while on Annual Continuous Training on HMAS Australia, at the request of his employer the PMG's Department, Bill was given a special course by the Navy on high power wireless equipment operation and maintenance because at that time, the Department was taking steps to build up a core of suitably trained staff as part of the Government's plan to take over the A Class stations to form the National Broadcasting Service. Following an examination by the Department's Radio Inspector, Bill was issued with 'Limited Certificate of Proficiency in Radio Telephony', Serial Number 2.

At the conclusion of his Naval training course and return to normal duties with the Department, he was sent to 2BL at Coogee to take over the station from the owner's Technical staff and to set up operation and maintenance procedures using company personnel who had accepted an offer to join the Public Service.

During 1929, after operation of the station had been established on a sound basis, Bill transferred to general duties in connection with a range of NBS activities and liaison with staff of the Australian Broadcasting Company in connection with technical aspects of program production.

In June 1930, he went to Beresfield to install Australia's first regional station 2NC Newcastle for the NBS. Bill had recently married and took up residence in the house erected on the site for the Officer-in-Charge.

While working at 2NC, he qualified as Senior Technician Research, but although offered a position in the Research Laboratories, declined the offer. He was appointed Officer-in-Charge of 2NC on commissioning of the station and remained there until July 1934 when he joined 2UE as Assistant Chief Engineer under Chief Engineer Murray Stevenson. The station which had been in service since Australia Day 1925 operated with two studios and control rooms on 6th Floor, 296 Pitt Street, Sydney and a 1000 watt transmitter employing Heising method of modulation at Lilli-Pilli, Port Hacking some 13 km from the GPO.

During his period with Commercial station 2UE, Bill was associated with the design, construction and installation of new studios on 4th Floor, 29 Bligh Street where facilities included five studios, three control rooms, disc recording equipment and hourly time signal 'pips' — an innovative 'first' at the time.

At the outbreak of the War in 1939, he was Commissioned in the Australian Military Forces, serving initially as an Instructor at Eastern Command School of Signals. In 1940, he became Assistant Chief Signals Officer, Eastern Command and later Command Wireless Officer. In 1943, Bill commanded the Heavy Wireless Company Allied Land Forces HQ in Melbourne at which he organised establishment of a chain of overseas radio services to London, New Zealand, Chungking, New Guinea and front line positions in Australia. He later served in New Guinea and at the conclusion of hostilities returned to Australia as Australian Staff Signals Officer, being demobilised in 1946 and returning to his previous position with 2UE.

Bill was appointed Chief Engineer of 2UE in 1956 and retired from the position in 1965. However, he maintained an interest in radio following appointment as quality Controller of Radio Equipment with Standard Telephones and Cables Ltd, until 1975.

Bill was also active in many community affairs. These included appointment to the Board of St George Hospital, Kogarah as Director in 1952, and a member of the Kogarah Council from 1953, serving as Deputy Mayor for five terms, and Mayor 1961–62.

For his community service, he was honoured in 1980 with the Medal of the Order of Australia.

Installation and commissioning staff associated with the 4RK Rockhampton station included Harry Conway, Les MacDonald, George Coley, Fred Emerson, Bert Jack, Ian Hamilton, Roy Ferguson and Nat Gould. Harry Conway was the first Officer-in-Charge.

The 2CO and 5CK transmitters when commissioned in 1931 and 1932 respectively, were the most powerful broadcast transmitters in Australia with capability of 7 kW into the aerial at 90% modulation, or 6.25 kW for 95% modulation. Although 2BL Sydney had capability of providing 8 kW into the aerial, it was normally operated at the reduced power of 4 kW on account of its location and problems with signal blanketing.

The transmitter was assembled on the unit system and included the AC unit comprising line voltmeter, AC regulating resistors, fuses, contactors, main 'stop' and 'start' push buttons; the DC unit containing generator field regulators and voltmeters, grid bias, 750 V and 1500 V smoothing filters, HT overload relays, DC contactors and fuses; the oscillator-modulator unit which housed all equipment for the generation of the carrier, its amplitude and modulation at low level, meters for anode, grid and circulating currents and the tuning controls for the first interstage circuit; the RF amplifier unit for amplification of the modulated carrier; the rectifier unit containing three water cooled rectifier valves forming the EHT rectifier with their individual filament transformers together with anode circuit ammeters and EHT voltmeter; the power amplifier unit comprising two 15 kW water cooled valves with associated coiled hoses, water flow alarm, water temperature indicator and anode and grid meters plus the tuning unit which housed the aerial coupling capacitors and aerial tuning coil, with tuning controls and RF meters being located on the front panel of the unit.

Behind the units, and within an enclosure cage, were located the EHT rectifier transformer, smoothing choke and capacitors, and the artificial aerial units.

The carrier was generated in the master oscillator stage by a 4102D valve, the frequency of which was controlled by a quartz crystal. The output of the 4102D was amplified by a 4102A(SS2029) valve, referred to as the first master amplifier. The carrier was further amplified by the second master amplifier stage employing a 4211E valve. The three valves were mounted in a screened box designed to minimise feedback from subsequent transmitter stages.

The next stage in the RF chain was the buffer stage fitted with a 4211E valve operated as an untuned stage. The buffer stage prevented changes in the master oscillator output as a result of changing load conditions on the modulated amplifier during modulation.

The modulated amplifier was a 250 watt 4212D valve operated with about 450 V on the anode.

The modulator stage used two 4212D valves in parallel operated with 1600 V on the anodes. The output of the modulators was coupled via a Heising choke to the anode of the modulated amplifier, a coupling capacitor being used to enable a lower value of DC anode volts to be used on the modulated amplifier. The modulators were driven by a 50 watt speech input valve 4012A(SS2029), the coupling being a resistance-capacitance circuit.

The first power amplifier following the modulated amplifier comprised two 4015A(SS1969) valves in parallel. An harmonic suppressor attenuated frequencies above the fundamental carrier frequency. The second or final power amplifier employed two 4220B water cooled valves in parallel.

The main inductor of the output circuit was a copper helix on a whitewood former, the tuning being effected by a sliding contact driven by a handwheel. All capacitors were fixed types.

The neutralising capacitor of the first power amplifier was a variable cylindrical air capacitor while that for the final amplifier was larger and oil filled.

The filaments of valves up to the first power amplifier were heated by DC from a motor generator set delivering 16 V. The filaments of the final stage were heated by a 24 V DC motor generator unit.

Grid bias for all stages was provided by a 300 V DC motor generator set.

The anode supply for the RF valves up to the modulated amplifier was supplied by an 800 V motor generator. The voltage was adjusted by series resistors to suit the various valves.

The anode supply for the modulators and speech input valves was 1600 V and was supplied by two series 800 V armature windings driven on a common shaft. The anode supply for the first power amplifier was 4000 V and was obtained by joining the 1600 V supply in series with a 2400 V DC machine on the same bed plate.

The anode supply for the final stage was 12000 V supplied by a three phase half wave rectifier using three 4222A half wave water cooled valves. The filaments were heated by AC from a specially insulated transformer. The anode input power of the final stage for 7 kW into the aerial was about 22 kW.

Measured carrier noise level during commissioning of the 5CK transmitter was 50 dB below level of full modulation.

Rain water was stored in a tank and circulated through rubber hosing to remove heat from the valve anodes.. The two power amplifier and three rectifier valves were connected in series. The water passed through a radiator system enclosed in a wind tunnel. Because the anodes of the three rectifier valves were at earth potential, long lengths of insulating hoses were not necessary with those valves.

Tap changing switches on the EHT transformer primary were provided, giving rectified voltages of 7000 V and 10000 V for testing and warming up. Horn gaps with limiting resistors were provided on each of the three phases of the EHT transformer and the DC busbars, as protection against power surges.

The 5CK project was controlled by Divisional Engineer Frank O'Grady assisted by Engineer Class 'E' Laurie Billan. The installation team comprised Bill Whisson, Jock Anders, Chris Comas, Ted McGrath, Len Cooper and George Ramsay.

PMG's Department State Engineer at the time of commissioning was Peter Kennedy. First Officer-in-Charge was Bill Whisson followed by Morris Wallace, Jack Grivell, Pat Callinan, Brian Blundell, Alf Cole, Roy Buckerfield, Ken Bytheway, Bill Roy, Brian Roberts, Dave Carthew and Brian Beyer.

Harry Weir of the New South Wales PMG'S Department controlled the 2CO installation.

STC representatives for 2CO were Messrs McQuillan and Bore, while Messrs McQuillan and Thow were on site at 5CK.

Frank O'Grady, who controlled the 5CK installation, later played a major role in upgrading the 5CL transmitter and the Adelaide ABC studios. He ultimately became Director General of the Post Office.

He joined the Postmaster General's Department in Adelaide in 1917 and after a short break in private industry, returned to the Department. In 1925 he qualified as an Engineer.

When responsibility for running the technical side of the newly formed National Broadcasting Service was transferred from the Wireless Branch to the Engineering Division in 1930, the South Australian station 5CL came under Frank O'Grady's control.

At the time of the take-over from Central Broadcasters Ltd, the 5CL service was in a very precarious state. The studios were run down with patched-up, unreliable equipment held together with very doubtful wiring, and no attempt had been made to improve the studio acoustics. The studio microphones were condenser types prone to sudden failure, and turntables for playing records were 'spin start' types, and frequently ran backwards.

The transmitter was even worse, and many a night session finished with the Operator holding a faulty brush against the commutator of a bias or filament generator. If both machines were in trouble, the session finished early.

The final stage had been changed by the company staff sometime earlier to include a water cooled valve, replacing the original air cooled 'football' types. The water cooling arrangements were very primitive and unreliable. The modulation choke was mounted behind the Operator's desk without any protection for the staff, and the 15 kW EHT feed, to and from the choke, was bare copper wire running up the wall and along the ceiling to the final stage.

Ted McGrath, who later became Supervising Engineer, recalled how Frank charged straight into the mess with characteristic enthusiasm and skill. Under his direction, the service was made safe and reliable while he set about the complete rebuilding of the station transmitter and studio equipment.

Frank chose the site for the first Regional station in South Australia, 5CK at Crystal Brook in 1931 after a physical survey of the area. The broad design of 5CK was later used as the model for many changes to the Metropolitan station 5CL but along the way, he experimented with a number of different modulation methods including grid, suppressor grid and anode techniques. He also tried different output coupling arrangements, finally settling on the pi network as used in the 5CK configuration.

The 5CL speech input equipment and program lines were upgraded and after many experiments, the master oscillator finally became an STC oven controlled crystal oscillator of high stability.

The original full wave, three phase six valve air cooled rectifier was replaced with a three phase, three valve water cooled system which reduced the ambient temperature in the building and was much more reliable. At that point, the whole station was then more reliable and provided an improved service to listeners.

Frank also tackled major problems with the external plant facilities. The 5CL aerial had always been unsatisfactory. The pattern was directional due to the slope of the wire and it was difficult to match efficiently. With assistance from the Department's Research Laboratories, Frank undertook experimental work using a shunt feed to the 60 metre support mast. Results were not very satisfactory and finally in 1944, the mast was jacked up and the bottom placed on an insulated spider arrangement. A 200 ohm 5 wire transmission line from the transmitter was constructed to feed the aerial.

Although Frank had brought the Adelaide studios to a reasonable degree of reliability over the years, he wanted further improvements and in early 1935, he started work on the complete replacement of all the equipment and introduced a new concept whereby each of the three studios had its own control room and Operator with each studio being linked into a master switch room where all external switching was performed. The new equipment was completely AC mains operated, and it was one of the first broadcast studios in Australia to be so powered at the time.

Not long after 5CK came into service, it became evident that there were a number of shortcomings in the equipment and Frank set to work to improve the facilities. The filament, bias and HT supplied up to 4000 volts were supplied by three sets of motor generators each of which was duplicated. The dressing of a high voltage commutator, even with the field control wound back, was a somewhat dangerous task for the maintenance staff. All of the motor generating equipment was replaced by static rectifiers.

In 1961, Frank became Director General, Post and Telegraphs, and in 1965 was made a Commander of the Order of the British Empire (CBE), for outstanding contributions to the development of telecommunications in Australia.

Peter Kennedy, State Engineer when 5CK was commissioned, began his career in the Western Australia General Post Office in 1896 when Western Australia was still a Colony.

Three years after he joined the Post Office, wireless telegraphy experiments were undertaken by Post Office staff to assess the practicability of establishing wireless communications with Rottnest Island. Although not a member of the group undertaking the experiments, Peter followed with interest the tests being carried out.

With a keen interest in the new technology, he was granted a licence with callsign XYD to operate an experimental station. Before the outbreak of the First World War, he was one of about a dozen active experimenters operating wireless telegraphy stations in Perth.

Peter had a particular interest in mercury coherers for the detection of wireless telegraphy signals. He built several models employing a number of novel approaches. He also imported a commercially manufactured unit from England to a design by Dr Muirhead. The device used a small rotating steel disc which grazed the surface of a globule of mercury covered with a film of paraffin. The disc was rotated by a clockwork motor and small rope belt. A micrometer enabled the wheel to be correctly adjusted on the surface of the mercury. The devise was in the collection of the former Adelaide Telecommunications Museum.

In 1917, he was appointed Assistant Engineer in Western Australia.

When experimental licences were granted after the War, he was allocated callsign A6AM and was one of the very active local operators.

When A Class station 6WF began operation with its high power transmitter located in the city area in 1924, the RF signals caused considerable interference with Post Office Exchange equipment and city telephone subscribers instruments. Peter was in charge of a group who tackled the problem and found a solution.

In 1927, he transferred to South Australia to become State Engineer. He was allocated callsign OA5AM for his experimental station and soon became active with the local Wireless Institute members.

When the Department took over A Class station 5CL as part of the plan to establish the National Broadcasting Service in 1929, he had a controlling role in integrating the broadcast activities into other Engineering Branch activities. With the construction of the first Regional NBS broadcasting station in South Australia, 5CK at Crystal Brook in 1932, he ensured maximum support was provided to the construction group for handling this project.

In December 1933, Peter transferred to New South Wales, as Superintending Engineer. He returned to South Australia in May 1937 to become Deputy Director.

Laurie Billin, who assisted Frank O'Grady on the 5CK and other broadcasting projects commenced with the Postmaster General's Department in Adelaide on 20 February 1922. In May 1923, he was appointed Junior Mechanic-in-Training in the Electrical Engineering Branch and on 23 December 1925 was advanced as Mechanic Grade 1. On 6 May 1927, he was promoted to Mechanic Grade 2 at the Adelaide Central Telephone Exchange.

With the commencement of work on the construction of the 5CK Regional station in 1931, Laurie was transferred to the installation staff. On 11 January 1932 he was officially appointed to the 5CL staff.

During the installation of 5CK and upgrading work at 5CL, he was Acting Engineer for a period.

On 13 June 1934, he moved to Melbourne to take up a position as Senior Mechanic in Central Office Research Laboratories.

On 16 May 1935, he returned to Adelaide to become Foreman Mechanic Grade 1 at 5CL Brooklyn Park.

Laurie had been studying for some time for the Open Engineers Examination and on successful completion of all necessary subjects, was appointed Engineer Grade 1 Transmission Section on 15 October 1936. He remained in this position until he retired from the Department on 25 January 1939.

The establishment of the four stations — 2NC, 4RK, 2CO and 5CK — over the period 1930–32 was carried out at the time when the country was in the grip of the Depression. There was a shortage of staff and particularly funds. The number of staff employed in the Postmaster General's Department declined considerably. Staff who retired or left the Public Service were not replaced and no recruitment took place. Technical training ceased, and many members were transferred to work areas, even to interstate, where they were employed on all manner of duties. For the first time, the number of telephone disconnections exceeded the new connections and revenue from local and trunk telephone calls fell sharply.

Such was the state of affairs in the Department, but of the five stations planned for regional centres, four were commissioned. The fifth station was intended for Western Australia, but was deferred due to the shortage of funds. Altogether some 16 centres were listed for establishment of stations but only five were developed fully for construction purposes.

Even though the Depression resulted in more than 30% of the Australian workforce being unemployed and those lucky enough to have a job having their wages slashed, the establishment of these stations breathed new life into the community. Listening to the radio was one way of pushing aside the worries of the day. The cost of a receiver was very high, but sales continued to rise. The Federal Basic Wage at the end of 1931 was £4/8/– a week and the price of an Astor Genii four valve table receiver was £23/15/– but somehow, people found money to purchase a receiver, probably on time payment, and to pay the Licence Fee.

By 30 June 1932, there were 12 National stations in operation giving service to some 370000 licenced receivers. It was at this stage that the Government established the Australian Broadcasting Commission to replace the Australian Broadcasting Company Ltd as the program body for the National Broadcasting Service. The whole of the technical services including studio apparatus and transmitting facilities continued to be the responsibility of the Post Office. The Post Office also provided the inter-connecting program transmission lines needed for simultaneous broadcasting from two or more stations.

By the beginning of 1934, the status of the transmitters of the NBS was 2CO Corowa, 7.0 kW on 560 kHz; 2FC Sydney, 2.5 kW on 451 kHz; 2BL Sydney, 3 kW on 855 kHz; 2NC Newcastle, 2 kW on 1245 kHz; 3AR Melbourne, 4.5 kW on 610 kHz; 3LO Melbourne, 3.5 kW on 800 kHz; 4QG Brisbane, 2.5 kW on 760 kHz; 4RK Rockhampton, 2 kW on 910 kHz; 5CL Adelaide, 2 kW on 730 kHz; 5CK Crystal Brook, 7.0 kW on 635 kHz; 6WF Perth, 3.6 kW on 690 kHz; and 7ZL Hobart, 1 kW on 580 kHz.

With expansion of the regional network, STC 7 kW transmitters were installed at 7NT, 2NR, 4QN, 3GI and 6GF. With the accumulation of operating experience and incorporation of overseas developments in transmitter designs, some changes were made to the equipment and plant which followed the earlier installations. For example, the power supplies necessary for the generation and modulation of the carrier were wholly obtained from stationary equipment either by transformation or rectifier conversion from public power mains with the only rotating plant being for the motor driven water circulating pump in the valve water cooling system and the water cooled artificial aerial resistor. With the exception of the final stage, power supplies for all valve filaments and anodes were derived from Westinghouse three phase copper oxide rectifier networks. The grid bias supply for all valves was also supplied from a metal rectifier system. The metal rectifier units were arranged in series-parallel groups to give the required voltage and current output.

The transmitter had six stages. These were the crystal oscillator, first and second coupling, modulator, modulated amplifier, first RF amplifier and the second or final RF amplifier. The coupling stages produced 6 watts, the modulated amplifier 45 watts, the first RF amplifier 400 watts and the final amplifier 7000 watts. The power supply requirements were provided as follows:

- Grid Bias.
  A three phase full wave Westinghouse metal rectifier provided a grid bias voltage of 350 volts DC at 1 ampere for all stages, with the voltage for each valve being reduced as required by dropping resistors.
- Filaments.
  Three phase full wave Westinghouse metal rectifiers employing three separate filter sections provided DC at 15 volts and 106 amperes for all RF stages except the final, 15 volts at 41.5 amperes for the modulator and 15 volts at 3.5 amperes for the speech amplifier.
  A Scott connected transformer arrangement provided power for the final stage. The transformer had a three phase primary and produced two single phase outputs of 24 volts at 100 amperes with a phase difference of 90 degrees.
- High Tension.
  Direct current of 1000 volts at 1 ampere was provided by three phase full wave metal rectifiers for low power valves in the RF stages while 5000 volts DC was provided by similar rectifiers for the modulator and first RF amplifier air cooled valves.
- Extra High Tension.
  The DC supply of 12000 volts at 3 amperes for the final water cooled power amplifier was provided by a three phase half wave water cooled thermionic rectifier system comprising three 4222A valves. Variations of the filament voltage for each valve was performed by means of taps on the primary of the transformer and by a hand operated resistor on the front panel of the unit. The filter system comprised a 20 henry choke and ten 1 MFD capacitors. In the case of 7NT, mercury vapour rectifiers were, according to a Radio Inspector's Report, in use during 1936.

A feature of the oscillator unit was the provision of duplicated temperature compensated quartz crystals contained in a thermostatically controlled oven set at 50°C temperature. The circuit was a tuned anode, choke fed type with a fixed coupling coil providing feedback to the grid. The valve employed was a 4033A type. In addition to the crystal oscillator unit, a self-oscillator unit was fitted.

Frequency of the unit was set using a wavemeter, or if on the same frequency as the crystal oscillator, by adjusting the coil/capacitor tuning for zero beat with the crystal controlled unit. Carrier frequency stability was measured by the Radio Inspector during commissioning of 4QN as ±10 parts per million.

Two stages were involved with the coupling (buffer) unit. The first was a single valve balanced stage with push-pull output and resistance load, while the second was a push-pull stage with resistance load. All employed 4211E valves.

The modulator unit employed a resistance coupled amplifier with 4211E valve followed by the 4015A modulator arranged for choke capacity output.

The modulated amplifier with two 4211E valves used a push-pull pi circuit with filters in place of anode stopping capacitors.

The first radio frequency amplifier was a Class B amplifier with two 4015A valves feeding a pi type output circuit.

The final amplifier with a pair of 4220B water cooled valves with two spare sockets was a Class C amplifier with a pi type circuit terminated in a 600 ohm transmission line. A series tuned filter circuit was included in each leg of the transmission line for harmonic elimination. The coupling leg was also designed to eliminate either the 2nd or 3rd harmonic by the addition of an inductor. The transmitter and power supply units were housed in expanded metal screens with key interlocked doors which had to be closed for transmission to take place. Keys which locked the metal screens had to be withdrawn after locking the door and inserted into the hand wheel of the main switch before the switch could be closed.

To meet a demand for 10 kW transmitters, STC upgraded the 7 kW model, and these were installed at 6WA Wagin in December 1936, 3WV Horsham in February 1937 and 2CR Cumnock in April 1937. Major changes to the design included four working 4220B valves plus two spares providing an anode efficiency of 29%, upgrading the power supplies for the power amplifier filament supply from 2.63 kW to 4.8 kW and the 12000 volt EHT DC power output from 22 kW to 34 kW. The ratings of the water circulating pump and the fan were also increased. The total AC power consumption for the 10 kW model was 62.6 kW compared with 45 kW for the 7 kW transmitter. The overall frequency response compared with 1000 Hz response point at 60% modulation was plus or minus 1 dB over the range 35 Hz to 10 kHz. The distortion measured at 1000 Hz varied from 31 dB at 40% modulation to 21 dB at 98% below the fundamental. Carrier noise level was 52 dB below 100% modulation.

During commissioning of the 3WV transmitter, the overall efficiency of the transmitter was measured at 23% at full modulation level.

The power gains for the various stages were the same as for the 7 kW transmitter except that the final stage produced an output of 10000 watts. To cater for the four working power amplifier valves, the three rectifier valves and the artificial aerial, the water cooling system was capable of dissipating 46 kW with a total water flow of 90 litres per minute. The system used distilled water with a specific resistance better than 10000 ohms per cubic centimetre.

The water cooling system was conservatively rated, and for an ambient temperature of 43°C, operating conditions without the artificial aerial in service resulted in a temperature to the input of the cooler of about 60°C, and an outlet temperature of 53°C. This allowed the dissipation of some 37 kW of heat with a water flow of 70 litres per minute. With the artificial aerial in circuit and operating at full power, the dissipated heat rose to about 47 kW. The centrifugal pumps were capable of providing a flow of 108 litres per minute against a head of 42 metres. The approximate heat dissipated by the various stages were 12.5 kW for the A bank of the PA, 12.5 kW for the B bank, 9.0 kW for the rectifier and 10 kW for the artificial aerial.

With the exception of 4QN where power was generated on site, the station installations 7NT, 2NR, 3GI and 6GF included standby power plant to cater for interruption to the public mains supply. A number of makes were installed, but the 3GI plant was typical. It comprised a Ruston Hornsby 5 cylinder 1000 RPM vertical compression ignition diesel engine of the airless injection type rated at 80 HP and direct coupled to an alternator and exciter of output 60 kVA at 400 volts three phase 50 Hz. The set was mounted on a massive concrete foundation, insulated from the main transmitter hall to minimise transmission of engine vibration. The engine was started by compressed air contained in a steel cylinder charged from a small engine driven compressor. The main engine was water cooled by gravity flow from an elevated tank through the engine into an underground storage tank. In the case of 5CK where a 120 HP Gardner engine was installed, the cooling water was contained in twelve large galvanised tanks which were later cement rendered because of water leakage problems resulting from corrosion of the steel.

The first major work which the PMG's Department undertook with the metropolitan stations of the NBS, was the complete replacement of 6WF Perth with a new station at a site at Wanneroo about 12 km from the city. Very little upgrading work had been carried out on the transmitter since installation in 1924, and it had become outdated technology involving high maintenance costs.

The new facilities were designed by the PMG's Department Research Laboratories staff and built in the Department's Melbourne Workshops. The station was commissioned on 14 December 1932. Staff associated with the design, construction and installation included Roy Badenach, Bruce Mair, Ted Stewart, Hector Adams, Alec McKenzie, Stan Hosken, Charlie Stradwick, Reg Turner and Henry Sansom.

In the team of Engineers on the project, Ted Stewart was one who played a major role. He qualified for appointment to the Postmaster General's Department as Junior Mechanic-in-Training following success in an examination held in Victoria in September 1921. After completing the Junior Mechanic course, he was appointed Cadet Engineer in 1925 but qualified as Engineer at an Open Engineers Examination and was appointed Engineer in 1927.

Ted transferred to Central Office from the Victorian administration in 1928, and when approval was given on 21 July 1931 to proceed with the design and installation of the 6WF replacement project, Ted and Hec Adams were put in charge of the Audio Frequency Equipment section of the work.

After six years in the Transmission Section he moved to the Research Laboratories, being promoted Divisional Engineer in 1935 and Assistant Supervising the following year.

During the Second World War, he was associated with radar investigations in liaison with the CSIRO Radio Physics group.

During the late 1950s, Ted was a member of the Radio Frequency Allocation Review Committee concerned with the re-allocation of radio and TV frequencies in Australia. He represented Australia on a number of overseas missions and in 1960, became the first Australian representative to the ITU Administrative Council.

At the time of his retirement in December 1965, Ted was Assistant Director, General Lines and Switching.

Charlie Stradwick, one of the Draftsmen who worked on the project preparing some 107 drawings, became Director General, Posts and Telegraphs in 1959 after having joined the Department as Telegraph Messenger in 1920. After 41 years with the Department, he resigned to become General Manager, International Telephone and Telegraph Corporation with headquarters in Hong Kong.

The main sections of the transmitter included the master oscillator unit consisting of a quartz crystal and 4102D valve, a separator stage with a QC05/15 valve and a high frequency amplifier producing 75 watts with a TC1/75 valve; a speech amplifier unit with a MC1/50 valve which amplified the program from the speech input equipment; a 250 watt modulator stage using a 4012D valve; a 75 watt modulated amplifier stage with a TC1/75 valve and the three stage power amplifier stage. The first stage of the power amplifier produced an output of 250 watts with a TB2/250 valve, the second stage produced 1000 watts with an air cooled 4015A valve and the third and final stage using a 4220B water cooled valve was capable of producing an unmodulated carrier of 3.6 kW.

Filament power for the main valves was supplied from a 24 watt generator while the 300 volt bias supplies was also supplied by a generator. The filament and bias generators were driven by the one motor. Two units were provided, and they were brought into operation by push buttons on the transmitter control panel.

Four rectifiers provided the various anode supplies. The master oscillator was supplied with 1100 volts by a full wave single phase rectifier using UX866 hot cathode mercury vapour valves; the speech amplifier, modulator and modulated amplifier were supplied with 1600 volts from a three phase half wave rectifier using UX866 types; the 4000 volts required by the first and second power amplifiers was supplied by a three phase half wave rectifier using Philips 1763 valves while the 12000 volts for the final power amplifier was provided by a three phase double Y rectifier employing MR9 high vacuum type valves.

The design included a number of protective devices including individual fuses in all filament circuits and the primaries of the anode supply transformers, water flow alarms and interlocks, delay device to prevent application of anode voltage before filaments had been properly heated, overload relays in rectifier circuits, gate switch and a device to prevent filament power being removed before removal of the anode supply.

The Foreman Mechanic in charge of constructing and assembling the transmitter in Melbourne was Stan Hosken who joined the Engineering Branch of the Postmaster General's Department in 1914.

When Government approval was granted for the establishment of broadcasting in Australia using the Sealed Set Scheme in 1923, Stan was among a group of people who constructed receivers to meet the Regulation specifications at the time. However, the Sealed Set Scheme did not last long, and specifications were changed by the Department to allow receivers to tune across the broadcast band.

When the PMG's Department took over the A Class stations in 1929 to form the National Broadcasting Service, Stan transferred into the broadcasting area as Mechanic. In Melbourne, 3LO and 3AR became part of the NBS.

Included among his involvement in broadcasting were the construction of an early VLR short wave transmitter at Lyndhurst and a new transmitter for 6WF to replace the original long wave AWA transmitter installed in 1924 for Westralian Farmers Ltd.

Stan later became Foreman Mechanic at 3WV Dooen, the first station in Victoria to operate with an armature radiator when it was commissioned in 1937. One of the unusual operating features of the station was that it generated power on site to power the 10 kW transmitter.

When 3LO/3AR transmitters were brought together at a common site at Sydenham using a dual frequency radiator, Stan was the first Officer-in-Charge, and lived in the residence provided on the site. He retired from the Department on Christmas Eve 1954.

A West Australian Departmental staff member who had involvement with the original 6WF transmitter, and the subsequent replacement transmitter was Tom Dagnia. Tom began service with the Department in 1925 as Junior Mechanic-in-Training in Western Australia.

In 1930, he transferred to 6WF when the Department took over the station from Westralian Farmers Ltd. In 1932, he was a member of the installation team which replaced the original AWA transmitter with the PMG's Department Research Laboratories designed 3.6 kW unit and installed temporary studios for the ABC at Wanneroo.

Another of the original NBS staff at 6WF was Percy Eaton who began service with the Postmaster General's Department as a Telegraph Messenger during September 1925. However, Percy was more interested in a technical career as he had been interested in wireless during his early days at school.

An opportunity to sit for the Telephone Mechanic Examination became available, and after passing, he was appointed to the Telephone Workshops in Lord Street in 1928. The following year, he qualified as Mechanic Grade 2 and was transferred to the newly formed Radio Section as Shift Operator at the new Milligan Street studios, which were provided by the Department after 6WF facilities were taken over by the Government.

Percy spent a good deal of his time on OB work. The OB equipment was manufactured in the PMG's Department Workshops and was very heavy and bulky. The equipment was housed in solid wooden boxes and with the six volt accumulator, high tension batteries, portable telephone, equaliser, fader box, microphones and cords, the total weight was in excess of 35 kg.

In 1936, he was involved in the installation of 6WA Wagin. Several promotional steps resulted in him being appointed Supervising Technician in 1950 and subsequently OIC at the Hamersley Transmitting Centre where he was responsible for the operation of 6WF, 6WN and VLW. Percy remained at the Centre until his retirement in July 1975.

The PMG's Department staff also undertook major improvements and upgrading work at other metropolitan stations taken over from the A Class station operators. Some of the A Class station Chief Engineers had previously modified their transmitters in the five year period between commissioning about 1924 and transfer to the PMG's Department about 1929. Station 5CL in Adelaide is typical of the status of transmitters as existed at about 1932.

The original AWA transmitter was similar to the 5 kW models provided by the company for 4QG, 2FC, 3LO and 6WF. It commenced operation at the Brooklyn Park site in 1925 and on 7 June 1926 Central Broadcasters Ltd, operators of the station, appointed Harry Kauper as station Chief Engineer. He immediately set about improving the transmitter performance. It had experienced teething problems for some time since installation.

In August 1926, a new electrical switchboard manufactured locally by Newton, McLaren Ltd, replaced the original facility, and the following year the high power stage was completely remodelled using a water cooled valve in place of the air cooled multiple valve arrangement. The sub-modulator was also remodelled and a new neutralisation system installed to improve stability. This was followed by replacement of the 24 V and 1000 V motor generator sets.

The PMG's Department staff carried out further improvements from 1930, including conversion of the transmitter to high level modulation operation. As at 1932, the carrier was generated by an Osram MT7A valve operating as a master oscillator with the filament being heated by direct current from the main station 22 V motor generator unit. The master oscillator circuit was a conventional type circuit not employing a quartz crystal which by that time, had been introduced at most other stations. Feedback to the grid was controlled by a rotatable coil. Fine frequency adjustment was effected by operation of a small variometer in series with a fixed air tuning capacitor. The master oscillator valve and associated equipment were mounted in a cage enclosure with bakelite front panels. The oscillator was very stable with maximum deviation from the assigned frequency of 730 kHz being better than 800 Hz.

The filament of the modulated power amplifier using STC type 4220B valve was powered from the 22 V generator. It consumed 41 amperes at this voltage. The Heising choke was an oil filled reactor of 50 henries and capable of carrying 1.5 amperes direct current. It was connected to the anode lead from the main rectifier and was common to the modulator and modulated amplifier in the usual Heising connection.

The output circuit of the modulated amplifier consisted of an RF anode choke, a Leyden Jar glass plate stopping capacitor, a main anode inductor and a parallel connected fixed air capacitor. The aerial was connected through an aerial loading inductor to a coil inductively coupled to the main tuning inductor. Records indicate that power into the aerial during 1932-33 was 5000 watts.

The modulator tube was a Philips MA 12/15000 consuming 77 amperes at 22 V for the filament. The anode was normally operated at 10 kV. Voltage for grid bias of the modulator and modulated amplifier was supplied from a motor generator unit.

The main high tension rectifier utilised six Marconi-Osram MT7A valves connected in a conventional three phase double star circuit with an interphase reactor.

The anodes of the modulator and modulated amplifier were water cooled by a system comprising two 2730 litre tanks with one for each valve. The water circulated through an insulating coil on wooden formers and heat was removed by a Ford car radiator with fan, fitted to each system. Distilled water was used for removing the heat because problems were experienced with rain water passing over the anode of the Philips valve. The anode was chrome-iron alloy in place of copper normally used for anode jackets. Very hard deposits of zinc chromate formed on the anode when rain water was employed. The problem was accentuated by the use of galvanised pipes and tanks although no difficulty was experienced with the copper anode of the 4220B valve using the same cooling water.

When Central Broadcasters Ltd ceased operation and handed 5CL to the PMG's Department, the technical staff included Harry Kauper, Chief Engineer; John Ryan, Outside Broadcast Operator; Ken Bertram, Apprentice; Bill Maddocks, Control Operator; Darby Tostevin, Control Operator; Don Gooding, Station Operator; Len Porter, Station Operator; Bill Launder-Cridge, Station Operator; and Tom Welling, Station Operator.

At the time of takeover of the station, the PMG's Department was finding difficulty in generating work for its permanent telecommunications staff as a result of cutback in funds because of the bad economic situation of the nation during the Depression years.

South Australia had a particular employment problem, so the Department decided that it would not invite the Central Broadcasters Ltd staff of 5CL to transfer to the Department. Instead, decision was made that Departmental staff would take over responsibility for operation and maintenance of the studio and transmitter technical facilities.

The Central Broadcaster's staff were unhappy with the decision, particularly as the Department had offered Technical staff at 2BL Sydney and 3AR Melbourne the opportunity to transfer to the Department's permanent work force. The 5CL staff argued that, as they were permanent staff of Central Broadcasters Ltd, they should have been transferred to the Department with the technical plant. They also argued that as members of the Radio Telegraphists Institute of Australia, they were qualified to operate the technical plant, whereas Departmental staff were not members of the Institute, and further, had no experience in broadcast station technology.

However, to assist in the smooth transfer of the facilities and to obtain instruction in the operational techniques, Messrs Launder-Cridge, Welling, Gooding, Tostevin and Porter stayed on at 5CL as temporary employees for a period, before leaving to work with Commercial stations.

Bill Launder-Cridge moved to Tasmania to work at 7UV Ulverstone operated by Northern Tasmanian Broadcasters Pty Ltd. He played a major role in operation of the station occupying the positions of Station Manager, Announcer and Engineer.

Initially, staff of the local Radio Inspector's office took over operational responsibility until formation of a group of the Transmission Section of the Department was organised. The group was controlled by Divisional Engineer Frank O'Grady, assisted by Engineer Laurie Billan. Technical staff associated with the 5CL facilities and other early NBS stations in the State included: Nelson Stone, Tom Collins, Ted McGrath, Chris Comas, Cec Pike, Brian Blundell, Len Cooper, Bill Whisson, Jim Harris, Bill Miles, Charles Ancell, Pat Callinan, Bob Hamilton, Jock Anders, Claud Mann, Bert Retallick, George May, George Ramsay, Bert Lampe, Bill Smith, Alf Johns, Ron Nicholls, Ron Haines, Ted Holton, Al Smythe, Alf Cole, Roy Buckerfield, Morris Wallace, Jack Grivell, and others.

Some of these people later occupied senior positions in broadcasting in South Australia. They included Ted McGrath, Supervising Engineer Radio; Chris Comas, Superintendent Radio and Jack Grivell, OIC of the ABC studios.

In the case of 4QG in Brisbane, an early 1930 circuit indicates that a number of changes had been made to the original transmitter. These included changes to the main oscillator (modulated amplifier) and modulator circuits. The original MT7A oscillator valves were replaced by a single 4220B water cooled valve and the number of MT7B modulator valves were increased to 10 working valves plus two spare working sockets.

The work had been carried out by the station staff which included Fred Stevens, Chief Engineer; Ray McIntosh, Station Engineer; Cyril Moran, Harold Oxford, Charlie Stephenson, Alf Jackson and others.

When the PMG's Department took over, early staff associated with operations, modifications and upgrading included Reg Baker, Alf Bauer, Geoff Beetham, Ralph Bongers, George Carrier, Arthur Clark, Bert Cowling, Peter Dodds, Roy Ferguson, Nat Gould, Vince Henderson, Snow Hendry, Jim Hutchinson, Vern Kenna, Jack Loth, George Macfarlane, Cec Morris, George Olsen, Bill Rohde, Sam Ross, Jim Schofield, Hughie Thain, Jim Todd and others.

Officer-in-Charge was Arthur Clark. Ralph Bongers and then Jim Todd followed as Officer-in-Charge when Arthur Clark retired. Vern Kenna and Bill Rohde subsequently held senior positions in Broadcast Engineering with the National Broadcasting Service.

Vern Kenna joined the Postmaster General's Department in Brisbane as Junior Mechanic-in-Training in 1924. Following the reorganisation of the Australian broadcasting system in 1929, he was one of a group of Technical staff who took over 4QG from the Queensland Government in 1930.

Between 1934 and 1936, Vern worked in the Department's Research Laboratories, then at 59 Little Collins Street, Melbourne. He qualified as an Engineer in 1936, and was appointed to the Transmission Section, Brisbane. At about that time, the Department undertook a large program of work for other Departments for the provision of radio communication and navigation facilities along the Empire and New Guinea air routes. With the commencement of the War, these activities were extended to other areas including the British Solomon Islands. Vern participated in much of this work as well as essential wartime activities for the National Broadcasting Service, including the establishment of 9PA Port Moresby, and the dispersal of 4QG and 4QR from the Brisbane city area to Bald Hills.

In 1954, Vern transferred to Central Office, Melbourne to work on the establishment of Engineering facilities for the National Television Service. In 1961, he was appointed Controller of Technical Services in the Australian Broadcasting Commission and remained in that post until his retirement in 1968.

He acted as advisor to the Federation of Australian Radio Broadcasters and was their representative to the Medium Frequency Conference in Geneva in 1975.

Vern joined The Institution of Radio Engineers (Australia) as a Senior Member in 1953 and was elected Fellow in 1968. He served on Divisional Committees in Brisbane and Melbourne and was a member of The Institution's Council from 1962 and served as President 1968–69.

Bill Rohde signed on with the Postmaster General's Department as Junior Mechanic-in-Training on 29 April 1924. Two years prior to that, Bill had been bitten by the wireless bug and it hounded him for the greater part of his working life.

When the Department assumed responsibility for the control and operation of 4QG on 31 January 1930, Bill was directed to report to the station on 3 February 1930 to commence duty.

Thus began an association with broadcasting which continued until 1937, and included such highlights as arranging outside broadcast facilities for the arrival of the record breaking aviatrix Amy Johnson at Eagle Farm airport in 1930, visit of the Duke of Gloucester in March 1934, the Forster Cup yacht race in Moreton Bay in February 1936, and in 1931, the installation of 4RK Rockhampton, the first Regional station in Queensland.

From 1938 to 1953, Bill worked in the Transmission and Trunk Service areas, and in 1953 transferred back to broadcasting as Divisional Engineer, having qualified as Engineer in 1947. Bill found himself responsible for National Broadcasting Service stations and associated studios throughout Queensland, Papua and New Guinea. From 1961, as Supervision Engineer Radio, he exercised control of all radio services including sound broadcasting, television and radiocommunications during a period of unprecedented expansion and development, until his retirement on 7 December 1972.

Both Vern Kenna and Bill Rohde were for many years active members of the Wooloowin Radio Club which was in existence from 1924 until 1931. Vern was known to his friends as 'Marconi' because of his outstanding ability as a Radio Engineer while Bill was highly regarded as a specialist in receiver designs having constructed most of the well-known circuits of the mid 1920s.

When the Department's New South Wales staff took charge of 2BL transmitter located in a building on the top of a hill in Higgs Street, Coogee in 1929, they found the building in a dilapidated condition and the transmitter in need of much maintenance. Being close to the harbour and subjected to salt laden air, corrosion was a major problem throughout the transmitter and the aerial system. The building comprised two rooms barely large enough to accommodate the equipment and plant and with little room to allow staff to undertake maintenance work. One room housed the transmitter and the other accommodated rotating machinery. Noise from the machines was of such a high level that in the transmitter room which had no sound absorbing material in the walls, staff could not hear the radiated program with a loudspeaker. When studio operators suspected a problem at the transmitter, the staff had to use a pair of headphones heavily padded to keep out the external noise to check on the signal quality.

The station at the time closed down for one hour at 11 am to allow maintenance work to be undertaken. The majority of maintenance work was associated with the generating equipment, particularly in cleaning commutators. The EHT provided by the plant was 13000 volts.

The Department's Foreman Mechanic was Ted Mosely. One of the initial staff members was H A G Stanford who later became Officer-in-Charge of the ABC Forbes Street Studios for over 20 years.

After provision of the 2CO and 5CK 7 kW transmitters, STC produced 10 kW versions in their Sydney works for installation at National stations during 1936–37. The main change to the transmitter design was in the use of four 4220B type valves in a parallel push-pull configuration under Class B conditions.

The mid 1930s was one of great activity for the National Broadcasting Service. Eight new regional stations covering every State except South Australia, were constructed. They were: 7NT, August 1935; 3GI, October 1935; 2NR, July 1936; 4QN November 1936; 6WA, December 1936; 6GF, December 1936; 3WV, February 1937; and 2CR, April 1937.

Technical innovations embodied in the new stations included:

- 10 kilowatt power into the aerial at three of the stations. This was the highest power hitherto used in Australia.
- New form of radiating mast developed in the PMG's Department Research Laboratories and employed at four of the stations.
- Four of the stations were designed to an ultimate power of 30 kilowatts and three for 60 kilowatts, including the new radiating system.
- Stations 2CR, 3WV, 6WA and 4QN were energised entirely by local power generating plant.

The power plants at all four stations, except for some minor variations, were identical. They comprised typically, a pair of six cylinder Ruston and Hornsby 6VCR diesel engines designed for 180 horsepower at 600 RPM. The diesel engines were directly coupled to alternators designed and manufactured by the Brush Electrical Company. The alternators, type NS72 were rated at 133.5 kVA and produced a three phase line voltage of 415 volts. The Brush type 70S exciters were capable of producing 1.6 kW at 81 volts. The plants were built at the Ruston and Hornsby works in Lincoln, England over the period 1934–35.

The engines were started with the assistance of compressed air at 300 pounds per square inch contained in one cylinder per engine. The air cylinders had a capacity of 11 cubic feet with the compressor being driven by a Ruston and Hornsby vertical power starter. The machine used petrol as fuel, and the cylinder was water cooled.

The engine sets were mounted on massive concrete beds. Typical sizes were 17 ft (5.2 m) long, 6 ft (1.8 m) wide and 6 ft (1.8 m) deep, and were insulated from the building floor slab with blocks of cork. Fuel was passed through a De Laval centrifugal separator to separate out any water which may have been in the fuel.

At 2CR Cumnock, three external fuel tanks were provided. They were of standard corrugated iron construction similar to water tanks and were fitted with a sloping roof top and spiked cap. Size of each tank was 8 ft 2 inch (2.5 m) in diameter and 6 ft 2 inch (1.8 m) high. They sat in a trench away from the station building.

Care had to be taken to ensure metal holding tanks were not in contact with the soil. At some stations where fuel tanks had been buried in the ground the tanks soon became pitted as a result of RF currents. The holes allowed fuel to leak out and water to seep into the tank. Station 2CO Corowa was one of several stations where this problem occurred.

The supply of fuel to these isolated stations was not without its problems. For example, at 4QN the fuel was railed to a railway siding and then taken by truck to the station site. In order to cater for the 'wet' season of North Queensland which often caused the station to be isolated for long periods, an extra 2000 gallons of fuel in 40 gallon drums was brought in just before commencement of the rains. The station needed at least three months supply to ensure continuity of power generation. The station was eventually provided with its own fuel tanker and was able to bring in supplies direct from Townsville.

For supply of power to meet the needs of staff residences, mast lighting and local external lighting, a small auxiliary 7 horsepower Lister diesel generating set was provided.

In addition to Technical staff to operate and maintain the transmitter, Mechanics were employed to operate and maintain the power plant at each station.

All of the power plants were removed over the years, except for one set at 2CR where it was still in situ in 1993. However, as it did not meet the requirements of modern day transmitting equipment, it was not considered an operational unit.

In the case of 2CR, 3WV and 6WA, magnificent station buildings were constructed to house the transmitter as was the practice at many other station sites during the mid to late 1930s. Many are still standing today but not all house operational transmitters. Modern technology has enabled transmitters to be housed in small metal framed buildings with the facilities operating in an unattended mode.

At the time, these grand Art Deco style buildings with porte-cochere entrances built on 20 hectare sites housed transmitters, an office, lunch and change rooms, store room and a workshop area. In the case of 6WA, seventeen staff were employed and in addition to the main station building there were four staff houses and single men's quarters. Facilities also included underground water tanks, a tennis court and a cricket pitch.

In 1995, the transmitting plant which included four transmitters for Radio National and Regional Radio services was housed in a nearby small metal framed building from where underground feeders linked the main and standby aerial systems.

Although planning had allowed for transmitters of 60 kW power to be installed for the National service, no positive steps were taken to implement the proposal, and the technical press raised the issue on a number of occasions. They were far from happy when AWA manufactured a 60 kW transmitter in their Sydney workshops and commissioned it in New Zealand on 25 January 1937, giving New Zealand the distinction of operating the most powerful MF transmitter in the Southern Hemisphere. The transmitter employed ten water cooled valves in parallel in the final stage. The transmitter remained in service for some 23 years.

The ABC programmers were anxious to provide two sets of programs for all capital city listeners, but were restricted in that only Melbourne (3LO and 3AR) and Sydney (2BL and 2FC) had two transmitters. This problem was overcome between October 1937 and October 1938 with the commissioning of 5AN on 15 October 1937, 4QR on 7 January 1938, 7ZR on 22 June 1938 and 6WN on 12 October 1938. By 1939, stations 2FC, 3AR, 4QG, 5AN, 6WF and 7ZL were designated as transmitting the Australian National Program and the other metropolitan stations 2BL, 3LO, 4QR, 5CL, 6WN and 7ZR as the State National Program.

The 5AN Adelaide station, the first of the group to be commissioned, employed an STC transmitter, configured to provide 500 watt output was located in an annexe at the Adelaide Telephone Exchange building. It employed 4242A valves in the modulator, buffer and grid modulated amplifier stages and two 4279A valves in the final amplifier. Type 6C6 valves were used with the crystal oscillator and two sub-modulator stages. Rectifier systems comprised nine 872A HCMV and three 83V types. EHT was 3000 volts. Negative feedback was employed to the first audio amplifier resulting in maximum distortion of 2.5% at 96% modulation and frequency response of ±2.5 dB over the range 350 to 10000 Hz.

The radiator, a self-supporting insulated tower 62 m high was located on top of a building 24 m high adjacent to the Exchange building where the transmitter was installed. A counterpoise system consisting of some 25 radials varying in length from 10 m to 90 m extended to adjacent buildings. The copper feeder was an 80 ohm concentric type using an outer tube 25 mm diameter and an inner tube 6 mm diameter.

In 1944, the transmitter and radiator were transferred to Brooklyn Park and the transmitter output increased to 2000 watts by Ted McGrath with the installation of four 4279A triodes in push-pull parallel configuration in the power amplifier stage.

A 200 watt transmitter constructed locally by Al Smythe was employed as a standby unit.

Station 6WN Perth went to air with an STC transmitter of similar type to the 5AN model, producing 500 watts on 790 kHz. The transmitter was installed on the 6th Floor of the Perth GPO with a self-supporting 60 m tower on the roof and fed by a rigid 80 ohm line.

The outbreak of the Second World War with Japan in December 1941 led to the removal of the station to a less conspicuous location in bushland at the Mt Lawley Golf Course about 4 km north of the city site.

The transfer was achieved one night after transmission had ceased, with the station reopening on schedule next day. A 40 m timber mast was used at Mt Lawley with the dismantled steel structure from the GPO being placed in storage for later installation at 6GN Geraldton.

By 1946, the facilities had been transferred to a site near Canning Bridge and the transmitter power output increased to 1 kW.

In 1953, a further move took place when a 10 kW AWA type J50961 transmitter was installed at a site at Hamersley 12 km north of Perth where 6WN shared a building with 6WF and VLW/VLX. The STC 1 kW transmitter became a standby unit until 1953 when a new Philips 2 kW type 1656 was provided for this purpose.

In 1962, an STC 10 kW type 4-SU-64 transmitter replaced the AWA model which was reinstalled at 6DL Dalwallinu.

The 6WN callsign was later changed to 6RN and operated on 810 kHz.

Station Officer-in-Charge at 1994 was Derek Prosser, Technical Manager, Hamersley District, Telecom Broadcasting.

After being operation at 6DI from 1963 until 1972, the AWA 10 kW transmitter was placed in the Wireless Hill Telecommunications Museum where it was still on display in 1994.

The 4QR Brisbane installation carried out by Jack Loth and Roy Ferguson used a similar STC 500 watt transmitter to the 5AN and 6WN services. Transmitter output on 940 kHz was fed via an 80 ohm coaxial line to a 55 m high lattice steel self-supporting tower located on the roof of the Central Automatic Telephone Exchange building in Elizabeth Street. Technical staff from the studios in Penny's Building in Queen Street carried out maintenance functions.

With the establishment of General MacArthur's Headquarters a short distance from the transmitter and its prominent radiator, decision was taken to transfer the facility to Bald Hills where it fed into an 80 m bore casing aerial. Vern Kenna and Alf Howard were associated with the design of the radiator. Col Elworthy and Neil Scott carried out a field strength survey to check on the service area provided by the station. The radiator was fed by an 80 ohm air dielectric feeder, some 116 m in length.

On 25 October 1944, the transmitter output was increased to 2 kW.

In 1938, STC produced a new design of transmitter to meet a large order for more National station transmitters. The design was a departure from earlier designs in that it allowed for production line assembly rather than for individual tailor-made assembly. The transmitter was put together using a series of modules allowing the production of transmitters in sizes ranging from 100 watts to 10 kW. For 10 kW models which were supplied for 2CY, 2FC, 3LO, 3AR and 4QS, the output was provided by two separate units each capable of providing 5 kW and combining the outputs. This had a number of advantages, particularly the ability to keep the station operational in the event of failure of a valve or component in one of the units. Each 5 kW unit employed two 4220B and later, 4220C water cooled triodes in the final stage with provision for a third valve as standby. Power for these valves was supplied by six 4078A hot cathode mercury vapour valves in a three phase full wave rectifier configuration. As a result of unsatisfactory experience with an earlier design which used porcelain tubes in the water cooling system, rubber hoses were used instead in this design. Another major feature was the employment of negative feedback which resulted in substantial improvement in frequency response, lower distortion and a signal-to-noise ratio approaching 60 dB below the level corresponding to full modulation. Mains input power at full modulation was 55 kW and overall efficiency 27% as measured when 4QS was commissioned.

The transmitter was designated Type A513 and was available in two configurations, A513A and A513B. The difference between the two was that in one configuration, the units were arranged to progress left to right while the other progressed right to left. This enabled a symmetrical layout in the transmitter hall where two transmitters were installed. Transmitter front panel length was a little over 5 metres. This compared favourably with a panel length of some 9 metres for 10 kW transmitters manufactured by STC three years earlier.

The transmitter was contained in six cabinets installed in line, with the high tension rectifier for the final stage being located in a protective enclosure at the rear. The pumps and cooling radiator associated with the water cooled valves were located in another room or outside the main building usually with a roof shelter.

The transmitter consisted of a crystal controlled oscillator, two separator stages, a balanced modulated amplifier using four valves in parallel push-pull and a balanced power amplifier using four water cooled valves in parallel push-pull.

Modulation was applied to the grid of the modulated amplifier from a three stage resistance-capacitance coupled modulator using three triodes operating under Class A conditions. Stabilised reverse feedback was applied to the first speech amplifier valve from a feedback rectifier located in the modulator unit, and coupled to the output circuit.

Design and layout of the transmitter were such that it could operate as a complete transmitter producing 500 watts output from the modulated amplifier. The change to reduced power could be accomplished quickly by moving four links and resetting the modulated amplifier output coupling control.

The crystal oscillator was self-contained, comprising a crystal oven and thermostat. The circuit was an improved Pierce circuit with a small two ganged capacitor being connected from grid and anode to ground for fine tuning adjustment The valve was a 6C6 pentode connected as a triode. Carrier frequency stability was ± 10 parts per million.

The first separator employed type 4061A RF pentode valve tuned by a tapped coil and variable capacitor. The second separator operated with a type 4242A neutralised 100 watt triode valve tuned by a balanced tapped coil and a split stator variable capacitor. The output circuit was designed to operate into a series tuned circuit so that variations of the output coupling would not affect the tuning.

The modulator used a single 4242A, a radiation cooled 100 watt triode as a Class A amplifier resistance-capacitance coupled to the modulation choke. Neon voltage regulator lamps were connected across the choke to limit the modulation voltage to that required for 100% modulation so protecting components in subsequent stages from high modulation voltages.

The RF amplifier unit contained sockets for mounting either two or four type 4270A radiation cooled 500 watt valves, the tuned grid circuit, grid loading resistors, neutralising capacitors, anode tuning capacitors, choke and blocking capacitors and grid and anode current meters.

The unit was designed to deliver either 250 watts using two valves in push-pull or 500 watts using four valves in parallel push-pull. The lower power was adequate to drive a 5 kW amplifier but the full power was necessary for a 10 kW amplifier.

The final amplifier valve unit contained all RF circuits for a balanced 5 kW amplifier with the exception of the anode tuning and output coupling circuits. Two such circuits were operated in parallel to give 10 kW output. Sockets were provided for three water cooled valves type 4220B — later 4220C — with the centre socket being a spare with knife switch changeover facilities. The grid and anode current meters of this stage were individually fused to protect them against heavy overloads such as Rocky Point effect. Horn gaps were placed across each of the high voltage terminals to ground to protect the components against surges.

The output circuit unit contained the tuning and coupling circuits for use with the final RF units operating as a parallel 10 kW amplifier. The circuit was tuned by fixed capacitors and a tapped balanced tuning coil in series with the primary of the coupling coil. Fine tuning was carried out from the front panel by means of a rotatable short circulated turn. The secondary of the coupling coil was provided with two tappings, one to vary the coupling to the transmission line and the other for coupling to the feedback and monitoring rectifiers in the modulator unit. The secondary of the coupling circuit was tuned to series resonance by means of a tapped coil and a capacitor. This circuit also discriminated against the high order harmonics of the carrier frequency. A second harmonic filter suppressed the second harmonic.

The EHT rectifier comprised EHT transformer, 12 kV rectifier unit, filter choke and filter capacitors. The equipment was mounted inside an enclosure with the gate being provided with a switch interlocked with the EHT contactor. The rectifier used six 4078A valves in a three phase full wave Graetz connected circuit. One spare valve was mounted in position with cathode normally heated at a reduced voltage. The spare valve was brought into service by knife switch operation. Each valve was fitted with an arc-back indicator so that a defective valve could be quickly located and replaced. The EHT was switched on and off in three steps. The contactor applied 415 volts to the primary of the transformer through two banks of resistors.

A temperature control unit was provided with the valve unit to enable the rectifier to operate at maximum efficiency under wide range of ambient conditions.

Both the EHT transformer and filter choke were oil immersed types. Four filter capacitors each of 2 MFD capacity were connected in parallel and fused with a high voltage chemical fuse. These fuses which could be recharged had to be handled carefully as a sudden jar could damage the element.

High tension supplies for other sections of the transmitter were 400 volts provided by an 83 V thermionic rectifier, 1250 volts provided by two 866 HCMV valves and 3000 volts provided by three 872A HCMV valves.

Filament power for modulator and RF amplifier was supplied at 10 volts AC and for the final power amplifiers by transformers connected as a Scott pair giving filament voltages 90 degrees out of phase. The secondary windings were tapped to give 18, 20 and 22 volts with tappings on the primary to allow variations of plus or minus 2½% and plus or minus 5% of the secondary voltage. A 200 ohm resister tapped at 150, 100 and 20 ohms was connected in series with the high tension lead to each water cooled valve. These resistors served as a protection against Rocky Point effect in the water cooled valves.

The water cooling system was similar to models in earlier transmitter installations using distilled water or non polluted rainwater circulating in a closed system, with the actual cooling being performed by an air blast cooler of the copper fin type through which air was blown. The equipment including pumps, cooler and tank were designed for installation out of doors so the intake side of the fan was protected by a stiff wire guard over which was mounted a bronze wire screen to prevent the ingress of leaves, insects, etc

The artificial aerial supplied with the transmitter comprised a water cooled resistor, integrating water meter, inlet and outlet thermometers and insulating hose coils. The resistor element was a Cressall woven wire mat of 88 ohms total resistance with tappings enabling the resistance to be set at 80 ohms plus or minus 5%, and plus or minus 10%. Power output was calculated by observing the difference in reading between the inlet and outlet thermometers. The rate of flow of the cooling water was determined by observing the total quantity measured by the integrating water meter over a measured period of time.

An interesting change occurred in water cooled valve construction in a series of STC transmitters built in the late 1930s and early 1940s in that a double-ended SS1971 valve was used in place of the earlier 4220B type. The valve allowed the transmitters to be used in medium frequency and high frequency bands up to 22 mHz. The filament supply was provided by a bank of selenium rectifiers to produce 20 volts DC at 64 amps. The VLQ and 4QR transmitters installed at the Metropolitan Radio Centre, Bald Hills near Brisbane employed SS1971 and later, the replacement 3Q221E types during their periods of service. The VLQ transmitter was commissioned in 1943, while the 4QR unit began operation in 1947 and remained in service until 1963 when it was replaced by a 50 kW STC 4SU-38 model. Sydney station 2BL was also fitted with an MF version in 1946. These models had an overall efficiency of about 30%.

When new 10 kW transmitters were commissioned for 2FC and 3LO in October 1939, dual frequency radiators were employed for the first time. The design and construction of the electrical dividing networks to facilitate the use of a single radiator for two transmitters was carried out by PMG's Department staff in which Alec McKenzie and Reg Turner played a major role.

The new 2FC transmitter was installed at a site at Prestons near Liverpool. The other Sydney metropolitan transmitter 2BL, was later transferred to the same site and a new 10 kW transmitter installed. Output of 2BL had been increased to 3000 watts at its Coogee site during 1932–33.

Engineers associated with the work included Horrie Hyett, Eric Watt and Harry Weir. Horrie subsequently transferred to the Department's Headquarters in Melbourne to head the Radio Section.

One of the Technical staff associated with the Prestons installation work and later maintenance of the complex was Wally Clair. Wally commenced work with the PMG's Department in August 1924 as Telegraph Messenger, delivering telegrams in Mosman. His ambition was to enter the Technical area of the Department's activities. He was later successful at an entrance examination for Junior Mechanic-in-Training. The course proceeded smoothly until the fourth year when the economy of the country hit rock bottom as a result of the Depression. The PMG's Department Training School was an early casualty and closed. Trainees were transferred to other duties. In due course, Wally found himself on the staff of the 2FC/2BL studios on outside broadcast duties. His experience widened to other areas in the studios including studio maintenance and control room duties. He passed the Open Mechanics examination, and was appointed Mechanic in 1935. In 1938, when work began on the establishment of the transmitting station at Prestons for 2FC, Wally transferred to the installation staff. On completion of installation activities he was appointed as a member of the maintenance team and remained at the station until retirement in October 1971. Wally saw the centre grow to include 2BL and the High Frequency Inland Service VLI, and both 2FC and 2BL being upgraded to 50 kW transmitters in 1962.

Since establishment of the 2FC/2BL complex in 1938, Officers-in-Charge of the facilities up to mid 1992 have included Arch Pirie, George (Charlie) Youngston, Keith Lovejoy, Roy Deal, Harry Harris, Len Greenway, Peter Vine, Alex Hanlon and David Wright.

With the opening of the 10 kW station 2CY in Canberra on 23 December 1938, residents of the Australian Capital Territory for the first time received ABC programs from a transmitter based in the Territory. A second National transmitter in the ACT did not become available until January 1953 when 2CN was commissioned with a 2 kW transmitter. The installation and initial maintenance staff of 2CY included Stan Bancroft, Hugh Dixon, Reg Feurro, Ron Hughes, Bob Jones, Jim Lahiff, Vic Le Pla, Tom Ryan and others.

The old transmitter at 7ZL Hobart hitherto providing the city National service was replaced by a new transmitter on 1 July 1939. The new transmitter was manufactured by Transmission Equipment Co., and installed by PMG's Department staff. It comprised a crystal oscillator, two buffer stages, power amplifier, two sub-modulator stages and modulator. The Class C modulated amplifier and the modulator stage both employed TA/2000 type valves. EHT of 12 kV for power amplifier and modulator was supplied by a rectifying system employing six DCG 5/2500 type valves. Early operational staff at 7ZL included T Edwards, E G Shelton, Max Loveless, Joe Brown and others.

There then remained only one of the original transmitters of the 1928 regime when the Department took over the A Class stations. That was the 4QG transmitter in Brisbane, located in the centre of the city.

At the outbreak of the Second World War, both National stations — 4QG and 4QR — had their radiators located on buildings in the city and with the establishment of General MacArthur's Headquarters in the central business area, it was considered prudent to shift the stations to an outer suburban site.

A lease was arranged for use of the former Commercial station 4BH site together with the building and T type aerial at Bald Hills. A 500 watt transmitter was assembled using components and parts available locally, and transmissions from the new site commenced on 16 April 1942.

The 500 watt 4QR transmitter had been removed on 23 March 1942 from its room on the top floor of the Automatic Telephone Exchange Building to another Bald Hills site which was planned to be the Metropolitan Radio Centre to locate all Brisbane based NBS transmitters. The aerial was an 80 m bore casing type designed and constructed locally. Field strength measurements indicated that the bore casing aerial was more efficient than the T aerial used by 4QG. The bore casing aerial gave a figure of merit of 175 millivolts per metre for one kilowatt input whereas the T aerial gave a figure of merit of 120 at the operating frequency.

As 4QG programs were considered to be more important than 4QR, the program circuits were rearranged so that the 4QR programs were transmitted using the leased site installation, while the 4QG programs were transmitted from the other Bald Hills site with the bore casing aerial.

However, the arrangement did not last for long. A 5 kW linear amplifier was assembled and added to the 500 watt transmitter at the leased site and 4QG programs returned to the site on 7 September 1943. Subsequently, the 4QR transmitter was increased to 2 kW.

The 4QR 2 kW transmitter was later replaced by an STC type A880D 10 kW water cooled type. The transmitter was one of the last of the series, and employed valves types 4061A pentode as crystal oscillator and following amplifier; 4282B as first buffer, second buffer and modulated amplifier; 4279Z as first RF linear amplifier and two parallel connected SS1971 water cooled triodes as final amplifier. The audio section employed two 4046A pentode stages driving a 4212E modulator which provided low level anode modulation to the modulated amplifier. The EHT power section used HCMV 4078 types.

The STC A880D transmitter was later replaced by an STC 4SU-11A 10 kW model until a new STC 4SU-38 50 kW transmitter was commissioned for 4QR in May 1963. The 4SU-11A then became a standby, but in 1988 was diverted to Parliamentary broadcasts, and a 2 kW Philips transmitter Model 1656 provided as 4QR standby.

In June 1992, the STC 50 kW 4QR valve transmitter was replaced by a pair of Nautel 25 kW solid state transmitters. The installation was carried out by Richard Womack, Dave Boreham, Paul Valentine, Paul Davies and Grant Beaumont.

After the War, facilities were installed to provide a new transmitter for 4QG at the Metropolitan Radio Centre site. An STC 4SU-11A 10 kW transmitter was commissioned with both 4QG and 4QR working into a new 198 m dual frequency radiator from 1 September 1948. Valves employed with the 4SU-11A included 6V6G as crystal oscillator followed by isolator stage also with 6V6G, 807 buffer two TG10 in push-pull as driver stage, with a push-pull pair of forced air cooled 3J221E triodes as the final stage. The audio section included push-pull throughout using 6J7G, 6V6G, 3C/150A, TG10 and 3J221E types. Later, when some types were difficult to obtain for maintenance purposes, the TG/10 was replaced by 5T30 and the 3J221E by TBL12/25 types. The original 12 kV EHT stage employed HCMV 4078Z diodes while the Minor HT stage was equipped with HCMV 872A diodes. These were both later replaced with stacks of silicon diodes.

In February 1963, 4QG was provided with a new STC type 4SU-64, 10 kW main transmitter and a 4SU-14, 2 kW standby unit. The 4SU-64 employed three 3X2500A3 valves in parallel in the final stage and a pair of the same type in the modulator.

Many staff have been associated with the operation, installation and upgrading works at the Bald Hills Radio Centre over the years since its establishment. They include Dan Baxter, Geoff Beetham, Clarrie Boettcher, Bob Browne, Otto Burmester, Arthur Burton, Ian Byrnes, Arthur Clark, George Coley, Colin Elworthy, Gordon Gilbert, Bill Graham-Wilson, Bill Grambauer, Vince Griffin, Bob Hansen, Mick Hall, Vince Henderson, Vern Kenna, Bill Krebs, Dave Laing, Cec Morris, Tony O'Brien, Mick Pike, George Richards, Bill Rohde, Jack Ross, Doug Sanderson, John Searle, Frank Sharp, Jim Todd, Bill Williamson and others.

The first Officer-in-Charge of the Centre was Harry Conway, who was appointed to the position in 1942. Harry had previously worked at regional stations 4RK Rockhampton and 4QS Dalby. He was followed by Gordon Andrews, Col Hattersley, George Marshall and Nev Cole.

The National service continued to expand to meet the program requirements of the ABC and the introduction of new program outlets resulting in the provision of many additional transmitters by the PMG's Department/Telecom and studios by the ABC. By mid 1991 there were five main radio services using the outlets of some 400 transmitters. These services comprised Metropolitan Radio in all State capitals, Canberra, Newcastle and Darwin; Regional Radio studios and outposts located at more than 40 regional centres; Radio National, a nationally networked service; ABC-FM, a national network devoted to music and performance and Triple J, an FM youth network broadcast from transmitters in all State capital cities, Canberra and Darwin, and domestic short wave. To assist in radio program and interchange activities, the ABC had 21 regional satellite earth stations in operation.

The initial stations which formed the National Broadcasting Service in 1929 were taken over from operators of A Class stations. From that beginning, expansion of the network resulted from installation activities of the PMG's Department and later Telecom, with the exception of some isolated cases including 4AT Atherton and 5DR Darwin which were originally established by others.

Station 4AT was operated by Atherton Tablelands Broadcasters Pty Ltd, and was commissioned on 15 February 1939, with a studio and transmitter located at Malanda Road about 8 km east of Atherton. The same building also served as an office, and to improve the isolation of the studio from noise generated in other parts of the building, the studio wooden floor was packed with a 100 mm layer of sawdust between floorboards.

The transmitter was a 500 watt AWA type J4825 with four 805 valves in parallel push-pull in the modulated amplifier, and operated on 680 kHz. The aerial was a quarter wave vertical steel pipe system fed by a two wire 600 ohm transmission line.

Station Chief Engineer was Ambrose Armistead who also undertook program production and Announcing duties. Prior to appointment at 4AT he had been on the Technical staff of 2HD Newcastle.

On 8 January 1941, the station was closed down under National Security Regulations and the licence revoked. As from 27 January 1941, the station was taken over by the PMG's Department and incorporated in the National Broadcasting Service with Alf Walker being the first Officer-in-Charge.

Other Commercial stations which were closed down at the same time by order of the Chief of the Naval Staff who was the authorised officer for the purpose of the Wireless Stations Control Order in the National Security Regulations were 5AU Port Augusta, 5KA Adelaide and 2HD Newcastle. The Postmaster General revoked the licences. However, only 4AT was taken over and incorporated in the NBS. The others reopened some years later as Commercial stations but under different management.

Station 5DR Darwin, although constructed by the PMG's Department under Ted McGrath, was commissioned on 11 February 1945, and operated by the Australian Army Amenities Service using a Tasma BC200 transmitter providing 200 watts into a centre fed flat top aerial. The transmitting and studio facilities were located at Cemetery Plains with a Receiving Station at Leanyah Swamp for rebroadcast of BBC and Radio Australia programs. Technical OIC was Sergeant Alf Cole, a former Departmental Officer in South Australia.

As from 12 March 1947, the station was incorporated into the National Broadcasting Service with programs provided by ABC Darwin based staff. The transmitting and receiving facilities were relocated to sites closer to Darwin but more up-to-date studio equipment was installed.

Although not part of the National Broadcasting Service, the Berry Springs Emergency Broadcasting Station located 33 km south of Darwin is an interesting example of a complete station erected purely for emergency purposes.

The station was approved in July 1963 as a Civil Defence objective to provide broadcasts to the public in emergency conditions. Emergencies at the time were thought to be major or sporadic attacks using conventional or nuclear weapons. However, following experience as a result of Cyclone Tracy in 1974, the role of the station was expanded to include natural disasters.

When originally commissioned in November 1968, a studio was established in a bunker in Bishop Street, Darwin and connected to the transmitter by UHF radio link. Facilities in the bunker studio comprised minimal equipment including microphone, tape and disc replay facilities and emergency power plant.

The transmitter was an AWA BTM2 transmitter providing 2.5 kW into a top loaded 60 m high vertical radiator. Power was provided by a 15 kVA diesel generator set. The transmitting station also included basic studio facilities to allow provision of programs from the site. The complete facilities were provided and commissioned by South Australian Telecom Broadcasting staff. David Young was Engineer responsible for the project.

Cyclone Tracy in 1974 was the real test of the facilities. The studio bunker in Darwin was put out of action so disabling the studio facilities.

Counter disaster plans subsequently formulated, required the facilities to be staffed and tested in a staged plan.

The facility was transferred to the Department of Northern Australia in 1975 and later to the Northern Territory Government.

The transmitter was set up on the 8DR frequency of 657 kHz so that the station would provide an alternative outlet should 8DR be put out of operation.

The local Darwin Telecom Broadcasting staff maintained the facility until June 1991 when it was decommissioned as a broadcasting station and the site transferred to the Northern Territory Police.

Although the designation National Broadcasting Service (NBS) was originally applied to the technical broadcasting facilities used to transmit programs generated by the Australian Broadcasting Commission and later the Australian Broadcasting Corporation, with the establishment of the National Transmission Agency (NTA) in 1992, it lost its original meaning. National broadcasting services now include services carrying the programs of the Australian Broadcasting Corporation, The Special Broadcasting Service and the Parliamentary Broadcasting Network. In the Radio and Television Broadcasting Stations book published in 1993 by the Australian Broadcasting Authority, the stations are categorised as National ABC, National SBS and National PB. At 30 June 1996, they numbered National ABC, 576; National SBS, 13 and National PB, 8.

NBS Technical Services

When the A Class stations began transmissions from 1923, all of the technical facilities were operated by the companies who owned the stations. This was similar to the practice at the B Class stations.

This practice continued up to the stage when the Government acquired the A Class stations in 1929 to form the National Broadcasting Service.

Under the new arrangements, control of programs and the technical facilities were separated, with the Australian Broadcasting Company Ltd, being formed to provide the programs and the Postmaster General's Department being responsible for operation and provision of all the studio and outside broadcast equipment, transmitting plant and program lines.

Technical staff of the A Class stations were given the opportunity of transferring to the PMG's Department, but very few took up the offer. Those who left soon found employment with B Class stations.

When the Australian Broadcasting Commission was formed in 1932 to take over program responsibility from the Australian Broadcasting Company Ltd, this divided responsibility continued.

Two of the State Managers of the new Commission were men with a technical background and they were far from happy with the arrangement, and made their views known on a number of occasions.

Thomas Bearup, Victoria Manager, had been associated with the technical aspects of radio since 1916 when he joined AWA Ltd. He had studied developments in Broadcast Engineering in England and joined 2FC on commissioning of that station in December 1923. He later spent five years with the AWA Research Laboratories. When the Australian Broadcasting Company Ltd, was formed in 1929, he was appointed Studio Manager of 3LO/3AR in Melbourne .On establishment of the Australian Broadcasting Commission in July 1932 he became Victorian Manager. He later became Assistant General Manager of the ABC and during 1940–43 acted as General Manager.

John Robinson was an early wireless experimenter, a graduate of the Marconi School of Wireless in Sydney, co-author of the book 'Wireless' and in 1923 became Assistant Manager 2FC. He was appointed by the Queensland Government to set up 4QG and remained as Manager until the station was acquired by the Commonwealth Government for the National Broadcasting Service. He then became Queensland Manager of the Australian Broadcasting Company Ltd, and in 1932 transferred to become the first Queensland Manager of the Australian Broadcasting Commission. He resigned in January 1934 following a disagreement with the ABC's General Manager.

The fact that the ABC program and management staff had no control over the Technical staff, particularly in relation to its studio and outside broadcast activities was the cause of a great deal of friction at all levels, and the Commission made repeated representations to the Postmaster General to have the role of the PMG's Department changed.

A major problem of concern to the ABC program professionals was that they could spend almost a full day on rehearsal for an important evening concert broadcast, liaising with the Technician on such matters as microphone placement, balance, levels, switching sequences, and generally fine tuning, to ensure there would be no last minute difficulties, only to find that another Technician had been rostered on, to operate the controls when the actual broadcast took place.

The arrangement whereby the PMG's Department was to be responsible for the technical facilities when the National Broadcasting Service was formed, was the brainchild of H P (Harry) Brown, the Director General of the Post Office, and he vigorously opposed any change every time the ABC or others raised the matter. If the Commissioners of the ABC had their way, they would have employed their own Engineers and Technicians rather than relying entirely on staff of the PMG's Department, who were assigned to the ABC studios.

In 1939, the Commission made a particularly strong case to the Minister for change. The Minister was indeed impressed with the submission, but he was reluctant to take on Brown, the Head of his Department.

Senior staff of the ABC considered that their absence of control of the technical facilities was a major handicap in the Commission's long struggle towards professionalism. They were seldom consulted about Announcer's desk designs and layouts, and facilities added from time-to-time for technical reasons, was a constant irritation to Announcers. The situation was aggravated by the PMG's Department's policy in always referring to the service as the National Broadcasting Service, giving the inference that the ABC was only an apparent appendage to the broadcasting service. Also, many ABC Producers and Supervisors knew very little of the qualifications and expertise of the Technical staff in the control rooms and at OB points. They were an unwanted intrusion, and some ABC staff had an ever present fear that the Operator at the mixing panel was a hazard to be watched, as he might ruin a live play or a symphony orchestra broadcast because of lack of the finer points of balance, music appreciation and other factors in which the ABC people specialised.

In 1940–42, a Joint Parliamentary Committee on Broadcasting looked into the matter of control of technical facilities following pressure by the ABC but the Committee was unanimous in recommending that the matter be left as it was. However, many years later with the coming of television, the ABC was successful in gaining control of at least the studio technical facilities and staff. This left the way open to eventually take control of the radio sound studios in 1964.

In 1976, the Commission recommended to the Green Inquiry into Broadcasting that responsibility for control of the National transmitting stations be transferred to the Commission. The Inquiry rejected the proposal.

During 1980, a Committee of Review of the Australian Broadcasting Commission under Chairman Mr A T Dix was set up to examine and report on the services, policies and performances of the Commission. Included in the Commission's submission to the Committee was a strong recommendation for the ABC to be given responsibility for the provision, maintenance and operation of the transmitters used to broadcast the ABC's programs.

Their reasons included the following:

- The ABC already had among its staff, Engineers and Technicians who had had experience with the former PMG's Department, the BBC and transmitter manufacturers.
- It could be expected that Engineers and Technicians of Telecom's Broadcasting group would transfer to the ABC as was

the case in 1964 when the ABC took control of the studio technical facilities.

- A pool of mobile Technicians would be established to maintain remote country transmitters.
- The efficiency of operating the National Broadcasting Service would be increased by transferring the separate functions carried out by the Post and Telecommunications Department and Telecom to the ABC.
- The ABC's control of its own transmitters would strengthen the Commission's independence as the national broadcasting authority and place it in a similar position to overseas organisations such as the BBC and CBC which controlled their own transmitting facilities.
- It was a source of embarrassment on the international front, that at conferences, the ABC could not participate in discussions about transmission matters. A Telecom Engineer had to be included in the ABC delegation.

However, 60 odd years on, the control of the transmitting facilities was still in the hands of others, and when the Government announced in October 1991 that it was establishing the National Transmission Agency (NTA) as a separate cost control centre within the Department of Transport and Communications to manage the National transmission facilities, The ABC Board was not entirely happy with the plan. Although the Board shared the Government's objective in endeavouring to achieve a more efficient operation of its transmission facilities, the Board remained committed to its position that the ABC should own and operate its own transmitters as provided in the ABC Act.

In its 1995-96 Annual Report, the Corporation commented on the fact that the ABC did not own or operate the transmitters which carried its programs but predicted that the situation may change in the future with the Federal Government indicating that the ABC will be provided with funding for transmission.

In assessing the performance of the ABC's operation against objectives, strategies and performance indicators of the Corporate Plan 1995-98 in relation to Technology and Infrastructure, the Corporation saw the outcome for 1995-96 as being one where the ABC advanced its position in regard to control over the transmission of ABC services. It saw its future direction as being to 'pursue the best transmission option in light of Government announcements regarding the provision of transmission funds to the Corporation and the proposed sale of the National transmission network'. The Government subsequently agreed to provide the ABC with funds for the transmission network as from July 1998.

Control of the transmission facilities for Radio Australia, the ABC's international service was conducted under the same arrangement as the National service and although many reports from groups and individuals who investigated various aspects of Radio Australia operations recommended that the ABC be given control of the technical transmission facilities, nothing changed. In an independent review by Dr Rod Tiffen in 1994-95 he referred to the arrangement as an 'institutional absurdity'.

With the changed role of the PMG's Department and establishment of Telecom Australia in 1975, the transmitting function of the NBS continued to be carried out by Radio Sections in the major States with the State offices being oversighted by a Central Office Radio Section located in Melbourne.

In 1983, a Broadcasting Directorate was established in Melbourne with activities in the States being controlled by Regional or State Broadcasting Managers. In 1989, the Broadcasting Directorate became the Broadcasting Division with a further change taking place in mid 1992 when the organisation became Telecom Broadcasting. As from 1 July 1995, Telecom Australia became Telstra, its legal and overseas trading name since 1993, and the broadcasting group became known as Telstra Broadcasting.

In mid 1992, the staff of Telecom Broadcasting including National and State offices comprised some 53 Engineers, 419 Technical staff and Artisans, 77 Communications Officers and 16 Drafting Officers plus administrative staff engaged in radio broadcasting and television activities. Radio broadcasting transmitters being serviced for the ABC increased annually and by mid 1992 totalled about 526 plus 14 Radio Australia transmitters.

The National Office of Telecom Broadcasting was headed by Leon Sebire AM, General Manager. Les Rodgers was Deputy General Manager with Branch and Technical Section Heads including Robin Blair, Head Broadcasting Development Branch; Roy Badrock, Head Broadcasting Operations Branch; Giff Hatfield, Operational Studies; Terry Said, Operational Services; John Webb, Provincial Services; Gordon Evans, Engineering Studies; John Bray, Head Engineering Services Section; Bruce Cook, Structures; Gary France, Buildings, Site and Power; Steve Perich, Facilities Co-ordinator; Alex Brown, External Plant Practices; Dave Duffy, Network Management; Ian Albury, Equipment Evaluation and Collective Schedule; Chris Dobson, Daily Operations; Mike Dallimore, and Terry McManus.

Regional Managers (RM) and State Broadcasting Managers (SBM) and their Technical Section Heads included:

- Mike Stevens (RM), Vic Audet and Ron Johnson, New South Wales.
- John Hodgson (RM), Ken Johnston and David Duffin, Victoria.
- Brian Cleary (RM), Greg Duncan and Graeme Christie, Queensland.
- Brian Hey (SBM), John O'Mara and Milton Cunningham, Tasmania.
- Bill Edwards (RM), Les Chidgey and Ivor Chapman, Western Australia.
- Graham Shaw (RM), Wayne Croft, Murray Fopp and Barrie Morton, South Australia and Northern Territory.

During July 1992, a reorganisation took place within Telecom Broadcasting resulting in National Office in Melbourne assuming control of all major activities previously handled in the States.

With Leon Sebire, AM as General Manager, Heads of the various technical groups included Les Rodgers, Engineering and Construction; Brian Cleary, Operations; and Graham Shaw, Business Development and Strategy. Regional Operations Managers comprised Barrie Morton, Queensland; Mike Stevens, New South Wales; Rod McKinnon, Victoria/Tasmania; Murray Fopp, South Australia/Northern Territory; and Bill Edwards, Western Australia. Senior Engineering staff in the Engineering and Construction group included John Hodgson, Robin Blair, Mike Dallimore, Gary France, John Webb and Terry McManus in Melbourne National Office, and Vic Audet, NSW; Graham Smith, Vic/Tas; Greg Duncan, Qld; Wayne Croft, SA/NT; and Les Chidgey, WA.

By April 1993, changes which had taken place included Ken Moore, Regional Operations Manager, New South Wales and Geoff Jones, Regional Operations Manager, Western Australia.

Leon Sebire, General Manager of Telecom Broadcasting, began retirement leave in 1993 after 37 years service with the Postmaster General's Department and Telecom Australia.

He commenced his career in radio on the production line at Radio Corporation, Melbourne. He later transferred to Steanes Sound Systems, West Melbourne and at the same time commenced night classes at the Melbourne Technical College, eventually graduating with a Radio Engineering Diploma. He also obtained a First Class Commercial Wireless Operators Certificate from Marconi School of Wireless and served a period at sea as a Ship's Wireless Operator.

Leon was appointed as an Engineer to the then Department of Defence Production during the Korean War, where his duties were concerned with the development of high reliability electronic components and environmental testing equipment for Services radio equipment. In 1956, the Department was absorbed into the Department of Supply and the staff transferred to Canberra whereupon he transferred to Head Office Radio Section of the PMG's Department at Jolimont.

Initially working in the MF Construction Division, his early tasks were concerned with transmitter power increases to 50 kW at major regional and capital city stations, aerial system designs and the development of a new range of low power stations operating for the first time on an unattended basis.

Moving to the radiocommunications area in the early 1960s, his most notable projects were the establishment of the Alice Springs HF Radio Subscriber Network and the Darwin-Gove tropospheric scatter system.

Transferring to television activities in the late 1960s, one of his major contributions was the development of the National Television Development Plan.

In 1976, he was promoted as Head of the then Broadcasting Branch of Telecom. He converted the organisation to a largely free-standing business Directorate in 1983, becoming its first Director until 1988, when it was re-styled a Business Division and he became General Manager.

Over the years, Leon was very active in International broadcasting forums where he delivered more than 100 papers and lectures on broadcasting subjects of topical interest. He was well-known and highly regarded within the Commonwealth Broadcasting Association and the Asia-Pacific Broadcasting Union.

In 1991, his contribution to the development of telecommunications, and particularly broadcasting, was recognised when he was made a Member of the Order of Australia (AM).

Les Rodgers became General Manager Broadcasting on the retirement of Leon Sebire.

Les Rodgers began his career in the Postmaster General's Department as Technician-in-Training in January 1951. He was advanced as Technician in 1955, and qualified as Senior Technician the following year.

Les worked almost exclusively in broadcasting as a Technical Officer, except for a short period tracking satellites at Island Lagoon, Woomera in 1962.

He was a member of the team which installed ABDQ3, the first Country National TV station in Queensland in 1963. He worked as a maintenance Shift Leader at the station until 1966 when he was appointed Trainee Engineer.

Les graduated as Engineer at the Queensland Institute of Technology in 1970 and worked as a Broadcast Engineer until 1975 when he transferred to other areas including Radiocommunications Operations and Construction, and Transmission and Trunk Network Planning.

After a period as Acting State Broadcasting Manager, Queensland, he transferred to Victoria to take up appointment as State Broadcasting Manager, Victoria on 1 May 1986.

Following the retirement of Les Rodgers as General Manager Broadcasting, a reorganisation took place which effectively divided broadcasting into separate construction and operations groups.

With the division by the National Transmission Agency of the National network into two areas of control for operations purposes, Telstra was awarded an Operations and Maintenance Contract covering the transmission facilities in Western Australia, New South Wales/Australian Capital Territory and Victoria/Tasmania. Telstra's National Manager Broadcasting at the time, Ray Vicino signed the Contract on behalf of Telstra. Operations and Maintenance Contacts for Queensland and South Australia/Northern Territory were awarded to Broadcast Communications Ltd.

In mid 1998, senior staff of the Telstra Media and Broadcasting group included Barrie Morton, Bob Gilliard, Mike Dallimore, Allan Wright, Steve Caswell, Ian Albury, Doug Brodie, Rod McKinnon, Doug McArthur, Terry McManus, Mark Stevens, Glen Moore and Bruce Wilson in Victoria; Geoff Jones, Peter Weider, Fraser Watson, Terry Sellner and Ross Kearney in Western Australia; Ken Moore, David Wright, Mahammad Bardouh, Max Whitford and Bill Metcalfe in New South Wales; Tom Mitchell in the Australian Capital Territory; Ian Campbell and Barry Riseley in Tasmania; Graham Baker, Northern Territory; and Jim Quabba in Queensland.

Since the formation of the National Broadcasting Service in 1929, a large number of people have been associated with the planning, design, installation, commissioning and operation of the technical facilities. A full listing of all Postmaster General's Department/Telecom/Telstra Technical, Communications Officers, Trades Groups and Engineers involved would be difficult to prepare. However, a listing of Professional Engineers to mid 1994 would include the following:

Dave Abbot, Hector Adams, Abe Ajzeman, Pat Alessandrini, Tom Allen, Albert Ambery, Don Anderson, Ted Ashwin, Vic Audet, Roy Badenach, Roy Badrock, Graham Baker, Ross Baker, Peter Barnes, John Bartlett, Bob Barton, Bill Beard, Arthur Bensley, John Bigeni, Stan Bickerdyke, Laurie Billin, Lindsay Birch, Robin Blair, Mark Borgas, Kevin Bourke, Bill Boyle, Reg Boyle, John Bray, Mick Bridle, Doug Brooke, Eric Brooker, Bob Brown, Fred Brown, Ron Buckland, Ross Burbidge, Jack Burgesson, Rudolph Buring, John Burton, Tony Byczynski, Anthony Cafarella, Ken Caldwell, Jock Campbell, Greg Candy, Barry Carlson, Len Caudle, Robert Cecchini, Max Chadwick, Dave Charrett, Alex Cherncichev, Wayne Chew, Les Chidgey, Paul Chippendale, Tech Chua, Peter Ciblis, Ross Clemens, Doug Cliff, Alex Cohen, Ken Constable, Bruce Cook, Doug Cook, Chris Cooper, Wayne Croft, Fred Cromie, John Crossingham, Rod Cunningham, Ted Curtis, Tom Dagnia, Mike Dallimore, Jenny Datskevich, John Day, Leon Defina, Milan Delac, Lawrie Derrick, Carl Dillon, Stasha Dobrynska, Peter Dodds, Gavin Dorr, Greg Dowling, Greg Duncan, Doug Dunn, Frank Dwyer, Charles Edmonds, Andrew Edwards, Arthur Edwards, Terry Elkins, Austin Ellis, Dave Ellis, Colin Elworthy, Ken Endacott, Gordon Evans, Ron Falkenberg, Charles Farah, Alex Feder, Keith Ferres, Leon Firestone, Brian Foster, Alan Fowler, Gary France, Norm Franke, Des Fulton, Allan Garner, Max Gill, Bob Girdwood, Tom Glass, Bill Gold, David Gosden, Trevor Gower, Doug Grant, Greg Grant, Henry Grant, Don Grey, Vince Griffin, Ralph Gurner, Hans Haagensen, Fred Hailstone, Alan Haime, Brian Hall, Mick Hall, Ken Hamilton, Brian Hammond, Tom Harrison, John Hart, Eric Harvey, Mark Harwood, Giff Hatfield, West Hatfield, Norm Hayes, Rick Hayllar, Kirk Hearder, Keith Henderson, Les Heritage, Murray Higgins, Ian Hill, John Hodgson, Peter Holt, Trevor Housley, Neil Howard, Jim Hutchinson, Horrie Hyett, David Ingham, Karina Ishak, Frank Jackson, David Johns, Ken Johnston, Sam Jones, Boen Jong, George Joosten, Chas Karliner, Harry Kaye, Peter Kelleher, Jim Kemp, Vern Kenna, Ted Kennewell, Joe Kilgariff, John Kornacki, Ron Kitchenn, Joe Kwong, Jack Kyne, John Lamprey, Volker Lange, Kent Lechmere, Roger Lees, Len Liang, David Lim, Chris Lin, Hans Lockhart, John Lush, Bryan Madeley, Tony Magris, Bruce Mair, Keith Malcolm, Jack Mead, John Metcalf-Moore, Robert Mews, Wolfgang Micke, Mick Miller, Steve Minz, Leo Moloney, Simon Moorhead, Len Mor, Frank Mullins, Noel Murphy, Hugh Murray, Ian McBryde, Alan McCarthy, Allan McCleary, John McCulloch, Don McDonald, Joe McDonough, Bruce McGowan, Ted McGrath, Alan McIntosh, Glen McIntosh, Alec McKenzie, Terry McManus, Staunton McNamara, David Naismith, Ken Newham, Les Nicholls, Frank Norman, Martin O'Donohue, Frank O'Grady, John O'Mara, Kim Ong, Jack O'Shannassy, Albert Ozolins, Janis Ozolins, Bill Papadatos, Lionel Parker, Tom Pascoe, Rob Payton, Steve Perich, Brian Perkins, Bill Pike, Ray Pontague, Tom Potter, Alan Poulsen, Eddie Powe, Hank Prins, Don Purdy, Jim Quabba, Joe Raffoul, Bert Retallick, Stan Roberts, Harold Robertson, John Robertson, Jim Robertson, Brian Robinson, Les Rodgers, Don Rodoni, Bill Rohde, Jack Ross, Sam Ross, Doug Rowell, Brian Rowlands, Jim Rule, Trevor Ryan, Gopalan Sampath, Doug Sanderson, Keith Sandham, Dimitrios Saribalas, Cliff Savin, John Schmidt, Chris Scott, John Searle, Leon Sebire, Terry Sellner, Bill Shapley, Dave Sharman, Frank Sharp, Graham Shaw, Frank Shepherd, Peter Sim, Jason Simms, Bob Slutzkin, Graham Smith, Neil Smith, Stewart Smith, Bill Smitheram, David Snowden, Len Som de Cerff, Jim South, Bob Spears, Roy Spratt, Bob Stainsby, Graham Stevens, Mark Stevens, Mike Stevens, Ted Stewart, Max Strohfeldt, Tony Stuart, Graeme Tabain, Andrew Thistlethwaite, Rod

Thompson, Vince Thompson, Ron Tolmie, Jack Tomlinson, Jack Toohey, Jack Truss, Theo Tsousis, Jack Tuite, John Urquhart, Alex Valentine, Alan Varey, F O Viol, Frank Waldron, Eric Watt, John Webb, Tom Wedderburn-Bishop, Harry Weir, Terry Wellard, George Whitfield, Paul Whiting, George Wielicki, George Wiencke, Roy Wightman, Frank Wilkinson, Jim Wilkinson, Phil Wilson, Bruce Withey, Richard Womack, Brian Woodrow, David Wright, Henry Wyatt, Cyril Yau. David Young.

Any listing of people associated with broadcasting in Australia, and in particular, with the National Broadcasting Service, would not be complete without reference to Harry Percy Brown, Director-General of the Postmaster General's Department and a dominant figure for the first 16 years of broadcasting in this country.

He had served with distinction in the British Post Office for 25 years before coming to Australia in January 1923 at the time when broadcasting was about to be introduced.

The Commonwealth Government invited him to Australia as Technical Advisor in relation to Post Office matters, and in December 1923, he was appointed to the position of Secretary to the Department. In 1934, the designation was changed to Director-General, Posts and Telegraphs.

Throughout his long association with the Department, he took a keen interest in the operation and development of broadcasting and has been considered by some observers as 'the father of the National Broadcasting Service'.

Since 1905, the Postmaster General had exclusive rights to issue wireless telegraphy licences which later came to include broadcasting and when consideration was being given to the establishment of broadcasting stations, Brown built up a position of power and was closely involved in all aspects and discussions concerning broadcasting planning and the technology. He did not like the arrangement approved by the Government allowing the establishment of privately owned and operated A Class and B Class broadcasting services. He was of the firm view that a national broadcasting organisation should be formed to co-ordinate all matters associated with the service and that the PMG's Department should regulate all the technical aspects of broadcasting.

With the privately owned A Class and B Class stations, broadcasting encountered many problems, particularly in relation to quality of programs and to service to country areas.

In 1927, the Government set up a Royal Commission to look into the future of broadcasting in Australia and following the Commission's report, the Government appointed an Advisory Committee to assist the Postmaster General in implementing the proposals and to examine the implications. Harry Brown was appointed Chairman of the Committee.

The Committee prepared a detailed scheme for the establishment of a National Broadcasting Service and extension of broadcasting generally throughout the nation. The scheme involved the acquisition by the Government of all A Class stations to form the National Broadcasting Service with the PMG's Department undertaking the provision and maintenance of the technical services of transmitters, studios and program circuits while the program service was to be let out under contract to a company.

The Committee also proposed the establishment of C Class stations to be installed and operated by the Postmaster General's Department with the station outlets being made available to service businesses, organisations and groups for publicity purposes. However, no funds were ever provided by the Government for establishment of the stations.

Brown had visited England in 1928, and was well briefed on the BBC arrangement in that country. He was keen to establish a Government owned system similar to the BBC and when the Australian Broadcasting Company Ltd decided not to seek renewal of their program contract after June 1932, he prepared the ground work for a Bill to replace the Company with a Commission modelled on the BBC, but leaving the B Class station arrangement intact.

Throughout his long involvement in broadcasting, Brown was a driving force in the expansion of the National service and in encouraging the establishment of Commercial stations. When he addressed the World Radio Convention organised by The Institution of Radio Engineers (Australia) in Sydney in 1938 during Australia's 150th Anniversary Celebrations he reported that there were 23 National and 93 B Class or Commercial stations serving more than one million licenced listeners.

Among the many posts he held, was one with the Radio Research Board formed following a Conference set up by the Council for Scientific and Industrial Research on 17 November 1926. He was a member of the Conference and acted as Secretary for the first meeting of the Board held in his office in Melbourne on 27 June 1927. He was a member of the Board until his retirement and attended his last meeting in November 1939 — his 39th meeting of the Board.

In September 1939 at the start of the Second World War, he visited Sydney to discuss with the Postmaster General certain aspects in relation to the control of Commercial radio broadcasting. When the Minister disclosed his intention of placing Sir Ernest Fisk of AWA in a position of authority in this area, Brown was appalled. He and Fisk had never been on friendly terms. Fisk had a habit of dealing directly with the Prime Minister of the day leaving Brown and his Department out of the discussions. There was a heated discussion, Brown rose, collected his bowler hat and left the room. Next day he forwarded notice of retirement to the Minister.

Throughout his long career, he was not without his detractors. Politicians, the press and some businesses were critical of his decisions and the influence he had with the Government of the day. One newspaper referred to him as 'Horse Power Brown' — a play of his initials as recognition of his power and influence in the community.

Harry Brown already held the honour of MBE on his arrival in Australia and in 1934 was awarded the CMG and knighted in 1938. He died at aged 88 on 5 June 1967.

MOBILE STATIONS

One of the first mobile broadcasting stations to provide a public service was a 500 watt transmitter installed in a trade exhibition train in New South Wales. AWA had imported two radio telephony transmitters from the Marconi Company in England and used them for public experimental broadcasting demonstrations in Sydney and Melbourne. It was one of these units which was installed in AWA's display carriage of the Great White Train which toured New South Wales in 1925–26. The transmitter with callsign 2XT (said to refer to Experimental Train) operated on a wavelength on 850 meters and with Harry Tuson in charge, broadcast speeches by local dignitaries at each scheduled stop. Harry Tuson who operated the technical facilities continued in the broadcast activities of AWA for many years. At the outbreak of the War in 1939 Harry was a Technician at Sydney station 2CH operated by AWA with a 1000 watt series modulated transmitter at Dundas and three studios at 47 York Street.

Although it was not known whether many people had receivers capable of receiving the broadcasts, the facilities created a lot of interest for visitors to the train.

Farmers were particularly interested as the press had announced that the United States Department of Agriculture estimated that 550000 American farms were equipped with wireless receivers in 1925, chiefly for the reception of market and weather reports and there was evidence that Australian farmers were just as keen to take advantage of country broadcasting services.

A station which made a significant contribution to bringing radio to areas not well served by other stations was 3YB. It was owned by Mobile Broadcasting Services Pty Ltd, of 430 Little Collins Street, Melbourne. It commenced operation on

13 December 1931 covering the Gippsland Valley area of Victoria, staying 3–5 days in each town visited.

The concept of the mobile station was developed by Jack Young, an Announcer at 3BA Ballarat. Young sought technical help from Bert Aldridge, and following financial support by Vic Dinneny, Bert Rennie, Arthur Stapleton, Les Callaway, Mr Purbrick (Myers Ice Cream) and Arthur Crosby (Sunshine Biscuits Co.), a syndicate was formed and an application for establishment of a broadcasting station submitted to the authorities. Hugh Adams in his history of the station, 'Pioneer of Country Broadcasting in Victoria–3YB', says the callsign '3YB' was derived from Young of Ballarat.

The equipment was originally housed in two motor vehicles of caravan types. A 'T' model Ford housed the transmitter and an 'A' model Ford was fitted out as the studio with two turntables and microphone. A 3 horsepower motor generator set was mounted on a trailer to provide power in situations where local power was not available. Two 12 m aerial poles in 3 m sections were carried on the transmitter vehicle.

In this fashion, the station and staff traversed a wide area of Victoria. It was claimed to be the first broadcasting station of its type in the Commonwealth. The first broadcast was carried out at Clunes with staff comprising Vic Dinneny (Manager, Announcer and Cook), Bert Aldridge (Chief Engineer, Driver and Mechanic) and Bert Rennie (Business Representative and Copywriter). Jack Young gave assistance in subsequent broadcasts.

A condition of the licence was that the mobile station could not transmit within 30 miles (48 km) of an existing station. This prevented operation in towns such as Ballarat, Bendigo, Geelong, Wangaratta and Hamilton where stations were in operation.

The transmitter comprised a crystal controlled master oscillator system with a choke controlled high frequency amplifier capable of 100% modulation with low distortion. It operated on 1060 kHz and produced 25 watts into the aerial which was a single conductor of braided copper wire supported between two 12 m guyed poles spaced about 30 m apart. The station provided good signal up to about 80 km.

In 1932, the facilities were transferred to the luxuriously appointed Melville carriage of the Victorian Railways. The carriage had been specially designed and fitted out in 1899 for the Duke of York during his State visit. The carriage was 18 m in length and divided into three compartments used as studio, operating room and living quarters. The domestic conveniences included kitchen, ice chests, cooking stove, cupboards, wardrobes, toilet and shower-bath. The aerial system comprised two collapsible 6 m masts at each end of the carriage. The transmitter provided 50 watts into the aerial. Chief Engineer was Max Folie who was later replaced by George Glover when Max left to construct 3MA. George held the position of Chief Engineer from 1933 until 1938. First transmissions commenced at Seymour on 17 October 1932.

The mobile station ceased operation on 15 November 1935 and commenced broadcasting as fixed station 3YB Warrnambool on 18 January 1936 with a 50 watt transmitter located at 'Wentworth' Weir Road, Spring Gardens.

A mobile station of a different type and operating in the short wave band was Marine Station 9MI on board the Motor Vessel 'Kanimbla'. The installation built and installed by AWA Sydney comprised a fully independent station complete with studio, transmitter, aerial and all necessary ancillary equipment for broadcasting purposes. The transmitter had a power output into the aerial of 50 watts and operated on frequencies 11710 and 6010 kHz.

Programs were transmitted four times a week and included music from the Kanimbla Quartette and recorded music from a 2000 record library. The service commenced when the vessel left Belfast on 25 April 1935 and continued for many years. Transmissions ceased with the outbreak of the Second World War in 1939.

A number of attempts were made in other States to establish mobile Commercial stations but without success. In South Australia, for example, one proposal put to the local Radio Inspector involved the establishment of a mobile station by Mobile Broadcasters of SA Ltd to operate in nine country towns using local halls as temporary studios. Although large towns like Mt Gambier, Victor Harbour, Kadina, Clare and Tanunda were included, the promoter could not raise the necessary capital funds to start the business.

Another interesting scheme involved fixed transmitters and a mobile studio. The promoter proposed the installation of permanent 50 watt transmitters at nominated sites in South Australia with the sites being so selected that the service areas would not overlap into adjacent towns. The mobile studio was to travel from station to station on a regular scheduled basis and transmit during the hours 7 pm to 11 pm on weekdays. It was intended that the program material would be provided by local musical societies, bands, singers and clubs. It also failed to materialise due to the lack of financial support.

LOW POWER TRANSMITTERS

Low power transmitters, i.e. those of 2 kW and less output were in the majority for many years and today still represent a considerable percentage of the total number of stations on air.

As early as 1924, AWA in its Radio Electric Works was building a low power transmitter for broadcasting purposes. The 500 watt transmitter comprised two units, the modulator panel and the oscillator panel. The modulator panel included the aerial circuit inductor consisting of a tapped inductor and variometer, three Marconi type E9B modulator valves, and sub-modulator valves. The anode voltage for the modulator valves was supplied by a motor generator set. The panel also included meters and switches necessary for monitoring and control purposes. The oscillator panel included closed circuit inductor, two Marconi E9B valves, switches, dials and regulating transformers. A DC motor generator unit provided high and low tension voltages.

Although many station staff built their own station equipment, there was a strong demand for commercially produced transmitters.

Both AWA and STC produced transmitters in the range of 50 watts to 2 kW to meet the demand for this power range for both National and Commercial stations. Commercial stations equipped with AWA transmitters in the 1930s included 4WK 50 watts, 2CH 1000 watts, 2GN 200 watts, 2HD 500 watts, 2SM 2000 watts, 3BO 200 watts, 2UW 2000 watts, 4BC 1000 watts and 4CA 100 watts, while STC units were in service at 2AD 100 watts and 4LG 300 watts. Other companies were also active, including Colville Wireless Equipment Co., of Sydney. Typical of their transmitters was the 2 kW model supplied for Commercial station 2TM Tamworth in 1937. It was a water cooled model employing Philips valves and comprised crystal oscillator, separator, modulator, modulated amplifier and linear amplifier. Excitation of the Class B linear amplifier was obtained from a tapping on the anode circuit tuner of the modulated amplifier stage. The linear amplifier employed a Philips water cooled pentode type PA 12/15. Anode supply for the linear amplifier was obtained from a three phase full wave rectifier system using six Graetz connected Philips DCG 5/2500 half wave gas filled rectifiers. The company also supplied the 50 watt transmitter for 4IP Ipswich and the 300 watt transmitter for 4AY Ayr.

An example of the state-of-the-art Commercial station transmitters constructed in the late 1930s by station staff, is 2GB designed and built by Chief Engineer Len Schultz and staff. The installation consisted of three twin racks comprising line and amplifying, equalising and monitoring equipment; major power supplies, and the transmitter proper. Although the station licence allowed for only 1 kW into the aerial, the transmitter had capability of producing 5 kW output. The transmitter unit consisted of a number of cubicles containing the power supply, control equipment, the main high tension supply unit, the preliminary stages from oscillator to modulated amplifier and the linear amplifier. The linear amplifier employed a pair of 4220C water cooled triodes in push-pull plus space for a pair of spare valves. High tension for this stage was provided by six type DCG5/2500 Philips gas filled rectifiers in a Graetz circuit delivering 11 kV. The six phase Graetz circuit was a very popular HT rectifier circuit with transmitter designers for many years. It was widely employed with hot cathode mercury vapour valves, where the inverse voltage had to be kept as low as possible to avoid arcing or flashback. The ripple frequency was six times the supply frequency, so simplifying filter circuit design compared with systems where ripple frequencies were only two or three times the supply frequency.

In the mid 1930s the highest power employed by a Commercial station was 2000 watts. Stations operating on this power included 2GZ, 4AK, 5PI and 6WB. Those on 1000 watts included 2CH, 2GB, 2KY, 2SM, 2UE, 4BC, 4BH, 5KA, 5RM and 6AM. Other powers in use were 750, 600, 500, 300, 200, 100 and 50 watts. Stations operating with 100 watts into the aerial were in the majority, with 17 stations out of a total of 74 being licensed to operate on this power.

By early 1991, MF transmitters of 2 kW power and below, comprised 76 Commercial, 8 Public, 53 National and 2 SBS. However, by June 1993, the number of Commercial stations had declined to 71 as a result of transfers from MF to VHF FM services. The Public stations had increased to 10 while National stations remained at 53.

POST WAR TRANSMITTERS

After the War, companies producing broadcast transmitters manufactured new designs to meet the demand for new stations and replacement of transmitters which had been maintained with some difficulty during the War years. Manufacturers included STC, AWA, Philips and Commonwealth Electronics. Philips, from their Adelaide based factory provided units for a number of stations, but mainly in South Australia and Northern Territory, while Commonwealth Electronics provided 50 watt units for 8TC and 8KN in the Northern Territory, 200 watt units for 6CA Carnarvon and other sites. STC and AWA provided a range of transmitters installed throughout Australia, dominating the market for transmitters with powers 5 kW and above. In later years, the imported transmitters, mainly from US, Canada and Japan were introduced for the MF and FM services and from US, Switzerland and France for the HF service.

Many of the high power transmitters designed prior to the Second World War employed two stages of linear amplifiers but after the War, anode modulation systems were widely employed so eliminating the low efficiency linear stages.

A feature of the new AM designs was the employment of anode modulation of the final RF power amplifier and the use of air cooled valves throughout, replacing the earlier water cooled valves in the high power stages. The initial arrangement was the employment of four air cooled valves of the same type with two in parallel with the Class C power amplifiers and two in push-pull for the Class B modulator. One of the most widely employed transmitters by National and Commercial stations was the STC 2 kW model 4 SU 14C identified by its corio sand colour of the cabinet. It used 4279Z valves which were very popular because of the extremely long life of this type of valve. Stations which employed this transmitter included 4AK, 4QA, 4QY, 5AN and many others. At some stations, the transmitter was still in service in 1992.

Many 10 kW models were supplied by both STC and AWA for National stations, but with upgrading of the metropolitan and some regional transmitters to 50 kW, STC dominated the market until the introduction of all solid state models. The first 50 kW transmitter was installed at 2NR Lawrence in 1958 and 35 years later, some of these transmitters were still providing service throughout Australia.

Some changes were made over the years as a result of valve supply and other problems but as originally manufactured, the transmitter employed five 3J/261E air cooled triodes with three in parallel in the Class C power amplifier and two in push-pull in the Class B modulator. The RF amplifier was driven by a single 3J/192E valve.

At June 1993, there were 14 National stations operating with 50 kW transmitters of various designs and manufacture.

* PHILIPS TRANSMITTERS

Of the Philips designs, the most widely installed models were the 200 watt and 2000 watt types.

The type 1648, 200 watt transmitter introduced in 1951 was entirely self-contained in a single cabinet and designed for use as a dual installation in a main/standby configuration using a pair of transmitters and external control circuits for automatic changeover. The RF unit included the crystal oscillator, the isolator, the driver and the power amplifier stages.

The crystal oscillator unit used a 6V6GT valve and was arranged as a Pierce oscillator with the crystal effectively between screen grid and control grid. The anode was electron coupled to the oscillator section. The crystal oven assembly was enclosed in an aluminium can and designed as a plug-in unit.

The isolator stage ensured that the crystal oscillator valve had a light and constant load. It used a 6V6GT valve arranged as a tetrode Class A amplifier.

The 6V6GT driver stage which employed a tuned anode circuit was capacitively coupled to the PA grid.

The tetrode power amplifier valve QB3/300 was arranged for simultaneous anode and screen grid modulation. The tank circuit was a two section pi-network, coupled to the anode via a DC blocking capacitor.

The modulator unit included the audio input amplifier, driver and the AF output stages.

Program was fed to the transmitter via a push-pull audio frequency amplifier which used a pair of 6V6GT tetrode valves.

The driver stage was also a push-pull circuit employing 6V6GT valves.

The AF output stage operated with a pair of QB3/300 valves in push-pull Class AB1.

The 400 volt minor HT supply was provided by a 5U4G rectifier and a double section input filter. The 2500 volt main HT supply which provided power for RF, PA and the AF output stages was derived from a pair of 866A mercury vapour valves.

Although the transmitter was designed to produce 200 watts carrier power, it had capability to operate with only 50 watt output. Stations 5AL (later 8AL) and 2AN were two stations which initially operated with a pair of these transmitters as main and standby units with 50 watts into the aerial. Stations which employed the full 200 watts included 5WM, 2ML, 5MG, 4SO and 4MI. The 5WM and 5MG stations were installed by Divisional Engineer Murray Higgins and staff.

The Philips 2000 watt type 1656 transmitter introduced in 1953, like the 200 watt model, was designed to be employed as a station pair with one working and the other on standby. The transmitter was capable of output power reduction to 1000 watts where this was required.

The modulator unit included three audio frequency and the modulator stage. The first AF stage comprised two 6V6GT valves operating as triodes in a Class A push-pull arrangement, the second stage used two 807 type valves as a tetrode connected Class A push-pull amplifier and the third stage operated with four 807 valves arranged as a cathode follower in a push-pull parallel manner. The Class B modulator stage was designed to use four triode valves, type TB4/1250 arranged in push-pull parallel.

The RF unit included master oscillator, isolator, two RF amplifier and the power amplifier stages.

The Pierce oscillator stage employing 6V6GT valve fed into the isolator stage also employing a 6V6GT valve and arranged as a tetrode.

A tetrode connected 807 valve was used as first RF amplifier with an untuned RF transformer utilising Ferroxcube core material in the anode circuit. The driver or second RF amplifier employed a QB3/300 tetrode working in Class C. The PA contained four triode valves type TB4/1250 in parallel, neutralised by the shunt method. The tank circuit was a double section pi-network using fixed ceramic capacitors and variable inductance coils. The variable inductance tuning was accomplished without resort to sliding contacts by arranging two equal coupled coils with adjustable axial spacing. One half coil was driven from a front panel control by a rack and pinion mechanism. The mutual inductance change between the two half coils gave fine tuning adjustment. Taps on each half coil allowed for coarse adjustment.

The minor HT rectifier utilised two 866A mercury vapour valves in a single phase full wave arrangement with a third valve being provided in a heated condition ready to be brought into operation should one of the working valves fail. The main HT employed four 872A HCMV rectifiers with one being a heated spare.

Stations which operated with this 2000 watt transmitter included 5DR (later 8DR), 5PA, 5MV, 2WN, 2CL and 2BA. Station 4QL was equipped with one as a standby unit. Stations 5PA and 5MV were installed by Divisional Engineer Jack Truss and staff.

* **AWA TRANSMITTERS**

Immediately after the War, there was large demand for MF transmitters to cater for replacement of many units which had been poorly maintained due to shortage of spare parts and skilled staff. The need for new station transmitters which had been deferred because of the War also had to be met.

Because it was impossible to predict the numbers required at the various powers then in use or likely to be approved, AWA prepared co-ordinated designs of transmitters to cover a range of power ratings. The designs covered a range of power outputs from 200 watts to 60000 watts. The application of standardisation to components and methods resulted in a number of advantages both in design and production without sacrifice of either performance or appearance in individual transmitters.

Features of interest in the designs included:

- Triode valves were used for all modulated amplifier stages to simplify the modulation process.
- Pi networks were used in radio frequency coupling circuits to obtain maximum efficiency by ensuring correct impedance matching between valves as well as between output stage and load.
- To avoid change of inductance and capacitance values for each frequency, the frequency range was divided into six parts with the capacitance value being fixed for each narrow band. Circuit tuning was carried out by the use of tapping points and variometers for fine tuning.
- The power range 200 watts to 60000 watts was covered by designs comprising 200/500 W, 500/1000 W, 500/2000 W, 5000/10000 W and 60000 W.
- Considerable attention was given to the types of valves used in the designs. For example, because of similarity in valve characteristics and anode voltages, the drive amplifier was similar for the 1000 W and the 2000 W transmitters and again for the 10000 W and 60000 W transmitters. Choice of valves for the audio section was co-related with requirements of the radio frequency section. Similar types were used in low power stages and for the modulator and modulated amplifier in each case. Valve types being restricted, allowed the use of common high voltage power supplies.
- Inductive neutralising was used for the triode stages.
- A standard crystal oscillator was used for each transmitter.
- Initial stages used identical valves and circuit components.
- Later stages used similar components where possible but making allowance for the purpose of the valve e.g. whether it was a driver or a power amplifier.
- To allow for wide frequency coverage and minimum phase change, the initial audio frequency amplifier stages used pentode type valves.
- The audio Class B stage was straight forward except for the physical size of the output transformer.

Included among the low power designs was the model 2J51316, a 200 watt transmitter installed at many National and Commercials stations to replace transmitters that had become outdated technology during the War years and new stations being established. New stations included 2TR Taree which went to air on Armistice Day 1948, and 2LG Lithgow which was commissioned during October 1949.

Of the AWA designs produced in the late 1940s and the 1950s, the 10 kW transmitter type J56700 with a 2 kW standby type 9J50511 was installed at several National stations. The 2 kW model was also installed at several National and Commercial stations requiring only 2 kW output. Another model was the 10 kW type J50961, one of which was installed at 6WN Perth in 1953. In 1963, it was transferred to 6DL Dalwallinu and in 1972 taken out of service and put on display at the Wireless Hill Telecommunications Museum.

The J56700 transmitter produced a power output nominally 10.6 kW and had capability of operating in a derated mode producing 5.5 kW output. Mains input power requirements for 100% modulation was 33 kW. The transmitter was designed to work into a transmission line impedance between 80 and 200 ohms unbalanced.

The transmitter consisted of four heavy gauge aluminium cubicles mounted on steel channels which accommodated inter unit cables and also acted as the base plinth. The cubicles comprised speech amplifier and modulator units, power amplifier unit, exciter unit and rectifier and control unit.

The main transmitter air blower, together with heavy components such as modulation transformer, filament transformers, HT filter inductors and capacitors occupied the lower compartments, whilst the main air ducting continued from cubicle-to-cubicle via trunking, was mounted directly beneath dividing shelves and had a subsidiary duct to feed the filter inductor in the lower front of the rectifier and control cubicle.

With the exception of the thyratron valves, all valves together with the subsidiary meters, were mounted in the front of each cubicle and arranged so that they were visible through windows in the sliding doors.

Valve types used with the transmitter comprised one 807 type for each of two crystal oscillators, one for RF amplifier No. 1 and two for the speech amplifier No. 1 stage; 833A type for RF amplifier No. 2; three BR191 types for the power amplifier and two for the modulator; two 813 types for speech amplifier No. 2 and two for speech amplifier No. 3; four 872A/872 mercury vapour types for low voltage supply and four 5563 thyratrons for the HT supply plus a 2D21 type for thyratron control.

The 2 kW transmitter type 9J50551 consisted of five main panels, two of which included subsidiary units. These were the radio frequency panel containing the crystal oscillator unit, the RF line coupling panel, the speech amplifier and modulation panel containing the speech amplifier, the rectifier and relay panel and the control panel.

The transmitter was contained in a single cabinet divided into two main compartments by central partitions. Access to each compartment was through a large door that formed part of the front of the cabinet. Heavy components such as modulation transformer etc, stood on floor plates in the two compartments.

Valves employed with the various stages were type 807 for the crystal oscillator, type 807 for the isolator, type 813 for the buffer amplifier, four type 833A types in parallel for the modulated amplifier, two type 1603 in push-pull for speech amplifier No. 1; two type 807 in push-pull for speech amplifier No. 2; four type 807 in parallel push-pull for speech amplifier No. 3 (cathode follower); four type 833A in parallel push-pull for the modulator; two 866/866A mercury vapour types for the bias rectifier; three 866/866A mercury vapour types for the minor HT rectifier; and three 872/872A mercury vapour types for the main HT rectifier.

The AWA 10 kW transmitter BTM-10 types 6J56700 and 7J56700 were also employed at National stations from about the mid 1950s. The two transmitters were basically identical and differed only in the provision of certain minor accessory facilities intended to fulfil particular requirements.

The mechanical construction and layout was not much different from the J56700 type. The valves were the same except that type 5762 was an alternative for the BR191 type used in the power amplifier and modulator stages.

National stations which operated with these AWA 10 kW transmitters, some of which were still in service in 1993, included 2CO, 2NC, 2GL, 2BA, 4QL, 7NT, 7ZL/7ZR, 3GI, 3WV and others. They have since been replaced with solid state designs.

In the case of the Hobart National transmitting station at Ralph's Bay about 14 km from the city, both 7ZL and 7ZR were operating with these types in 1993. The site established in 1958, replaced the earlier site at the base of Mount Wellington known as Radio Hill. Station Officers-in-Charge have included Tom Edwards, Len Edwards, Joe Brown, Roly Shorthouse, Pat Albion, Graeme Wilmot and Jim Darling.

The most powerful AWA MF transmitter provided in Australia was the 50 kW broadcast transmitter BTM 50 type 2J60640 commissioned for 2CR Cumnock during April 1963. It was in service until January 1994, when it was replaced by a Nautel solid state transmitter.

The output of a crystal oscillator was amplified in four stages before being applied to a high efficiency Class C power output stage which was modulated by a push-pull Class B modulator. In the audio section, program input was amplified in two push-pull Class A stages which fed a push-pull cathode follower stage, the cathodes of which were directly coupled to the Class B modulator. Partial modulation of the RF driver stage was employed to improve the linearity of modulation in the power output stage.

Five rectifier circuits provided main and auxiliary HT supplies, number 1 minor HT supply, number 2 minor HT supply, bias voltages and control supply.

Brief details of the RF circuits are as follows:

- Crystal Oscillator

The crystal oscillator unit comprised a crystal oscillator and an aperiodic amplifier.

The oscillator was a modified Pierce circuit in which the crystal was connected between the screen and grid of a 6AK5 valve. Twin crystals were provided with trimmer capacitors for fine adjustment of frequency. Crystals were mounted in individual thermostatically controlled ovens assembled as plug-in units.

Output from the oscillator valve was capacitively coupled to an aperiodic amplifier which drove an RF stage.

- RF Amplifiers

Output from the crystal oscillator unit was applied via back-to-back transformers to an RF stage comprising valve type 6146 for first FR amplifier and type 7094 for second RF amplifier.

Output from the second amplifier was matched to a coaxial line by a ferrite transformer.

- Driver Stage

The driver stage used a directly heated BR191 valve operated in Class C with fixed neutralisation over the frequency range of the transmitter.

The driver stage was partially modulated via a modulation choke in the auxiliary HT supply.

- Power Output Stage

The power amplifier stage used a directly heated triode type BR189 in a high efficiency Class C circuit which was self-biased.

The output circuit consisted of a double pi network, the output of which was connected to the transmission line via a directional coupler, the nominal output impedance being 200 ohms.

The stage was tuned by the selection of fixed capacitors and tapped inductors with the addition of a fine tuning capacitor.

Full modulation of the stage was effected with the HT being applied to the anode via the modulation choke.

Neutralisation was achieved by a capacitor in association with a wideband neutralising transformer. Parasitic suppression was provided by an inductor shunted by a damping resistor in the grid lead.

High efficiency operation was obtained by using the third harmonic to produce almost flat topped wave and thus to improve the Class C operation. With normal anode circuit losses, the resultant overall power amplifier efficiency was about 85 %.

Brief details of the AF circuits are as follows:

- AF Amplifiers

Program from the station program input equipment was connected via a variable attenuator and a low pass filter to the input transformer, the secondary of which comprised two balanced windings to provided inputs to the first audio stage. This stage employed two beam power 6146 type valves arranged in push-pull and biased to Class A by a common cathode resistor.

The output of the first audio stage was R–C coupled to the second stage comprising two beam power valves type 7094 operating in Class A.

The third stage employed four 7094 type valves connected as parallel pairs in a push-pull cathode follower configuration giving good regulation of the drive to the modulators.

- Modulator

The modulator employed two BR1121 type triodes operating under Class B conditions. Modulation was applied to the RF output stage via a blocking capacitor with the main HT being connected via a modulation choke.

Partial modulation of the RF driver was achieved by using a tapping on the modulation transformer secondary winding in association with a modulation choke and blocking capacitor.

A network across the primary of the modulation transformer provided approximately 20 dB of negative feedback to the grid circuit of the first audio stage.

The original main HT rectifiers were English Electric AR63 mercury arc excitrons of a single anode mercury pool type. The supply circuit was a three phase full wave rectifier employing six rectifiers and associated components.

In 1966, the system was converted to solid state rectification using 3R63663 type kit with six assemblies each consisting of 15 GEA38P silicon avalanche diodes, 15 capacitors and 30 resistors. The transmitter also originally included an electronic crowbar in the HT using an AR63 excitron in the HT circuit to prevent damage to the high power valves in the event of an internal flashover. The high current surge from the HT rectifier triggered the excitron placing a short circuit on the HT line thus absorbing the high energy content of the supply. The crowbar action was so rapid that the HT line was shorted before the faulting arc had reached sufficient energy level to cause damage. The main HT circuit breaker was also tripped by a subsidiary circuit. The transmitter was cooled by forced air from an external blower which supplied air via underfloor ducts to the three cabinets. Subsidiary ducts built into the cabinets directed air to the valves and components requiring cooling, the heated air being exhausted through the top of each cabinet into a canopy in which the artificial aerial was mounted.

By the time the 2CR air blast transmitter was placed in operation in 1963, the design was many years old. A transmitter had been supplied to New Zealand by AWA in 1950 followed by two more units in 1960. The two units manufactured in 1960 were operated in parallel mode to produce 100 kW carrier power into the aerial for the Broadcasting Corporation of New Zealand's Wellington station.

AWA had a long standing presence in New Zealand with Branch Manager in 1922 being Mr G Robertson.

* STC TRANSMITTERS

One of the most popular transmitters produced by STC shortly after the cessation of hostilities in 1945 was the Standard 1-2 kW type 4-SU-14 MF transmitter. Many were supplied for both National and Commercial stations during the late 1940s and late 1950s.

In Queensland alone, they were in service at 4AK, 4QA, 4QG, 4QN, 4QY and 4RK at various times. A high frequency version, 4-SU-14B was also produced, with VLI at Liverpool being one station equipped with this model. VLT Port Moresby which was part of the National Broadcasting Service also used a 4-SU-14B model when commissioned on 28 June 1948.

To facilitate on-site installation, the equipment was completely self-contained in one steel cabinet. The cabinet was zinc sprayed to improve electrical shielding characteristics as well as to prevent metal deterioration in the tropics. The cabinet was painted Corio Sand colour, a departure from the earlier black and battleship grey colours.

The transmitter employed air cooled valves throughout, with the cooling air being drawn through a viscous oil filter by an inbuilt blower. The unit could be operated at either 1 kW or 2 kW output.

The major valves used in the 2 kW model included 872A, HT Rectifier; 3C/150A, RF Driver; 4279Z, Power Amplifier A; 4279Z, Power Amplifier B; 3C/150A, AF Amplifier A; 3C/150A, AF Amplifier B; 3C/150A, AF Driver A; 3C/150A, AF Driver B; 4279Z, Modulator A and 4279Z, Modulator B.

For operation as a 1 kW unit, one valve was removed from the Power Amplifier or TG10 valves replaced the 4279Z valves. The power could also be limited to 1 kW by reducing the coupling to the aerial. Provision was made for maintaining a spare rectifier valve in position with its filament heated ready for immediate use.

A Star/Delta switch on the primary of the HT transformer enabled operation to be checked on one third power output and to facilitate lining up.

The power amplifier was a push-pull Class C amplifier with fixed as well as self-bias, and fitted with anti-parasitic resistors and shunt inductors in the grid of each 4279Z valve. Cross neutralising was employed using variable capacitors in series with damping resistors. The output was inductively coupled to the aerial or artificial load. The output coupling inductor was so arranged that it swung between the anode tuning inductors and was shielded from them by means of an electrostatic screen which suppressed the coupling of radio frequency harmonics into the output circuits. The screen also protected the output line from any flashover that may have occurred.

In the audio section, two 3C/150A type valves were used as cathode followers to drive the following Class B modulator stage. The driver stage had a very high input impedance and thus ensured good regulation as a driving source for the grids of the modulator valves.

The modulator was coupled to the power amplifier via a modulation transformer, capacitor and a reactor. The HT for the modulator stage was supplied by a 2500 volt HT rectifier via the primary of the modulation transformer.

Audio negative feedback was employed to reduce distortion and noise in the audio amplifier stage.

When station 4QY Cairns was decommissioned in early 1997, the transmitters had operated for more than 47 years.

In the 1950s, STC produced a 10 kW model using all forced air cooled valves. Maintenance requirements were reduced substantially by the elimination of all the equipment associated with water cooling equipment, which was a feature of pre-war 10 kW models. The transmitter was designated type 4–SU–11A. Station 4RK was one station equipped with this model which was in operation from 1954 to 1988. When commissioned the transmitter required 40 kW of mains power at 100% modulation and provided an overall efficiency of about 36%.

The equipment with the exception of the larger oil filled transformers and inductors was housed in four steel cabinets. The cabinets were spaced by means of screens and a central doorway giving access to equipment mounted behind. Each cabinet was sealed and provided with its own blower which drew air through a viscous oil filter and discharged it via a common duct to outside the building. Total front panel length was just over 5 metres.

Provision was made for the inclusion of spare AF and RF exciter units in the modulator and power amplifier cabinets respectively. Spare sockets were provided in all circuits employing HCMV rectifier valves, enabling spare valves to be maintained heated for immediate service if required. Star-delta switches were provided on all rectifiers enabling operations at reduced power.

In keeping with accepted design philosophy of the period, both operating personnel and equipment were fully protected by a comprehensive system of electrical interlocks. All doors giving access to dangerous voltages were fitted with double gate switches.

Both the oscillator and isolator stages employed a 6V6GT radiation cooled beam tetrode valve while the buffer used two 807 beam tetrodes producing 10 watts each. The RF amplifier used a pair of TG10 triodes and the power amplifier employed two 3J/221E air blast triodes. These were later replaced by Philips TBL12/25 types.

The first speech amplifier used two 6J7G valves, the second a pair of 6V6GT valves and the third a pair of 3C/150A triodes. The modulator driver circuit used two TG10 triodes and the modulator a pair of 3J/221E air blast triodes. As with the power amplifier stage, the 3J/221E types were replaced by Philips TBL12/25 valves during 1984.

In the original installation, the main bias rectifier employed three 872A HCMV valves, the 2000 V rectifier also used three 872A HCMV types and the 10000 V rectifier was fitted with six 4078Z type valves. These were later replaced by solid state stacks.

Two other transmitter models produced by STC, with some units still being operational as late as 1994, included 5 kW type 4-SU-55B employed at both National and Commercial stations and the 50 kW type 4-SU-38 in operation with the National service.

The 5 kW model produced about 1964 was designed to deliver an output of 5.5 kW unmodulated carrier power over the range 525–1610 kHz. It was completely self-contained in a cabinet using two modules fitted with two hinged doors at the front and two removable panels at the rear. It used high level Class B modulation and fed a 200 ohm unbalanced line. Power consumption for 100% modulation was 16.8 kW.

Valve types employed with the transmitter included two EF37A low noise pentodes, two 807 beam tetrodes, five 4–125A radiation cooled tetrodes, three 3X2500F3 forced air cooled triodes, one 6X5GT twin diode and six 872A HCMV rectifiers. The HCMV rectifiers were replaced by silicon rectifiers in later transmitters. These were assemblies of six 20 silicon diodes RS640AF in series or of three 18 silicon diodes RAS508AF in series depending on the type provided. The assembly using RS640AF types required the addition of voltage suppression components across the secondary windings of the high tension transformer. Where rectifier assemblies used avalanche rectifiers type RA5508AF, no suppression of the transformer was required as the rectifiers were capable of withstanding switching surges.

Most of the National stations employing this series, operated in a parallel configuration to produce 10 kW into the aerial. Although most were replaced in recent times, stations which operated with the series in 1989 included 2CY, 2KP, 2NU, 5CK, 5PA, 6DL, 4QB, 4QO, 4QS and 4QW. By 1994, most had been replaced by solid state types.

The 50 kW transmitter 4–SU–38 was the most powerful STC MF transmitter in service in Australia, and had been in operation since July 1958 when 2NR Lawrence was put on air with one of the first models produced. The station had been using STC transmitters since it was commissioned on 17 July 1936. The original transmitter had a rating of 7 kW and was installed by PMG's Department staff with assistance by an STC Engineer. The first station Officer-in-Charge was S R Crichton and staff included R L Deal, A Brown, M Francis and D A M Phillips. Modifications to the transmitter were carried out in 1952 resulting in power output being increased to 10 kW. The transmitter remained in service until replaced by the 50 kW model.

Other 50 kW installations which followed, included 2BL, 2CR, 2FC, 3AR, 3LO, 3WV, 4QD, 4QN, 4QR, 5AN, 5CL, 6WA and 6WF.

The transmitter was a very reliable workhorse and it was not until 1988 that the first replacement was undertaken. This was at

3WV where the STC unit was replaced by a Nautel 50 kW solid state model when it became necessary to vacate the original building because of structural problems with the 52-year-old building.

A notable feature of the design of the STC 50 kW transmitters was the method of heat removal from the valves and other components. The cooling air was sucked across the valve fins instead of being blown as was normal practice with designs at the time. David Abercrombie and his staff prepared the design. The arrangement resulted in great reduction in the acoustic noise level.

The transmitter was housed in a single steel enclosure and in order to conserve building space certain components had been designed for outdoor mounting. It used radiation or forced air cooled valves in all stages. For a carrier output of 52.5 kW the power supply demand under 100% modulation conditions was 156 kVA at a power factor of 0.93. Output was fed to a 200 ohm unbalanced transmission line.

The units which could be mounted outside, were the high tension supply transformer and filter inductor, the high tension supply starting resistor, the modulation transformer and inductor and the exhaust fan. The artificial aerial was mounted inside the ducting on the exhaust fan outlet.

The radio frequency unit included three amplifying stages at the carrier frequency. These were the buffer amplifier, RF driver and power amplifier. The carrier frequency was generated by a crystal employed in a Pierce anode-grid connected oscillator circuit. The power amplifier operated as an anode modulated Class C amplifier originally using three STC type 3J/261E valves in parallel. The final stage of the modulator circuit consisted of two valves in push-pull Class B operation which fed the primary of the modulation transformer. The secondary of the transformer modulated the anode supply to the power amplifier.

Valves originally employed in the transmitter consisted of one 6V6GT beam tetrode in the oscillator, one of the same type in the isolator, two 807 beam tetrodes in the buffer stage, one 3C/150A radiation cooled 150 watt triode in the buffer stage, one 3J/192E forced air cooled triode as the RF driver, three 3J/261E forced air cooled triodes in the power amplifier, two 807 type as first speech amplifier, two 3C/150A type in the second speech amplifier, two 3J/192E type in the modulator driver stage and two 3J/261E valves as the modulator. Power supplies included one 5U4G valve for the RF exciter high tension supply, one 6X5GT for the RF exciter bias rectifier and six 2V/561E HCMV rectifiers for the 9 kV EHT supply. The 3J/192E valves were later replaced by TBL 7/8000 valves and the 3J/261E valves by TBL 12/25 valves, and the bias and EHT rectifiers by silicon diodes stacks. The EHT rectifier used six assemblies, with each assembly comprising twenty-eight RS845ANF silicon diodes.

These 50 kW transmitters were usually provided with a 10 kW standby unit employing 6V6G and 807 types in RF exciter, an RF driver of two parallel 450TL type and three 3J/192E valves in parallel as RF power amplifier. The audio section featured push-pull arrangement throughout with types, EF37A, 6V6G, 3C/150A, and a pair of 3J/192E valves as modulator.

By December 1995, nearly all these 50/10 kW STC combinations had been replaced by solid state models.

During its long association with the design and construction of transmitters, STC manufactured some of the valves employed and provided test facilities for those imported from overseas.

Valve manufacturing facilities were put into operation just prior to the outbreak of the Second World War in 1939 and continued until 1962.

Many valves were made for use with UHF transmission equipment but those associated with broadcast transmission included tetrode type 4282A; radiation cooled triode types 4242A, 4251Z and 4279Z; high vacuum water cooled rectifier type 4222Z; hot cathode mercury vapour rectifiers 4078Z and 872; and water cooled triode 4222Z with anode dissipation of 20 kW. Those manufactured overseas for locally built transmitters included SS1971 (3Q221E), F124A and 3J261E types.

For nearly 50 years, STC designed and manufactured transmitters fulfilled a key role in the National and Commercial broadcasting industry. Many Engineers and Technicians were involved in their design and production including the following:

- 1929–35, Claude McQuillan assisted in the field by Jim Mallinson.
- 1936–61, Bert Wood, David Abercrombie, Les Tindall, Bob Long, Winston Muscio, David Hutchinson, Jack Trivett.
- 1962–75, Phil Humphries, Clive Pickup, Alec Ralph, Yee Chen, Dr Rudolph Guertler, Bill Carfax-Foster, Gordon Shaw, Bill Kirby.

Jack Trivett and Rex Giles also undertook some overseas engineering and installation activities.

Phil Humphries and Clive Pickup were responsible for the design and development of the final range of 10, 50, and 100 kW HF and MF broadcast transmitters produced by STC with almost all of the larger units being exported to overseas broadcasters.

Other staff associated with company transmission equipment included Robert Brown, Brian Cox, Alex Kennedy, John Matthews and Lawrie Thomas.

One of the company Engineers associated with the design of transmitters produced immediately after the War was Winston Muscio. He joined STC in 1933, and initially worked on receiver design and manufacture. During the War years, he was involved in the design and manufacture of HF communications transmitters for the Services with power outputs ranging from 500 watts to 20 kW. One of the company's outstanding achievements was the mass production for the RAAF of 500 watt ground and mobile transmitters. About 1000 units were produced, notable amongst them being the 14S and AT20 series. Winston was also associated with the design and production of the VHF FM mobile radio telephone system which found wide application during the 1954 Royal Tour as mobile OB units by the ABC. In 1962, he transferred to the Radio Transmission Division taking on commercial responsibility for MF and HF broadcasting and mobile radio links. Prior to retirement in 1980, he was responsible for management of all STC Radio Engineering activities other than mobile radio. He is the author of the book 'Australian Radio — The Technical Story 1923–83'.

* **COMMONWEALTH ELECTRONICS TRANSMITTERS**

Commonwealth Electronics Pty Ltd built a number of transmitters during the 1959–60s including MFT3/50 models for 8TC Tennant Creek and 8KN Katherine, a 200 watt MF3/200 model for 6CA Carnarvon and a Westrex MFT8/2500 model for 6GF Kalgoorlie.

The company was established in 1950 by Ron Hope, Alan McKenzie and Bob Zucker all of Sydney with the factory being located at Baulkham Hills near Parramatta. Later, a factory was established at Derwent Park in Tasmania with John Dodds, Bill Nicholas and David Hildyard as local Directors.

For a period, the company formed an association with Westrex Australia Pty Ltd to take advantage of Westrex research and development expertise, particularly in transmitter technology.

About 1969, Commonwealth Electronics became part of the Philips organisation and the name changed to CE Electronics Pty Ltd. About 1972, the Tasmanian branch operations closed down.

Following takeover by Philips, the Sydney operations were transferred to a Philips complex at Brookvale and continued activities there until operations were closed down.

The MFT8/2500 transmitter had inbuilt facilities for remote unattended operation, and the control, supervisory and protection circuits were arranged so that transmitters could be operated in pairs with one transmitter on standby.

The major units comprised RF exciter unit, AF driver unit and low pass filter, control unit, sequence relay mounting assembly, overload relay mounting assembly, power distribution unit, modulator unit, cathode follower mounting assembly and the RF power amplifier unit. The cabinet assembly included the power transformers, filter reactors and associated components, and all other components fitted to the cabinet framework and front panels.

The RF exciter unit contained two piezo electric crystals each in a thermostatically controlled oven, a crystal oscillator and two RF amplifier stages. A Pierce circuit was employed with a variable capacitor, for fine frequency adjustment being located adjacent to each crystal oven. The oscillator and first RF amplifying stages employed solid state active elements. The anode tuned circuit of the second RF amplifier using a type 4CX250B radial beam power tetrode valve was pi connected to the RF power amplifier grid circuit.

The RF driver amplifier anode circuit unit contained the driver amplifier tuning coil and associated tuning capacitors. Fine tuning was achieved by means of a rotatable short circuited turn located inside the coil. The position of the turn was controlled from the transmitter front panel.

The RF power amplifier unit housed two type 4/1000A tetrode valves operated as a parallel connected Class C anode and screen modulated amplifier. The anode was connected to the load through two coupled resonant circuits. The first, the main amplifier tank circuit contained two coils in series, the smaller providing for continuous fine tuning of the circuit, and the larger, for inductance variation in steps of one turn.

The output coupling circuit consisted of a mechanically movable coil and a fixed capacitor. The inductance was variable in increments of one turn with residual reactance being tuned out by the amplifier fine tuning control. Loading of the amplifier was varied by moving the coupling to alter its mutual inductance with the main anode tank coil.

The AF drive unit comprised push-pull Class A solid state amplifier stages. The output of the fourth amplifier stage was transformer coupled to the grids of the cathode follower stage which drove the high level modulator. A low pass filter attenuated frequencies about 10 kHz.

The modulator valve unit contained two 4/1000A radial beam power tetrode valves operated in Class AB2. An associated sub-assembly carried two type 6DQ5 valves connected as cathode followers directly coupled with the aid of a split winding reactor to the modulator grids.

The modulation transformer was mounted on the cabinet base with the modulation reactor. Impedance and phase correcting inductors were mounted above the modulation transformer, and the modulation coupling capacitor was located above the adjacent HT filter inductor.

The cooling system blower unit was a centrifugal type direct driven by a three phase motor. The inlet to the system was through four air filters. Air pressure interlock switches prevented application of filament power to the RF and modulation valves until air flow had been established in the valve cooling systems. Air exhaust was through the roof chimney which contained the artificial aerial and HT starting resistors.

Power supply systems were solid state types. The main HT rectifier employed silicon diode type IN3495/MR326 with 96 connected as a three phase full wave voltage doubling rectifier with 16 diodes in each leg. The screen supply rectifier used a similar silicon diode type with 18 connected as three phase full wave voltage doubling rectifier with three diodes in each leg. The bias supply rectifier, auxiliary supply rectifier, the 24 volt control supply rectifier and the 50 volt control supply rectifier all employed silicon diode type IN3492/MR323 in their systems.

By 1992, all National stations which had employed Commonwealth Electronics and Westrex transmitters had decommissioned the transmitters and installed more modern units.

*** NIPPON ELECTRIC COMPANY LTD TRANSMITTERS**

Included among NEC AM transmitters was the type MBN-7237B, 5 kW medium wave transmitter installed at Commercial station 2NX Bolwarra during the 1970s. The station which had been originally established by Hunter River Broadcasters Pty Ltd on 30 August 1937 with licensed callsign 2HR Singleton, within about 12 months, became known as 2HR Lochinvar. The transmitter was located at Lochinvar but studios were located at Maitland and Cessnock. On 14 January 1954, the station became 2NX Bolwarra. The original studios and 300 watt transmitter were constructed by the station Technical staff under Chief Engineer Alex Mather.

The NEC transmitter employed four tetrode valves and a high efficiency circuit for the modulated power amplifier. Modulation was affected by anode and screen modulation of the final stage. The rated carrier output of the transmitter was 5 kW over the band 525 to 1605 kHz with audio frequency response over the range 30 to 10000 Hz being within ± 1.5 dB referred to 40 % modulation level at 1000 Hz. Audio frequency distortion was less than 3 % at 95 % modulation within the frequency band 50 to 7550 HZ, and noise level was better than 60 dB unweighted for 1000 Hz at 100 % modulation.

The RF amplifier section consisted of a solid state RF driver unit, main and standby crystal oscillators, buffer amplifier, pre and final driver amplifiers, an exciter stage and the modulated power amplifier stage. The exciter stage used an air cooled tetrode 4-400A valve operated in Class C mode with self-biasing. It was linked to the modulated amplifier by a pi matching circuit. The modulated power amplifier stage used a forced air cooled 4CX500A tetrode to obtain up to 5.5 kW output power.

The output circuit employed a single stage pi matching unit with second and third harmonic eliminating circuits to suppress spurious radiation.

The Class AB_1 push-pull modulator-amplifier stage consisted of two forced air cooled 4CX3000A tetrodes. The stage modulated the anode and screen grid of the power amplifier through a modulation transformer and modulation choke. The stage was also provided with a ladder network to provide negative feedback to the solid state AF driver. The modulated amplifier had capability to provide 125 % positive peak modulation.

The power supply unit consisted of a bias voltage power supply, screen grid power supply and high tension power supply. Silicon rectifiers were employed with all the power supplies. The high tension supply provided full voltage to the pair of modulator 4CX3000A valves and the 4CX5000A power amplifier, and half voltage to the 4-400A exciter valve.

As from 1 April 1983, the company changed its English trade name from Nippon Electric Company Limited to NEC Corporation.

*** RCA TRANSMITTERS**

Transmitters manufactured by Radio Corporation of America were first employed at Australian broadcasting stations when a 50 kW HF transmitter was commissioned on 1 May 1944 as part of the establishment of Radio Australia, Shepparton. The transmitter was subsequently made into two operational units by making use of a redundant RF channel and adding audio and power equipment. The transmitters remained operational until late in 1991.

During the late 1970s, the first of 17 Commercial stations was equipped with the RCA type BTA5 model by John S Innes.

Basically, the system comprised an exciter-modulator section feeding two parallel Class C amplifiers which were brought together in a combining and output network to feed the aerial. The exciter-modulator section comprised audio input, crystal oscillator, phase modulator, phase delay, drive regulator and feedback detector modules and a pair of pulse generator modules.

The main amplifier section comprised two identical chains which included solid state pulse amplifier driver and power amplifier modules feeding into a combining and output network.

The oscillator module contained circuitry to produce a high impedance output to drive the associated modulator. Provision existed to operate two temperature controlled crystals of the plug-in type in a main/standby mode.

The drive regulator was an audio amplifier providing voltage and power gain. Capability was provided in the stage by the threshold and stretch controls to stretch (distort) the audio signal in the negative peak region to cancel out transmitter non linearities (distortion) in the transmitter driver and power amplifier stages.

The modulator module was designed to supply two channels of RF pulses that were phase modulated in opposition. Output of channel 1 lead channel 2 by 135 to 140 degrees.

The pulse amplifier was driven by a rectangular-wave signal from the exciter at the RF carrier frequency.

The power amplifier stage utilised a type 3CX5000H3 power tetrode valve, operating saturated Class C at carrier and above. The stage was conventional except for the anode circuit tuning. The coupling network from each PA tank circuit to the combining point was a pi network which had the impedance inverting properties of a 90 degree network. The phase shift in each pi network was adjusted so that the voltage at the output of channel 1 tank circuit was in phase with the voltage from the channel 2 tank circuit. The required voltage phase shift from the input of the coupling network was 157.5 degrees for channel 1 and 22.5 degrees for channel 2, based on 135 degrees initial carrier angle. The voltage phase shift in each network was 90 degrees following neutralisation.

The phase modulated currents from the two power amplifiers were combined across a capacitor and the output amplitude modulation was produced at this point.

Solid state rectifiers were used in all power supplies with the highest voltage being 5000 volts for the PA anode supply.

Commercial stations equipped with these transmitters included 2BS Bathurst, 2GZ Orange, 2WL Wollongong, 2OO Wollongong, 2WM Moree, 3MP Mornington, 3BA Ballarat, 3UL Warragul, 3NE Wangaratta, 4BU Bundaberg, 4GY Gympie, 7BU Burnie and 7SD Scottsdale. Stations 2WL, 2OO and 3MP were equipped with a pair. Many of the transmitters were still in operation in mid 1994, but some had been moved to other sites as a result of transfer of AM stations to the FM band.

* TBC TRANSMITTERS

Station 3KZ Melbourne was one Commercial station equipped with TBC transmitter. The transmitter was an AM10KD, 10 kW model derated to provide 5 kW output and designated AM5KD. It was operated by 3KZ until the licensee was granted a licence to operate in the FM band from 1 January 1990. The facility was later operated by Print Handicapped (Vic) Co-operative Ltd using callsign 3RPH but maintaining the 3KZ frequency 1179 kHz.

The transmitter was a high level amplitude modulated type designed to operate at any frequency in the band 535 kHz to 1606 kHz.

Vertical panel construction was utilised for ease of accessibility and maintenance.

Principal features of the transmitter included:

- A solid state temperature stabilised crystal controlled oscillator and two valve RF amplifier stages. A single 4CX3000A tetrode was used in the PA to produce a nominal 5 kW output to line. Typically the power was 5750 watts.
- A modular hybrid solid state audio amplifier driving push-pull 4CX3000A Class AB modulators.
- Six solid state power supplies.
- Centre panel metering and control units.
- Single steel enclosure cabinet with access through front doors and removable panels; swing-down centrally located meter and control panel; rear doors and secondary removable panels.
- High capacity centrifugal blower system for RF and audio stage cooling.
- Separate fan for maintaining positive cabinet pressure.
- Individual standard dust filters replaceable without shutting down the transmitter.
- Cooling system provided 12 cubic metres of air per minute, resulting in temperature rise of 24°C over the intake air temperature.
- The transmitter power requirements was 11 kW at 0% modulation, and 14 kW at 100% modulation.
- Starting time from cold to full power was variable from 3 to 30 seconds.
- Transmitter had power reduction capability to 2000 watts by push-button control.
- Audio frequency response ±1 dB over the range 50 to 10000 Hz.
- Audio frequency distortion 1.5% maximum at 96% modulation over the range 50 to 10000 Hz.

The company produced a range of MF band transmitters with 100 to 10000 watt output capability until about 1986 when manufacturing operations ceased.

* HARRIS TRANSMITTERS

Harris transmitters designed and manufactured in USA have been part of the broadcasting scene since 1922 and today are in operation in over 150 countries of the world.

Australian representative of Harris Corporation is Comsyst Pty Ltd, North Ryde.

A wholly owned Australian company since 1985, Comsyst specialises in the engineering, supply, installation and commissioning of AM, FM and TV broadcast systems, point-to-point microwave and satellite systems for the transmission of data, voice, television and radio.

Executives of the company in 1998 were Mario Fairlie, Managing Director; David Thomas; Darren Kirsop-Frearson; Neville Lee; Lorraine North and Shirley Harris.

Comsyst offers services including system design, and turnkey installation of all broadcast equipment including AM directional aerial systems, aerial couplers and dummy loads, microwave studio-to-transmitter audio and/or video links analogue and digital.

In recent times, the company has provided a range of facilities for AM broadcasters including masts and towers, aerial coupling equipment, feeders, power direction for directional systems, aerial switching systems, transmitters and program input equipment, emergency studio, standby power generating systems and mains voltage stabilisers.

Harris Broadcast Corporation facilities for which Comsyst are distributors include MF and VHF transmitters for AM, FM and TV broadcast stations, together with a complete range of studio equipment.

In 1994, the range of Harris transmitters included Solid State FM transmitters, 100 W to 1000 W; Solid State FM transmitters, 2-20 kW; Solid State MW transmitters, 1-5 kW, frequency agile, 5 kW; Single valve FM transmitters, 3.5-35 kW; Digital MW transmitters, 10-2100 kW, frequency agile, 100 and 300 kW; and Digital FM exciter, 3–55 W.

Stations in Australia equipped with Harris transmitters included 4AM-AM, Atherton; 4RR, Townsville; 4MK-AM, Mackay; 4BU, HITZ-FM, Bundaberg; 4RO-AM, Rockhampton; 4HI-AM, Emerald; 4CC-AM, Gladstone; 4VL-AM, Charleville; 4ZR-AM, Roma; 4GY-AM, Gympie; 4SS-AM/FM, Sunshine Coast; B105-FM, 4TAB-AM, 4EA-AM, 4KQ, 4QQQ-FM, 4RPH, Brisbane; 2MW-AM, Easy Hits, Tweed Heads; 2LM-FM, ROX-FM, 2LM-AM, Lismore; 2CS-AM, Coffs Harbour; 2AD-AM, Armidale; 2RE-AM/FM, Taree; 2KO-FM, 2EA-AM, Newcastle; 2GO-AM/FM, Gosford; 2WS-FM, 2SM, MIX-FM, 2UE, 2RPH and 2SER-FM, Sydney; 198-FM, Wave-FM, 2EI-AM and Power-FM, Wollongong; 2WG-AM, Wagga Wagga; 2AY-FM, Albury; 2DU, Dubbo; 2NM-AM/FM, Muswellbrook; 2TM-AM/FM, Tamworth; ROX-FM, Port Macquarie; 2MO-AM, Gunnedah; 2WEB-AM, Bourke; 3TR-AM, Gippsland; 3BO-FM, Bendigo; SCV-AM, Maryborough; K Rock-FM, Geelong; 3YB-AM, Warrnambool; 3AK-AM, 3TR-AM, Trafalgar; 3TT-FM, 3XY-AM, 3FOX-FM and 3EA-AM, Melbourne; 7QN-AM, Queenstown; 7HO-AM, 7TTT-FM, and 7RPH, Hobart; 5SE-AM, Mt Gambier; 5MU-AM, Murray Bridge; 5AD-AM, SA-FM and 5KA-FM, Adelaide; 6NW-AM, Port Hedland; Triple G-FM, Geraldton; 6SE-AM, Esperance; 6MM-AM, Mandurah; 6WB-AM, Katanning; 6VA-AM, Albany; 6BY-AM, Bridgetown; 6MS-AM, Bunbury; 6PM-FM, 6IX-AM, and

6PR-AM, Perth; In addition, Radio Australia stations included 1 Harris SW100 100 kW short wave transmitter at Carnarvon and 6 Harris SW100 100 kW short wave transmitters at Shepparton.

In addition to Harris transmitters, Comsyst represents Jampro Antenna Inc., with its range of broadcast aerial systems.

In June 1990, Comsyst was awarded a contract to design, manufacture equipment, install and commission the Radio Rebroadcast System for the Sydney Harbour Tunnel.

The 2.3 km long tunnel is divided into three segments; a 960 m submerged tunnel in a trench dug in the harbour bed links two pairs of excavated land tunnels, one 400 m long on the south side and the other 900 m long on the north side.

Following system design and procurement of equipment, the installation commenced in December 1991, and was completed in February 1992.

The purpose of the Radio Rebroadcast System was to retransmit the city's radio programs in the AM and FM bands within the tunnel tubes — an area that would not normally receive signals from existing broadcast sites. In addition to the AM/FM programs, emergency frequencies for the fire brigade, ambulance and police are rebroadcast within the Tunnel. The radio broadcast equipment was located in a room inside the Tunnel and received the audio/composite signals from Off-Air Receiving Equipment and retransmitted them as radio frequency signals via radiating cables. The radiating cable for the VHF/UHF signals was constructed with a random slot unit approximately every 20 m. The length of each slot was specifically designed for the VHF/UHF frequencies. Since both AM/FM and VHF/UHF radiating cables were used in both tunnel tubes, the total length of cable installed was 9.2 km.

The system allowed the Tunnel Operator to interrupt the normal program audio to the AM and FM transmitters and broadcast emergency messages on all broadcast station channels.

Comsyst has been one company to benefit from the demand for AM and FM radio broadcasting transmitters resulting from amendments to Section 39 of the Broadcasting Services Act enabling additional radio transmitters to be licensed to Commercial broadcasters. The Act which is administered by the Australian Broadcasting Authority was amended on 8 December 1995 and became effective from 5 January 1996. The amendment provides for issue of an additional Commercial radio broadcasting licence to an existing licensee if there is only one Commercial broadcasting licensee in a licence area and that licensee is providing a service in the licence area. Other conditions were also applicable.

Early preliminary studies indicated at least 55 Commercial radio licensees were eligible for an additional licence under the new conditions. By mid 1996, some 36 licences had been issued.

Some broadcasters took the opportunity to also upgrade existing transmitters resulting in high demand for AM, FM and TV transmitters. Comsyst received orders for about 60 transmitters in a two month buying spree period with the majority of units being for new FM stations with 47 units sold. Stations for which Harris manufactured transmitters were supplied included 2GF, 2CS, 2LF, 5UV, HOT 100, 6MM, 3BA, K ROCK, 5CC, 5SE, 3CS and 3SH. The most popular model supplied was the Harris Platinum PT Series FM transmitter with digital exciter.

In June 1997, station 2DAY operated by 2DAY FM Australia Pty Ltd, commissioned a Harris 20 kW solid state FM transmitter model 20CD, with switchless combiner unit. It was a significant technological advancement for an FM transmitter of this power rating as no power valves were employed. Instead, interchangeable 1350 watt FET solid state modules were used providing an estimated 250000 hours of mean time between failure. Darren Kirsop-Frearson of Comsyst was involved in negotiations for provision of the unit. Because the transmitter design enables it to digitally generate an FM signal, it placed the owners in a good position for future digital radio technology.

* **OTHER BRANDS**

Other brands of transmitters installed at various periods include Gates 50 W at 6BE and 2CP; Sparta at 2KY, 2MW, 4BC and 6NR; Collins 10 kW at 2NA, 2.5 kW at 8TOP, 2.5 kW at 2KO; Continental 5 kW 315-1 at 3WM and others.

A few local transmitter manufacturers were also active in providing for the broadcasting industry for AM and FM services. These included Radio Transmission Engineering (RTE), Ian Hill and Associates and Radio Manufacturing Engineers (RME).

After a long period of development Radio Transmission Engineering displayed its 10 kW Kikkert FM transmitter at the IREECON in late 1987. RTE expanded into the FM manufacturing field at its Guildford factory following the take over of the Kikkert designs from the Wyong firm TBC in late 1986. The Kikkert FM exciter was designed by James Cook University Electronics Lecturer Professor Keith Kikkert.

The 10 kW transmitter at the IREECON display employed an Eimac 4CX7500A valve with associated Eimac CV2228 cavity. The transmitter designated FMT-10K was built into a standard 19 inch wide cabinet, 40 rack units high and 702 mm deep. At the same display, the company exhibited a new range of studio-transmitter links based on the Kikkert modulation process and also the FML series of Kikkert VHF off-air translator modules.

During 1990, Radio Manufacturing Engineers Pty Ltd, signed an agreement to manufacture the Ian Hill and Associates range of pulse power transmitters allowing Ian Hill to concentrate on research and development activities. The Alpha AM series of solid state transmitters covered the power range 30 W to 2000 W. Stations provided with this equipment included 100 W at 4VL and 500 W at 2BH. The FM range of 20 W to 1200 W was marketed under the Beta label.

During 1992, the company was involved in the provision of 250 watt MF transmitters for the Sydney Harbour Tunnel project.

RME had been supplying and servicing the broadcast industry since April 1967 and in late 1992 was acquired by Southern Group, a Perth based organisation owners of subsidiary company Southern Broadcasting Systems specialists in the development of new broadcasting technologies, particularly the Digital Audio Mass Storage system.

The Southern Broadcasting Systems/RME combination enabled a wide range of services to be available to the broadcasting industry from a single house. They included feasibility studies, preparation and planning of submissions and licence applications, project management, turnkey studio installations, transmission system service, broadcast engineering consultancy services and others.

At the FARB Conference and Exhibition held in Melbourne during 17-19 October 1992, the group exhibited a range of products including RME Alpha 250 and 1000 MF transmitters; MF and VHF FM transmitter program input equipment; Phoenix Series studio mixers integrated with DAMS system; studio, switching and monitoring equipment and digital recording equipment.

A recent addition to the Alpha series of MF transmitters was the AM2000 providing 2 kW to line by paralleling two 1 kW units via an automatic combining unit. The system allowed for local or remote control and offered a high degree of redundancy in the design.

NORTHERN TERRITORY

The residents of the Northern Territory were the last people in an Australian State or mainland Territory to be provided with local National and Commercial broadcasting stations. They had, however, been provided with an ABC shortwave service from transmitters in Victoria and Western Australia from the 1930s but the programs had very little of local interest to the isolated residents and travellers in the Northern Territory.

Following Japanese bombings of Darwin from 19 February 1942 in which the first two raids resulted in 243 people being killed and some 300 wounded, the town and its port were in a shambles so the authorities decided that the civilian population was to be evacuated.

In 1944, Ted McGrath of the Adelaide PMG's Department accompanied by an Army officer visited Darwin and Adelaide River to select sites for broadcasting stations to be operated by the Australian Army Amenities Service for entertainment of Servicemen in the areas.

At Darwin, two sites were selected, with one being for a transmitting station at Cemetery Plains and the other at Leanyah Swamp for a receiving station.

The transmitter/studio building was a couple of Sydney-Williams huts joined together to form one large structure and lined with sound absorbing material. One section housed the transmitter and another housed the speech input equipment which consisted of microphone, gramophone equipment and landline switching panels for program lines from the receiver site. This section also served as the studio. Programs consisted mostly of 16-2/3 RPM records of USA origin with news and other items available from the BBC and Radio Australia via the receiving station site facilities. The transmitter, a BC200 manufactured by Thom and Smith Pty Ltd, Sydney was one of a series of eight broadcast transmitters built for service throughout New Guinea and other areas under military control north of Australia. It used two 813 valves in parallel providing 200 watts RF output. The modulator employed a pair or 813 valves in push-pull.

The transmitting aerial was a centre fed flat top with three elements connected to wooden spreaders at each end. The array was mounted between two sectionalised guyed wooden masts 30 m high and 76 m apart. Matching equipment linking a six wire 200 ohm transmission line to the aerial comprised an inverted L network and meters mounted in a metal box.

At the receiving station, receivers were mounted in a single Sydney-Williams hut. Aerials comprised reversible rhombics aimed at Shepparton and London, plus three centre fed dipoles. All were supported by 23 m Metters towers, and used open wire transmission lines.

The buildings, transmitter and receivers were supplied by the Army which also acquired the sites and provided landlines. The planning, design, supply and installation of the rest of the facilities were carried out by staff of the PMG's Department Broadcast Division from Adelaide, including the Radio Lines party. The broadcasting facility was completed and handed over to the Army on 11 February 1945 using callsign 5DR.

The Army station was controlled by 17 LOC Signals group. The Lieutenant-in-Charge had been an Announcer with Adelaide Commercial station 5DN, and program presentation was conducted in a professional manner. Technical maintenance was the responsibility of Sergeant Alf Cole a former Departmental officer. After the war, Alf returned to duty with the PMG's Department and on retirement was OIC at the Metropolitan Transmitting Centre 5CL/5AN Pimpala.

At Adelaide River, a site was selected just south of the old town alongside the main road. The transmitter building was the same type as that at Darwin and a similar aerial system was erected when the PMG's Department staff had finished the Darwin installation.

However, when this stage of the project had been reached, the War fortunes had changed, and it was decided by the Army to abandon the Adelaide River installation, and no further work was done on the site. The abandoned hut, aerial system, winches and transmission line were a feature of the local landscape for many years. No transmitting equipment was supplied to the site.

The callsign allocated to Adelaide river was 5AL, but this callsign was later used for the Alice Springs station.

In 1946, decision was made to include the 5DR station in the National Broadcasting Service. The buildings and equipment were recovered and re-installed closer to Darwin, the transmitter and studios being located at Gardens Hill, later known as Blake Street, and the receivers located on the then defunct racecourse.

The PMG's Department staff who installed the equipment were under control of Ted McGrath, Divisional Engineer and included Joe Brady, Engineer; Bert Lampe, Supervising Technician; Brian Woodrow, Ted Fuller, Ted Jensen, Bill West and a Radio Lines team which included Norm Kelly, Line Inspector; Aubrey Johns, Jack Buzacott and Charlie Ford.

As an ABC station, 5DR commenced transmission on 12 March 1947 with the majority of its program being generated locally but with news, current affairs and sporting segments rebroadcast from high frequency receivers tuned to HF inland services VLM and VLQ located in Brisbane and VLW located in Perth. Hours of transmission were approximately 0630 to 2300 Sunday to Saturday with breaks 2 to 3 hours morning and afternoon on weekdays. Brian Woodrow headed the operating and maintenance staff comprising Ted Fuller, Ted Jensen and Bill West.

The 18 m by 6 m angle iron framed corrugated Sydney-Williams buildings were mounted end-to-end on a concrete foundation that had been poured for an advanced observation/command post. Approximately half was allocated for a 9 m by 6 m studio and a 6 m by 6 m control room/transmitter hall. The other half was divided into offices etc, to house administration and logistic support staff associated with running the facility.

The Tasma BC200 transmitter fed the flat top aerial via a 200 ohm transmission line with the aerial being suspended by the former Army station sectionalised wooden masts spaced 36 m apart. The station operating frequency was 1500 kHz.

A second transmitter was installed in August 1947.

During the latter part of 1948, a program line between Adelaide and Darwin was established and 'live' program from Adelaide was broadcast from 17 December of that year.

The station output power was increased from 200 W to 2000 W with the installation of a pair of Philips 1656 transmitters manufactured in Adelaide in 1955. In 1959, the operating frequency was changed to 650 kHz and a 40 m high umbrella loaded guyed steel mast was erected as the main radiator.

The station callsign was changed to 8DR on 11 July 1960, but in more recent times was changed to 8RN.

By 1963, the population of Darwin was increasing at a rapid rate with new housing developments, predominantly in the northern suburbs, and also for other reasons, decision was made to relocate the station to a new site. In 1965, the transmitting station was established at its present site at corner Douglas Street and Ludmilla Terrace, Ludmilla. The site being of a swampy nature was superior to the Blake Street site which had rock at almost surface level for the whole of the area.

In 1978, twin STC 1000 watt type 4-SU-125 transmitters replaced the Philips 2 kW units. About the same time, the ABC established a new studio complex in the town business area.

In 1993, plans were developed to replace the twin STC 1 kW transmitters with twin Nautel ND1 units for 8RN and at the same time install a second MF transmitter in the same building with callsign 8TAB for the NT Racing Commission. The 8TAB transmitter was to employ a Nautel ND2.5 transmitter with the two transmitters being coupled to the single 40 m radiator by a dual frequency aerial coupling unit.

The 8TAB service operated by The Northern Territory Racing Commission came into operation during late December 1993 using the frequency previously employed by local Commercial station 8DN. Station 8TAB is a narrowcast service operating in the AM band but other outlets operate in the FM band at eight sites throughout the Territory. In addition to Darwin, the race programs are broadcast from stations in Alice Springs, Tennant Creek, Katherine, Jabiru, Pine Creek, Groote Eylandt, Nhulunbuy and Yulara. The service operates through the studios of Community station TOPFM at the Northern Territory University. Programs are sent over land line to Alice Springs where they are uplinked to satellite and subsequently downloaded to the transmitter sites for local transmission.

In order to rationalise local Government funded radio and television broadcasting services, the National Transmission Agency established a centre at Deloraine Road, about 14 km from the city centre. Prior to establishment of the new centre, the 8RN service transmitted the MF service from Douglas Street, the 8DDD Radio Regional service was located at the Telecom Blake Street site and 8ABCFM and 8JJJ transmitted from an interim facility located at Hudson Creek.

The temporary facility at Hudson Creek was established in 1988 to cater for the planned expansion of ABC FM services because of loading problems with the Telecom Blake Street tower.

The Deloraine Road facility comprises a 130 m tower with two metre face width, torsionally stabilised at the 45 m level to provide structural rigidity. The VHF FM aerial is a SIRA FM–03/12 four level three sided array of mixed polarisation being fed by two 4⅛ inch Flexwell feeders.

The aerial systems, building and ancillary systems were designed to cater for a final station configuration of eight VHF FM services together with television services and were designed to operate under cyclonic weather conditions.

An SBS FM service became operational on Australia Day 1994 following the installation and commissioning of a 5 kW NEC transmitter, patch panel and splitter. This was followed by the relocation of 8DDD, 8JJJ and 8ABCFM services to the Deloraine Road site.

Just before Easter 1997, the NTA provided a fast track temporary transmitting service for the Parliamentary and News Network (PNN) because of local interest in the euthanasia issue being debated in the Federal Parliament. The service was planned to become a permanent facility in the 1997–98 works program. The service was provided in the FM band and at the time, was the only PNN service being broadcast in the FM band. All other stations transmitted in the AM band.

As at mid 1997, five FM services operated at the Deloraine Road site providing coverage for listeners within about 50 km from the station. Operational frequencies were SBS Radio, 100.9 MHz; ABC Class FM, 107.3 MHz; ABC Triple J, 103.3 MHz; ABC Metropolitan Radio, 105.7 MHz and Parliamentary and News Service, 102.5 MHz.

In 1998, NTA awarded a contract to Broadcast Communications (Aust.) Pty Ltd to provide additional facilities at the site including an FM transmitter, an FM combiner for ABC and SBS radio services and other equipment associated with television at the site. The new transmitter was provided to act as standby for the five FM radio services. It had 'frequency agile' capability, enabling it to be tuned to the required frequency should any one of the five operational services fail.

Over the years, many Departmental staff worked on the 5DR/8DR facilities maintaining studios, transmitters and receiving equipment. Today, the studios are maintained by ABC staff and the transmitters operate in an unattended mode with maintenance responsibility as at December 1995 being undertaken by locally based Telecom Broadcasting staff. Others have since taken over this role. Early staff included Brian Woodrow, Ken Soar and Bob Fuller (former OIC's), Ted Fuller, Peter Williams, Bob Campbell, Keith Sommer, Bruce McGowan, Lew Grubb and others. Both Bruce McGowan and Lew Grubb were later to occupy senior positions in Telecom's Broadcasting Directorate.

Bruce McGowan who retired as Supervising Engineer, Engineering and Construction Section joined the PMG's Department as Telegraph Messenger in 1940. In 1941, he transferred to the technical area, began training as Junior Mechanic-in-Training and completed the course in 1947 following two years service in the Royal Australian Air Force. Bruce was sent north to 5DR in 1947 and returned to Adelaide in 1949 where he worked on radio telephone installations until selected as Trainee Engineer in 1958. On completion of training he was appointed to the Broadcast Transmitter Division with his first task being to match and align the 183 m antifading radiator at 5CK Crystal Brook. In later years he became involved in most of the broadcasting activities in South Australia and Northern Territory. On formation of the Broadcasting Directorate in South Australia, Bruce was appointed to the position Supervising Engineer. He retired from Telecom on 4 July 1986.

Lew Grubb who retired as Broadcasting Operations Manager, joined the PMG's Department in 1942 as Technician-in-Training. His initiation into broadcasting took place at the ABC studios in Adelaide where he was involved in the operation of disc, wire and tape recorders and in outside broadcast activities. In 1948, Lew transferred into the transmitter area where he was sent to Darwin to maintain the 5DR facilities. He returned to Adelaide in 1950 and for five years worked on transmitter installations followed by a period of two years as OIC of 5PA Penola. When television came to Adelaide, Lew was one of a group selected for training in the new technology. He subsequently worked at ABS2 Mt Lofty for six years from the first day of transmission. With the establishment of the Broadcasting Directorate in South Australia, he became Broadcasting Operations Manager for all National stations in South Australia. Lew retired from Telecom in January 1987.

Ted Fuller took leave during 1958 to 1960 to serve at the Australian base in the Antarctica with the Radiocommunications Group with responsibility for the maintenance and installation of the radiocommunications network. He arrived at an exciting time. Some 12 Nations had set up more than 50 bases on the Continent as part of the International Geophysical Year which was celebrated in 1957–58.

Shortly after returning to 8DR, he left to take up a position with the Northern Territory Administration being responsible for the Administration's radiocommunications network throughout the Territory including base stations and outpost stations. Equipment was mainly Codan and Philips manufacture.

The first Commercial broadcasting station established in the Northern Territory was 8DN Darwin. It began operation in December 1960 with a 2000 watt transmitter feeding a 55 m lattice steel radiator. In February 1983, a 500 watt relay station at Katherine operating on 765 kHz was linked to the 8DN studio. In February 1992, 8DN surrendered its licence and the Government invited applications for an FM licence.

In November 1948, a broadcasting service was put into service at Alice Springs with the commissioning of a 50 watt transmitter for the NBS. It was located near the local Post Office and fed a vertical wire aerial attached to a wooden pole outside the building housing the transmitter. The station using callsign 5AL transmitted on 1530 kHz with programs initially from Darwin but later from Adelaide.

The transmitter was replaced by a pair of Philips 1648, 200 watt units on 6 October 1955 and derated to 50 watts for operation as a main/standby configuration.

A new site was established on The Gap Road in April 1959 and transmitting facilities relocated there with a T type main aerial and similar standby type. The transmitter output power to the aerial was increased to 200 watts in 1968.

There was a basic studio on site where local programs of interest were recorded and sent to Darwin via landline. These were later broadcast back down the track to Katherine, Tennant Creek and Alice Springs. Programs during the day came from Darwin via the overland trunk route some 1500 km in length, and at night the programs were switched to Adelaide trunk circuit. Switching was controlled from the Darwin studios by a caihlo circuit.

A Commercial station 8HA commenced operation in Alice Springs in March 1971 using a 200 watt transmitter feeding a 46 m umbrella loaded aerial at a site on the south side of Heavitree Range. The National station 8AL was transferred to the same site as the Commercial station in November 1978 and shared the radiator. A pair of STC 4-SU-25A 1 kW transmitters with combiner were installed with combiner at the new site giving an aerial input power of 2000 watts.

With the commissioning of a microwave radiocommunication system between Darwin and Alice Springs in 1979, the program circuit was changed over to the radio bearer. On 23 February 1983, the 8AL frequency was changed to 783 kHz.

During 1993, the 8AL STC transmitters were replaced by two Nautel ND1 1 kW transmitters operating in parallel mode.

At the time, 8AL was the only ABC Regional Radio Network station in the Northern Territory. New studios were completed during 1990 and six full-time Radio staff produced 48 hours of program per week including three regional news bulletins a day.

On 11 June 1960, 8TC operating on a frequency of 680 kHz and a power of 50 W commenced transmission from a site at the southern end of Patterson Street, Tennant Creek. Two Commonwealth Electronics MFT3/50 models were provided and operated in a main/standby mode. The radiator was a T type fed by a coaxial cable. In 1973, 500 W AWA BTM 1J61560 replacement transmitters operating in a parallel mode were installed and the T type aerial replaced with a 49 m mast. Program was derived from the Darwin to Alice Springs channel.

In 1985, 8TC was relocated to the HF Broadcasting Station site on the Peko Mines Road where a Harris MW-1A 1000 W transmitter feeding a 49 m radiator was installed. Program was fed via the ABC Alice Springs studio.

Station 8KN Katherine operating on 670 kHz and employing similar equipment to 8TC commenced service on 5 July 1960. It was later relocated to the HF Broadcasting Station site near the Katherine Agricultural College using a Nautel AMPFET 5 transmitter operating at 2000 W output on a frequency of 639 kHz and feeding a 40 m mast radiator. Program was provided from the ABC Darwin studios.

In December 1974, the bauxite mining town of Nhulunbuy was provided with a National service with the commissioning of 8GO using a pair of AWA BTM P51J61650 transmitters in a main/standby configuration and operating on a frequency of 990 kHz. Power into the aerial was 500 watts. The radiator was a guyed lattice steel structure 61.5 m high.

Program was provided from the ABC studios over a three hop tropospheric scatter radio link. In November 1988, the program circuit was transferred to a newly constructed broadband microwave link. A further change was made in November 1991 when program was channelled via satellite to a receiving station at Mt Saunders from where it was taken by landline to the transmitter.

In May 1990, the lattice steel radiator was replaced by a new structure because of severe corrosion of the metal work and guy ropes resulting from the aggressive environment.

The original twin AWA transmitters were replaced in November 1990 by a single Nautel AMPFET1 model with the transmitter being derated from 1000 watts to 500 watts.

Station 8JB is situated in the Kakadu National Park. Service was initially established in 1980 with transmitting facilities located on part of the Ranger Uranium Mine Project area by the mining company and subsequently handed over to the Commonwealth. The Commonwealth however, was not granted any right of occupation to the site. Several sites were examined for relocation of the transmitting station during 1987 and a site selected in the Jabiru Industrial Zone about 2 km north of the township.

The original radiator was not considered to be satisfactory for removal and a sixteen section 50 m Skilfast mast was recovered from 8TC Tennant Creek site and re-erected at Jabiru. The radiator was designed as an earthed folded monopole capable of supporting an FM aerial and band three TV aerials. The earth mat comprised 75 copper wire radials each wire being 105 m in length and laid in the ground approximately 225 mm deep.

The original twin STC 130 W solid state transmitters operating in parallel mode were transferred to the new site. Operating frequency was 747 kHz and commissioning at the new site occurred on 26 November 1987. Programs were provided from the Darwin ABC studios.

Atmospheric noise — referred to some years ago as 'sferics', atmospherics or static — is produced by natural causes such as lightning discharges and is of major concern when planning an MF broadcasting station in the northern regions of Australia, such as the top end of the Northern Territory.

Data has been collected over many years from worldwide recording stations and maps and data are available indicating the expected median values of atmospheric noise at 1 MHz in dB above thermal noise. This median value is dependent upon geographic location and ranges from 55 dB just below Tasmania, to 85 dB in the top end of the Northern Territory and the top end of Cape York Peninsula in Queensland.

In order to determine the level field strength necessary for satisfactory reception in the presence of atmospheric noise, a formula is employed which takes into account frequency and the median value of the atmospheric noise. The protected field strength varies logarithmically with channel frequency and has a 9 dB variation across the MF broadcast band. For the Darwin area, the useable field strength to overcome the atmospheric noise alone is 15 mV/m for the lowest frequency of the band and 6 mV/m for the higher frequencies.

However, there are a number of other factors which have to be taken into consideration when allocating a frequency including the poor conductivity of the soil in many areas, ,particularly during the dry season. When the earth mat was installed for a vertical radiator for 8DR in 1959, trenches for the copper radials had to be blasted out of solid rock.

As at 1996, the seven MF stations in the Northern Territory were operating on frequencies ranging from 657 kHz to 990 kHz.

In addition to MF stations, the Northern Territory has many other broadcasting services including HF and FM stations. HF transmitters are located at Katherine, Tennant Creek and Alice Springs providing complete coverage of the Northern Territory with programs provided jointly by the ABC, and Alice Springs based CAAMA. ABC station 8ABC FM became operational in December 1983, 8TOP commenced operation in Darwin in June 1981, 8CCC was commissioned in Alice Springs in January 1981 and 8KIN Alice Springs went to air in February 1985. In 1996 there were 19 transmitting stations using the 8KIN callsign. There is also a large network of FM transmitters throughout the Territory forming part of the ABC Second Regional Network.

As at early 1996, broadcasting services in the Northern Territory included seven MF stations, comprising 5 National and 2 Commercial; 3 HF stations; and 105 FM services comprising 28 ABC National, 1 SBS National, 14 Retransmitting ABC programs, 55 Community, 6 Retransmitting Community programs and 1 Commercial.

AM STEREO SYSTEMS

Although AM stereo broadcasting officially started in 1985, the principles had been known for many years. At the World Radio Convention in Sydney in 1938, Ray Allsop, Director and Chief Engineer of the national sound picture organisation Harrington-Raycophone and a prominent Broadcast Engineer arranged a demonstration in the Plaza Theatre, Sydney at which 2000 guests attended. The audience heard for the first time in Australia, electrical reproduction of an orchestra possessing effects in the aural field similar to stereoscopy in optics. Mr Allsop called his system 'steroscopic sound'.

With the introduction of two channel stereophonic disc recordings in the 1950s, Commercial station Engineers were eager to broadcast these records using stereo mode. One Engineer involved was Neil McCrae on the staff of 3UZ Melbourne. He constructed a stereo record player using an ACOS crystal pick-up to play some of the first stereo records acquired for the station record library.

In 1958, 3UZ combined with 3XY to undertake the first stereo broadcast in Melbourne by Commercial stations. The right channel of the record output was transmitted by 3XY, while 3UZ transmitted the left channel.

In 1957, staff at the Adelaide NBS studios were given the opportunity to try out some of the ideas which were appearing in the technical literature concerning stereo broadcasting technology. Occasionally, two studios used by the ABC were free, and these were used to undertake a program of tests.

Studio 520 was set up with three microphones and two OB amplifiers via tie lines, plus normal studio output circuits. All circuits were fed to monitoring amplifiers and speakers in Studio 510. Staff soon became familiar with new terminology such as 'binaural', '2 or 3 channel stereo sound', 'hole in the middle' and others. Outstanding sound effects were performed by Ted Penny, particularly the sound of passing high speed trains.

The first on-air tests involving the two metropolitan transmitters 5AN and 5CL were scheduled for early May 1959, with the transmitters being used after the cessation of normal programs. ABC Announcer, Toby Symonds had been busy for some days preparing a suitable script for the presentation, but at short notice Toby had to go to Sydney.

Technical staff were determined that the show must go on, so Cliff Moule, Supervising Technician stepped in, and without script, gave listeners some idea of what was going on and how to arrange two speakers in the home to obtain maximum benefit from the broadcast. Another member of the Technical staff played discs from the control booth.

There was a delay of some months before stereo transmissions became a regular part of normal ABC programs. Because the two local transmitters were not equal in output power (5AN was 4 dB down on 5CL), the experimental Adelaide FM mono transmitter and 5CK Crystal Brook, the nearest regional transmitter were fed with the same program as 5AN to provide better coverage, particularly for mid-north listeners.

The stereo broadcasts ceased after about a year because both the ABC and the PMG's Department were busy with the establishment of TV and the construction of a new metropolitan transmitting centre for 5AN and 5CL at Pimpala. However, by the mid 1960s, the ABC was asked to make a few commercial stereo recordings which required shifting a lot of portable outside broadcast equipment to the two orchestral venues then available at the Adelaide Town Hall and Studio 525 at Norwood.

In early October 1968, a mixer unit referred to by Technical staff as the 'green monster' arrived. The name was appropriate. It was 710 mm wide and extremely heavy. It included all-valve equipment, many large iron core transformer inputs, output and power. Each side — left and right — had a mixture of low level microphone and line level inputs with the usual master volume and balance controls, so the front panel had an impressive array of knobs. It was accompanied by a large and heavy packing box for transport of the unit to and from other States. Later, a companion mixer, the 'blue monster' arrived so OB operators were back to pre-war days with transportable equipment so bulky and heavy that even two operators struggled to cope with movement operations.

From 1972, Graham Milne played a key role with stereo recording operations when the Adelaide Festival Theatre became available as another recording venue. One of the notable recordings made at the Festival Theatre was Peter Sculthorpe's 'Rites of Passage'.

The ABC were able to transfer all remaining activities from the City to their new building at Collinswood, an Adelaide suburb, by October 1975, with all production studios being equipped for stereo operation just prior to the start of regular FM stereo programs in January 1976 to transmitters in Adelaide, Canberra, Melbourne and Sydney employing FM Stereo mode.

With the establishment of FM broadcasting services, the AM broadcasters came under attack from the listening public about their low quality music transmissions. The AM broadcasters were forced into a position of bias towards talk-back, talks and news programs at the expense of musical entertainment.

The critics were answered to some degree with the development of AM Stereophonic Sound Broadcasting Technology. However, because of the absence of firm guidelines from regulatory authorities, many different systems were being developed throughout the world, adding confusion to both transmitter and receiver manufacturers. This was particularly so by 1981 in the USA. Systems trialled included Kahan, Harris, Magnavox, Diora and Motorola, with Motorola being finally approved as the national standard in late 1993.

The Motorola system was taken up by most countries including Australia where the Motorola C-QUAM system was accepted as the transmission standard following decision by the Minister for Communications in October 1984.

C-QUAM is the Compatible Quadrature Amplitude Modulation method of stereo transmission by which a main (L+R) and a subchannel (L–R) signal are transmitted on a single carrier. This is accomplished by using two modulation modes to transmit the main and stereo information channels. Stereo receivers separate the signals to ultimately produce left and right channel audio while typical monophonic receivers detect only the L+R (mono) content of the C-QUAM signal. The most important feature of C-QUAM is that no compromises are made in monophonic performance in order to transmit stereo.

A typical AM Stereo Exciter is designed to convert a monophonic station to C-QUAM AM stereo. The exciter receives left and right channel audio signals and produces RF and audio signals for one or two transmitters. The RF signal from the exciter replaces the RF signal from the crystal controlled oscillator in the transmitter. The audio signal is fed to the transmitter modulator input. The exciter contains switchable delay circuits and adjustable high and low equalisation filters to compensate for modulator characteristics on a wide variety of transmitters.

In terms of transmitter specifications, audio frequency response for an MF AM mono service is typically 30 Hz to 10 kHz ± 1 dB compared with 50 Hz to 7.5 kHz ± 2 dB for an MF AM stereo transmitter. Noise level below full modulation is about the same at 60 dB and harmonic distortion specification is typically 3% at 96% modulation depth for MF AM mono service and 4% at 80% modulation depth for an MF AM stereo service transmitter.

The first National station to begin stereo broadcasting was 2BL Sydney which commenced on 1 February 1985. This coincided with the officially authorised date for commencement of AM stereo in Australia.

In addition to considerable studio changes in order to shift over to AM stereo, National and Commercial broadcasters found it necessary to make a number of changes to transmitter and aerial equipment. For instance, tests required to assess the suitability of the transmitter included incidental phase modulation, amplitude response of sidebands, symmetry of the modulation amplitude, and sideband phase response. The performance characteristics of the aerial and feeder systems was also important with tests being carried out to assess the overall radiation system impedance variation presented to the transmitter across the sidebands; aerial Q; sideband phase shift of feeder cables; losses and sideband amplitude and phase response of matching unit, power dividers and phasing circuits where installed; far field performance in relation to left and right hand channel separation, stereo and monoaural noise and distortion for envelope and synchronous detection, and other tests concerning combined transmission systems.

Just as the majority of Commercial broadcasters were quick off the mark to go to round-the-clock broadcasting once it was approved, AM stereo was encompassed at the same rapid pace. By April 1985, conversion to AM stereo was in full swing with 3AW being amongst the early ones when it went to air on 1 February 1985, using the new format. By June 1990, about 50 Commercial stations had been converted but the National service was much slower in the changeover process. National stations transmitting on AM stereo included 2CN, 2BL, 2NC, 3LO, 4QR, 5AN, 6WF and 7ZR.

Although the broadcasters spent large amounts of money to upgrade their facilities to take advantage of the improved service which AM stereo provides, listeners have not been as enthusiastic. The sale of domestic receivers designed to take advantage of the new technology has been disappointing. Also, no Australian manufacturers took up the opportunity to produce AM stereo receivers.

Enthusiasm for broadcasters to convert to AM stereo format tapered off considerably following an initial burst of activity and at 30 June 1993, only 1 Community, 51 Commercial and 8 National stations were transmitting in the stereo mode. This was less than 23% of the total stations operating in the MF band. The situation in the US was just as disappointing. Only 660 stations out of a total of nearly 5000 converted to AM stereo.

As at early 1996, the number of transmitters broadcasting in AM stereo mode was only 57 mainly as a result of some Commercial station licences being surrendered for licences in the FM band.

SOLID STATE TRANSMITTERS

Although transistors and related devices soon replaced valves in radio receivers when they became available in large quantities, it was some time before they made an impact on transmitter technology. Broadcast transmitters employed high signal levels and required circuits of high linearity.

However, designers recognising the high reliability and higher efficiency of the transistor devoted considerable effort to improvements in transistor manufacture and circuitry specifically suited to transistor application. A major change was a departure from linear amplifier format to a switching mode.

In 1967, AWA Engineers including Hugh Bartlett, J G Abel and J G Ewing described a fully solid state transmitter developed by the company at The Institution of Radio and Electronics Engineers, Australia, Convention in Sydney. The 50 watt broadcast transmitter described was the first completely solid state MF broadcast transmitter to be produced in Australia.

Major features of the transmitter included:

- Low level transformerless modulation.
- No tuned circuits apart from the output circuit.
- Transistors used in switching modes giving immunity to temperature variations and transistor parameter variations.
- Overall high efficiency.
- Modular construction for easy maintenance in the field.
- Simple paralleling enabling the uses of multiple low power units to produce high powers.
- Ideal for unattended operation.

Another local company, STC was also active in developing solid state broadcast transmitters during this time with a number of its units being exported overseas, as well as employed with local MF stations. The design provided 130 watt output using single ended Class B push-pull high level modulation stage. Many were employed as combined units providing 250 watts output. In overseas developing countries it was known as 'The Village Broadcaster'.

However, it is only in recent years that powers of 5 kW and above have been widely employed to replace valve type transmitters in Australia.

This became possible with the availability of power MOSFETS as power amplifying elements. Nautel, Harris and BE models, all of overseas origin, are brands which have been installed in recent times at many stations.

The first Nautel transmitter was installed at Commercial station 2WS employing a Model 10 transmitter in November 1983. The first National station to be equipped was 8KN with a Model 5 unit in May 1985.

By the end of 1989, about 50 Nautel transmitters ranging in power from 400 watts to 50000 watts had been commissioned throughout Australia. National stations equipped with 10 kW transmitters included 4CH, 3WA, 2NT and 6KR in 1987 and 3GI, 4RK and 4QL in 1988. Others have been installed in more recent times.

The first 50 kW transmitter installed in Australia was at 3WV in September 1987. The transmitter consisted of 48 identical 1.25 kW power sub-systems combined into 5 kW groups. The twelve 5 kW blocks were combined in the final harmonic filter/combiner unit to provide 60 kW output capability. Sub-system failure did not result in an off-air situation. The integral modular reserve design provided for continued operation at slightly reduced power without additional stress on the remaining sub-systems.

The Nautel line of transmitters is the product of Nautical Electronic Laboratories Ltd, Canada. Rod Thompson, Engineer with the Australian Distributor was responsible for technical support to customers.

The first dual 50 kW installation was completed at 3LO/3RN, formerly 3LO/3AR in 1991. STC 50 kW valve transmitters were replaced with Nautel ND25 solid state PWM types. Whereas the old equipment was configured with 50 kW main and 10 kW standby transmitters for both services, the new facilities comprised parallel 25 kW Nautel units. Each of the four 25 kW transmitters had multiple redundancy in the power amplifiers in the form 12 x 2.3 kW modules and any individual failure only resulted in a minimal power reduction. Faulty modules could be replaced without interrupting the service. The main DC power supply system in each 25 kW transmitter supplied 72 volts at 670 amperes under 100 % sine wave modulation condition.

A number of special features were designed into the internal and external transmitter control to take account of the inevitable lightning strikes and for VSWR problems associated with high structures during storms and the fact that modern transmitters may not be as tolerant as older valve types.

The 3LO/3AR transmitting station at Sydenham was the centre for a number of important developmental trials with the National Broadcasting Service over many years. Equipping the station with the first dual 50 kW solid state installation follows earlier patterns of technological development for the station.

Officers-in-Charge who have played a major role in station activities include Stan Hosken, George Kendrick, Fred Chapple and Russell Rolls.

One of the last 50 kW Nautel NBS transmitters to be installed during 1993 was provided at 2CR Cumnock. The unit was commissioned on 28 January 1994.

The installation comprised a pair of AMPFET ND25 units operating in parallel through a combining system and differed from other 50 kW installations in that the combiner incorporated contactors for switching, instead of a manual patch panel. Should the power output of one transmitter fall 3 dB below the other transmitter, the faulty transmitter was automatically switched to test load, and the normal transmitter switched directly to the aerial so that half its power was not dumped to the combiner absorber load.

Nautel units have also been installed at many Commercial stations. By mid 1989, stations included 2WS, 2HD, 2CC, 2LM, 2GB, 2WL, 2CA, 2KY, 4AK, 4GR, 4BH, 4RR, 4MB, 3DB, 3UL, 3SR, 3AW, 3UZ, 3CS, 7LA and 5DN. Others have since been equipped with these solid state transmitters, but some stations had disappeared from the MF scene by 1993, having surrendered their licences to transfer to the FM band.

Typical of Harris brand installations is the equipment provided for 6MM which commenced transmission in March 1988. The installation comprised two Harris SX2.5A solid state units with one acting as the main and the other as standby. A Harris C-QUAM stereo exciter fed the transmitters with program drive via two peak limiters, a line failure/automatic changeover system and an emergency tape program source.

Broadcast Electronics Inc., of USA also introduced a new generation of solid state AM transmitters in 1992-23. These were handled in Australia by John S Innes Pty Ltd.

The transmitters all include built-in C-QUAM AM stereo and high efficiency Class E operated power modules. The range included AM1, with nominal 1 kW output with five preset power level capability; AM2.5 with nominal 2.5 kW output featuring the 'Star' combiner network for uninterrupted operation, with minimal power reduction without the use of dummy modules; AM5, of 5 kW nominal power output with eight plug-in power modules rated at 700 watts RF power, four power supply assemblies and one stereo exciter control unit and AM10, of 10 kW nominal power output with five preset power levels available and two sets of aerial equalisation switched by remote control.

Commercial station Operators who ordered AM5 transmitters for installation during late 1994 included 2DU Dubbo, 2PK Parkes and 2MW (Radio 97) Murwillumbah.

Until the advent of the all solid state transmitter, the majority of transmitters utilised high level modulation for high efficiency and consisted essentially of an RF power amplifier, a power modulator, low level excitation circuitry, power supplies and control/monitor circuitry.

The new solid state designs have basically the same sub-systems, but the details of the amplifier and modulator designs are very different, utilising digital switching rather than analogue techniques. Such techniques are not new but their application has been given considerable impetus by modern technological developments.

Transmitters designed to employ valves in the output stage used dedicated power amplifier and power supply unit stages, individually designed for a particular power or performance level.

Solid state transmitters, however, use common functional modules. This feature allows a cost-effective mixture of transmitters to be employed at any one station backed by common spares.

This advantage extends to other areas including test equipment, special servicing tools, test jigs and training in the case of a large system or network.

However, the design of solid state transmitters does require that meticulous attention be paid to the operation and protection of the transistor devices used in the equipment.

Most transmitter designs incorporate a fast acting output protection circuit which senses the amplitude and phase of the radio frequency currents to protect the transmitter against unacceptable loads as well as aerial, transmission line and aerial coupling unit arcing.

The power rating of solid state broadcast transmitters has steadily increased to take advantage of the technology. In October 1995, USA firm Harris Allied announced that it had completed factory assembly and testing of the world's first 1000 kW solid state Model DX1000 transmitter for installation at a Voice of America relay station in Thailand. A second DX1000 model was being assembled for later installation at a VOA site in the Philippines. In mid 1996, the company announced that it had secured a contract to supply three 500 kW and one 2000 kW solid state AM transmitters employing digital amplitude modulation technology for the Voice of Vietnam broadcasting service.

Modern solid state equipment provides a number of advantages compared with earlier valve type equipment. These are evident in the case of station 4RK Rockhampton where a 10 kW STC valve transmitter was replaced by a 10 kW Nautel solid state unit in 1988.

- The original 4RK building was erected in 1931 to accommodate a 2 kW STC water cooled transmitter. The building was a typical Queensland low set building of timber and a tiled roof. Some additions and modifications were made over the years to cater for new and replacement equipment. The STC 4SU-11A 10 kW valve transmitter had a front panel length of about 5.3 metres and was provided with a 2 kW STC type 4SU-14C standby unit recovered from 4QN in 1963.

The Nautel installation comprised one Amphet 10 model Serial number 235 and was installed in a small Logan type building erected behind the original timber building. An emergency power generating plant was installed in the same building.

The overall width of the Nautel transmitter was 660 mm, only 12.5 % of the STC unit.

- Mains input power input requirement of the Nautel transmitter was only half that of the STC unit at 100 % modulation.
- As measured during commissioning operations of the two installations, the overall efficiency of the Nautel transmitter was double that of the STC unit — 72 % compared with 36 %.
- Measured total harmonic distortion was 2 % at 96 % modulation for the Nautel unit compared with 4.9 % for the STC transmitter.
- High tension supply for the Nautel transmitter was 72 volts compared with 10 kV for the STC transmitter providing a less hazardous environment for maintenance staff.

Another early NBS station where a large rundown building was replaced by a much smaller building because of the small size of modern solid state equipment was 2CO Corowa which was commissioned in the same year as 4RK Rockhampton in 1931.

In 1997, two solid state transmitters in parallel configuration with integrated combiner and automatic switching capability replaced a pair of AWA BTM 10 units and were installed in a small prefabricated building and the old building demolished. Standby power plant was provided in a small building nearby. Cost of the replacement facilities was $743000.

Short Wave Transmitters

Short wave or high frequency broadcasting commenced in Australia six days before experimental transmissions beamed to Australia from the UK began. The British Post Office granted Gerald Marcuse, a well-known British experimenter a licence to transmit speech and music for two hours a day with a 1000 watt transmitter. A series of broadcasts in the form of concerts were broadcast to Australia commencing 11 September 1927 on a daily basis until August 1928. Two boy members of the Adelaide YMCA Radio Club reported having received some of the broadcasts using a three valve regenerative receiver they had constructed under supervision at the Club.

The BBC began experimental broadcasts on 11 November 1927 with a broadcast of the Armistice Day Cenotaph service using a vertically polarised Franklin type aerial system fed by a transmitter producing 8–10 kW. Callsign used was G5SW.

However, it was not until 1932 that the BBC installed a properly designed short wave station at Daventry with two transmitters producing 10–15 kW and aerials beamed to five zones including Australia. It began operation on 19 December 1932. On Christmas Day, it broadcast King George V's Christmas Day message. It was the first time this special broadcast had been transmitted to listeners outside the UK.

The broadcast was received in Australia about 1.50 am Eastern Standard Time on Boxing Day with the program being received by the newly completed PMG's Department Receiving Station at Mont Park in Victoria. It was relayed over program circuits for rebroadcast by National stations 3LO, 3AR, 2FC, 2BL, 5CL, 7ZL, 4QG and 6WF and Regional stations. B Class stations which also took the program included 3DB, 3AW, 3UZ and 3KZ. The program was of one hour's duration and commenced with the BBC Choir singing 'Land of Hope and Glory'.

Australia was the first British Dominion to establish a regular overseas broadcasting service to the world.

Amalgamated Wireless (A/Asia) Ltd had been for some time actively involved with the Marconi Company in establishing facilities for a beam wireless system connecting Australia with England using short wave radio. The beam system was a success from the beginning, and soon challenged the cable companies with their worldwide network of submarine cables for a slice of the lucrative communications business. It came into service on 8 April 1927.

Flushed with the success of the beam service, AWA employed a 20 kW transmitter it had constructed at Pennant Hills, Sydney to transmit a broadcast program to the UK. The transmission using callsign VK2ME took place on 5 September 1927 with a program from 2FC studio in Sydney and was a great success. It became known as the Empire broadcast with further programs being transmitted on 17 October, 31 October, 7 November and 26 December 1927, all of which were rebroadcast by the BBC. Arthur McDonald, AWA Chief Engineer, supervised AWA facilities associated with the transmissions. George Cookson was Resident Engineer at the station at the time.

The 20 kW transmitter VK2ME had been designed for either telegraphy or telephony operation and occupied an entire room in the AWA Pennant Hills Radio Centre. It comprises seven panels —

modulating, two rectifying, key absorbing, drive, No 1 and No 2 magnifying panels. The high power valves were oil cooled types with the oil being circulated by pumps through an air cooled radiator. The valves employed in the modulator panel dissipated a power of 3 kW each while the main oil cooled valves in No 2 magnifier were capable of dissipating powers as high as 10 or 12 kW each continuously. The transmitter operated on 28.8 metres (10.4 MHz) and was first used for telephony transmission on the occasion of the international broadcasting of the Eucharistic Congress held in Sydney.

The transmitter had been originally designed and developed in late 1924 by AWA Engineers for research into international short wave communications and when commissioned was the most powerful short wave transmitter in the Southern Hemisphere. Syd Newman played a major role in its design and development.

In forwarding a verification card to Mr J White, Ship-Aerial Wire Company, New York City, in regard to reception of VK2ME on 25 February 1930 with a Super-Wasp receiver, Chief Engineer McDonald said there was no regular transmission schedule as the service was experimental only.

About the same time, Engineers of A Class stations were experimenting with short wave broadcasting, not only for overseas broadcasting purposes but to extend station coverage beyond the service areas of their medium or long wave stations within Australia.

In August 1927, Associated Radio Company who held the original licences of both 3AR Melbourne and 7ZL Hobart were given approval by the Chief Inspector of Wireless of the PMG's Department to construct a short wave station employing 250 watts on a wavelength of 55 metres (5.45 MHz) to broadcast 3AR programs.

Station 3LO Melbourne conducted short wave broadcasting every Monday morning 4.30 am to 6.30 am local time, for overseas listeners during late 1927 on 36 metres (8.3 MHz) but in December of that year changed to 32 metres (9.37 MHz) following feedback of reception reports from BBC monitors in England. The broadcasts were well received in many countries with reports being received from listeners in Alaska, USA, Canada, a number of Pacific Islands, Java, Ceylon, India, Malaya, England and many African and European countries.

On Sunday 6 May 1928, 3LO undertook experiments to assess whether short wave transmissions could provide an Australia-wide daytime broadcasting service. Considerable publicity was given to the tests including announcements over the station, and advertisements in the technical press.

To assist listeners who did not possess a short wave receiver capable of receiving the transmissions on 32 metres, the station Technical staff produced a booklet to guide listeners in constructing a short wave receiver and setting up a suitable aerial system.

The transmissions took place 9.45 am to 10.15 am, 12.45 pm to 1.45 pm and 4.45 pm to 5.45 pm.

Analysis of listener reports was not made public.

About October 1927, Engineers of 4QG Brisbane were busy conducting experiments on 32 metres (9.37 MHz) for long distance broadcasts and on 100 metres (3 MHz) for improving service to listeners in North Queensland.

Wally Coxon, Chief Engineer of 6WN Perth employed an imported 200 watt transmitter on 104.5 metres (2.87 MHz) in the late 1920s to provide service to outback Western Australia areas not covered by the 6WF long wave transmitter on 1250 metres (240 kHz). The transmissions were carried out from equipment installed at Mt Lawley, one of Perth's inner northern suburbs. Records indicate transmissions taking place through 1927 and 1928 and may well have continued up to the time when the Government took over 6WF in 1929. Reports of reception were received from overseas listeners in New Zealand, South Africa and USA.

AWA continued with its experiments with short wave broadcasting and on 4 July 1931 a regular service on a weekly basis was inaugurated from VK2ME. The service known as 'The Voice of Australia' opened and closed transmissions with a recording of the Kookaburra or 'laughing jackass'. The transmitter designed and built by AWA, had a rating of 20 kW and transmissions were conducted on 28.5 metres (9590 kHz). It comprised seven units and employed 22 air and oil cooled valves. The transmitter was also used to conduct the first international duplex and telephony experiments in 1928 by the company.

AWA Engineers associated with the short wave broadcasts included Sydney Newman and J Murray Johnson. Mr Newman had joined the AWA Engineering and Research group in 1920 while Mr Johnson joined the company in 1922 after having been involved with early Coast Radio Station work since 1910. Another of Mr Johnson's tasks was to draw up plans for the 2FC guyed masts erected by Morts Docks Engineering Company at the station site at Willoughby.

Other experimental short wave broadcasting stations operated by AWA were VK3ME at Braybrook, Melbourne and VK6ME at Perth. The Melbourne service employed a 1.5 kW transmitter on 9510 kHz feeding a half wave vertically polarised aerial for low angle uniform radiation. The transmitter comprised four units including two high tension double wave three phase rectifiers and employed high power modulation.

First experimental transmissions were conducted on 21 November 1927 with regular transmissions being performed from December 1930.

The Perth service came into operation on 22 March 1937 with a 200 watt transmitter on 9590 kHz.

In 1939, VK2ME transmissions were conducted at different times throughout the month, on Sundays only, with typical times at GMT being First week 0600–0800, Second and Third weeks 1000–1400 and Fourth week 1430–1630. The VK3ME service operated nightly from Monday to Saturday (inclusive) 1100–1300 while VK6ME Perth using the same frequency as VK2ME transmitted nightly Monday to Saturday (inclusive) 1100–1300.

By this time, the Melbourne VK3ME service had been upgraded to an output power of 5 kW.

At the outbreak of the Second World War, the experimental licences were withdrawn by the Postmaster General's Department and the service closed down. However, the Government was anxious to establish a short wave service quickly, and following Cabinet approval on 18 October 1939, an overseas broadcasting service known as 'Australia Calling' commenced on 20 December 1939 with programs being broadcast by transmitters in Sydney leased from AWA, and the Department's Lyndhurst transmitters.

One of the Announcers who broadcast over VK2ME was Philip Geeves who entered the broadcasting industry as an Announcer for the AWA station 2CH Sydney in 1936. In April 1937, he transferred to the VK2ME Announcing staff. In later years, he became AWA Archivist and did much to record the history of the company, and in particular, its role in the development of broadcast technology.

In 1993, an Electronics Australia publication entitled 'The Dawn of Australia's Radio Broadcasting' was published by Federal Publishing Company, being Part One of a projected history of radio broadcasting which Philip Geeves had compiled before he died in 1983.

Government involvement in short wave broadcasting began in 1928 when the Research Laboratories of the Postmaster General's Department established an experimental transmitter at Lyndhurst out from Melbourne. The transmitter provided a carrier power to the aerial of 600 watts on 9580 kHz. Transmission was limited to two or three hours daily with programs being beamed to Northern Australia.

On 12 March 1934, the transmitter was put into regular service broadcasting ABC programs and operated with callsign VK3LR. The transmitter power was increased to 1000 watts in 1936 and fed into a horizontal half wave aerial without any directional elements. During December 1937, the callsign was changed from VK3LR to VLR.

The response from listeners who were remote from the service area of the National MF stations was so encouraging that equipment was designed to provide an improved service.

The new facilities designed by Research Laboratory staff and manufactured in the Melbourne Postal Workshops were put into operation on 1 October 1938. The transmitter with 2000 watt output was designed to operate on three frequencies and used callsign VLR1 when operating on 9580 kHz, VLR2 when operating on 6140 kHz and VLR3 when operating on 11880 kHz.

The design was unusual in that, with the exception of the modulator unit, the whole of the transmitter was arranged for push-pull operation. This technique offered a number of advantages over single valve stages for high frequency working because the radio frequency circuits were balanced to earth and simplified neutralisation. The transmitter was constructed on the unit basis with each unit having its own power supply. This enabled a high degree of isolation to be obtained, so minimising feed back in filament circuits or other common power supplies. All the RF circuits were coupled together with low impedance transmission lines. Particular attention was paid to avoid parasitic oscillation. This phenomena was of particular concern to transmitter designers of the 1930s and many novel solutions could be seen in transmitters to overcome problems in particular sections. These parasitic oscillations manifested themselves in many ways, including high anode feed currents, excessively high grid currents, instability or violent voltage transients.

The carrier frequencies were generated by three low temperature coefficient cold type crystals with the final carrier being obtained from frequency multiplying circuits using pentode valves. The output of the master oscillator was applied to two 100 watt pentodes in push-pull which comprised the modulated amplifier with the audio frequency from the modulator being applied to the suppressor grid.

The output of the modulated amplifier was about 30 watts and was applied to the first linear amplifier which produced 250 watts of output using two triodes in a conventional cross neutralised push-pull circuit. The output was fed to the final linear amplifier located about 1.5 m away in another enclosure and connected by a long length of 200 ohm lead covered RF cable laid in a floor cable trench. The final amplifier consisted of four air cooled valves in a neutralised push-pull circuit delivering 2 kW carrier to the aerial. The valves dissipated more than 4 kW in heat and were force cooled by two fans located in the bottom of the cabinet with a ceiling fan exhausting heat from the hall.

All filaments were heated by AC with the final amplifier filaments being fed from a Scott connected transformer to give 90 degree phase difference between each side of the push-pull circuit. This allowed improvement in carrier noise from this stage. Anode power supplies used mercury vapour valves throughout providing 4 kV for the final amplifier, 3 kV for the modulated amplifier and first linear amplifier and 500 V for the modulator and master oscillator. Bias supply was provided by a copper oxide unit.

On 16 June 1941, a 10 kW outlet was provided at Lyndhurst and used as part of Australia's initial International broadcasting service.

In 1945, a third service was put into operation using callsign VLH and offering an alternative to the VLR transmissions.

Three 10 kW RCA transmitters were added to the Lyndhurst facilities in 1958 resulting in substantial improvement to listeners in remote areas.

In the late 1960s, the transmitting facilities were updated with the installation of eight new STC 10 kW transmitters and associated input and monitoring equipment. The schedule provided two Radio Australia, two Time Signal Services, a sideband link to Perth and Inland Services VLR on 6150 kHz and VLH on 9680 kHz, 11800 kHz and 15230 kHz. The VLR transmitter served New South Wales and South Western Queensland with 3LO program, while VLH served Northern Australia with 3AR program.

The single sideband link was later used to provide backup program facility to Radio Australia, Cox Peninsula. Newer, more powerful 30 kW SSB transmitters were installed for this service in the mid 1970s and also served Radio Australia Carnarvon transmitters after Cyclone Tracy rendered the Cox Peninsula complex inoperative in December 1974.

The need for the Lyndhurst station gradually declined, and the station ceased operation on 12 June 1987. Three of the transmitters were shifted to Brandon in North Queensland to provide services to Papua New Guinea and Coral Sea areas. At the time of its closure the aerial systems included five curtain arrays and rhombics.

The last two Officers-in-Charge at Lyndhurst were Ken Bytheway and Max Fowler. When the station was decommissioned, besides Max Fowler, operating and maintenance staff included John Nott, Martin Greasely, Mark Bellis, Max Bartlett, Neil Williamson, Colin Bithell, John McKenzie, Ray Arrowsmith, Bruce Gardner, Malcolm Gall, Greg Coe and Leon Bones.

The success of the early Lyndhurst experiments led to the preparation by Post Office Broadcast Engineers of a master plan during 1938–39 for the establishment of a High Frequency Inland Service. The plan envisaged the establishment of a chain of 10 kW HF transmitters with two being located at Lyndhurst, Perth, Brisbane, Darwin and Adelaide and one at Sydney. The two transmitters at centres other than Sydney were to provide suitable transmitting frequencies to cover both short and long distances with the one program.

The scheme was part of an overall plan to cover the whole of the populated areas of Australia with ABC programs using a combination of medium frequency and high frequency transmitters.

The Darwin and Adelaide stations were never established. Stations were subsequently established at Katherine, Tennant Creek and Alice Springs in 1986 using 50 kW transmitters to cover the Northern Territory and the far north of South Australia.

In the late 1930s, broadcast planners prepared a design for a station to be located near Perth to feed the vast inland and northern area of Western Australia, and also the Northern Territory. A station with callsign VLW was established at Hamersley on the 6WF site about 10 km north of Perth with test transmissions commencing on 18 March 1939. The service was officially commissioned on 1 December 1939, employing a 2 kW transmitter manufactured by Transmission Equipment Pty Ltd and operating on frequencies of 9560 kHz and 11830 kHz. The aerials were supported by Oregon masts which in later years when dismantled, were sawn up and used in the construction of the hull of a boat by a member of the station staff.

The equipment operated in its original configuration throughout the 1940s but in the mid 1950s was upgraded with rebuilt RF and PA stages driven by ex-RAAF AT13 500 watt AWA HF transmitters tuned to the two operating frequencies.

It was evident from listener's reports that improved signals strength was required in some service areas and decision was made to purchase an additional HF transmitter. An STC 10 kW water cooled transmitter was provided and operated in the 11 and 15 MHz bands with callsign VLX. It was an STC type 880A transmitter similar to the 10 kW model installed at VLQ Brisbane and employed a pair of SS1971 water cooled triodes in the final power amplifier stage. The transmitter was installed during 1949, in an extension of the original 6WF building which also housed a new 10 kW AWA transmitter for 6WN, the original 1 kW unit being on standby.

VLW and VLX continued to operate until replaced by new STC transmitters in a new building during 1962–63. This plant, still in service in 1994, consisted of two 10 kW units STC 4–SU–48B and a 50 kW STC 4–SU–61. The modulator of the 50 kW unit consisted of two Machlett ML6427 valves operating in Class B push-pull mode, modulating two RFPA Machlett ML6427 valves in Class C push-pull, producing the required 50 kW output. Band changing in the 50 kW transmitter was achieved through the use of pneumatic rams, remotely controlled by the normal frequency selection switches in the 10 kW driver unit.

STC Engineers associated with the design and manufacture of the transmitters included Phil Humphries and Clive Pickup.

The VLX callsign was later dropped and the service operated as VLW6, VLW9 and VLW15 operating on frequencies 6140, 9610 and 15425 kHz respectively. Programs are provided from the ABC Perth studios. By 1993, the facilities were operating in an unstaffed mode with frequency changes being under time clock control.

However, at 0600 hours on 22 January 1994, operation of the service ceased for a month's trial period to assess response from listeners on termination of the service. Decision was subsequently made to close down the service permanently.

At an ABA Planning Seminar held in Canberra in February 1997, Daniel Scherr, Project Manager, Information and Communications Access Branch, Public Sector Management Office, Ministry of the Premier and Cabinet Government of Western Australia delivered a paper 'State Government and Broadcast Planning' in which remote radio services in the State were discussed in some detail.

It was claimed that the Federal Government had made an earlier attempt in the mid 1980s to close down VLW short wave service but action was deferred following a report by the State's Department of Computing and Information Technology in July 1986 which identified some 44000 people who were dependent on the VLW service at the time.

In 1994, when it was announced that the VLW service would be closed, the ABC and NTA claimed that less than 200 people would be adversely affected by the closure. However, a report by the Mid West Development Commission dated June 1995, 'VLW Short Wave Radio Service Report' estimated at least 2500 people had been left without a radio service following shut down of the VLW transmitters.

In the paper at the ABA Seminar, Daniel Scherr commented:

'Although this number is more than 12.5 times larger than ABC/NTA estimates it is a very conservative figure, because it deals solely with listeners on pastoral properties. It would be reasonable to assume that there are at least another 1000 people in remote locations not picked up by the survey where VLW was the only domestic radio service available. Additionally, there are likely to be approximately 2000 travellers throughout remote areas of WA at any one time, who would benefit by access to VLW or a replacement service. This should be a realistic projection given that the 1986 Report found that there was an average of 1000 travellers on the Eyre Highway alone, beyond the range of conventional AM or FM radio transmissions.

Despite pledges to provide all ex-VLW listeners with access to a radio service by alternative means, little has been done. The ABC is transmitting The Country Hour over part of the Royal Flying Doctor Service network Monday to Friday. Although this ABC initiative is commendable it does not come close to replacing the full radio service which was taken away.'

The short wave Inland Service was expanded to other States to improve area coverage and to provide appropriate ABC State programs. In Queensland, two transmitters were installed at the Metropolitan Radio Centre, Bald Hills. Planning for VLQ, the first transmitter began in 1941, and an STC type A880A water cooled transmitter was delivered to the site in 1942. An aerial system comprising three dipoles with reflectors was erected using four wooden support poles with the aerials being erected on a lobe bearing of 310 degrees. Transmission lines were balanced open wire types of 600 ohm impedance.

The 10 kW transmitter was commissioned on 17 February 1943. It employed two double ended valves type SS1971 in parallel as the final linear amplifier. In all, there were seven RF stages.

The 11 kV EHT supply was provided by six 4078A mercury vapour diodes with one mounted spare. Current drain was 3 amperes.

Modulation was applied to the anode and screen of the modulated amplifier. The oscillator was a Pierce type with provision made for holding four crystals. Subsequent frequency doubling, where necessary was carried out in the first buffer stage.

A feature of the design was the method of supplying DC power to the filaments of the SS1971 water cooled valves. DC generators had been widely used in earlier power supply designs. The 20 volt 64 ampere filament supply was supplied by step down transformer and selenium rectifiers.

The selenium rectifier banks were manufactured in the company factory in Sydney. In 1938, STC made a decision to acquire selenium metal technology from Germany and France. Manufacture of selenium discs began in early 1942 and continued until the mid 1960s when silicon diodes became available.

During 1942 when the transmitter was being constructed for VLQ in the STC Alexandria factory, a number of other transmitters were being constructed and tested for other clients, including Defence. Staff involved in the work included Jack Trivett, Winston Muscio and Fred Hoe.

Three frequency changes were undertaken during daily transmissions by VLQ. Morning transmission was on 7215 kHz, day transmission on 9660 kHz and night transmission on 7240 kHz.

From about 1947, frequency changes were abandoned, with transmission being maintained on 9660 kHz only.

The original water cooled transmitter was replaced by an STC type 4-SU-48B in 1968. The new transmitter used valve type 3X2500A3 triodes in the power amplifier and modulator stages. Rectifier circuits used solid state components.

During the period 1973 to 1976, Radio Australia programs were transmitted from the Centre to Papua New Guinea on 11880 kHz using a rhombic aerial. The VLQ 4-SU-48B transmitter was used for this service and the A880A used for the Inland Service. In May 1976, the 4-SU-48B resumed its VLQ service and was still operational on 9660 kHz until decommissioned in December 1993.

In 1996, the transmitter was transferred to the National Standards Commission radio VNG service where it was employed as a standby unit to minimise off air time due to failures and maintenance.

The second Inland Service transmitter, VLM, began operation on 7 September 1949 using a 200 watt AT14 transmitter feeding into a temporary wire aerial attached to the 4QR pipe radiator. The 200 watt transmitter was replaced by a 10 kW STC 4-SU-12A type in January 1951 and fed a delta matched dipole which replaced one of the original VLQ aerials. The operating frequency was 4917.5 kHz. On 1 June 1953 the frequency was changed to 4920 kHz.

The transmitter employed valve type 3J/221E triodes for the power amplifier and modulator stages with EHT being provided by 4078Z diodes. The 3J/221E valves were later replaced by Philips TBL 12/25 type while the mercury vapour 4078Z valves were replaced by silicon diodes.

From July1966, both VLQ and VLM broadcast the Queensland third network programs of the ABC.

Both the VLQ and VLM services ceased operation at midnight 17 December 1993 for a month's trial period to assess listener reaction to termination of the services. Decision was subsequently made to close down the service permanently.

Following representation in 1944 to the National Committee on Engineering Heritage of the Institution of Engineers, Australia by Doug Sanderson retired Telecom Engineer who spent a working lifetime with the National Broadcasting Service, decision was taken for heritage plaquing of the half century old VLQ transmitter and its housing at Bald Hills.

A New South Wales station VLI located at the 2BL/2FC Liverpool site at Sydney commenced service on 22 December 1948 to cover outback areas of the State using an STC 2 kW 4–SU–14B transmitter operating on 6090 kHz. The aerial was a half wave dipole supported by two 21 m wooden poles and was fed by a 600 ohm open wire transmission line. The service ceased operation on 7 October 1983.

Even with the introduction of satellite technology to cover the whole of the continent with broadcast programs, short waves still have their place. This is evident in the commissioning of three 50 kW stations in the Northern Territory. The stations were commissioned at Alice Springs (Roe Creek) on 20 February 1986, at Katherine on 31 March 1986 and Tennant Creek on 14 May 1986. The Alice Springs station with callsign VL8A operated on 2310 kHz and 4835 kHz, Katherine with callsign VL8K operated on 2485 kHz and 5025 kHz and Tennant Creek with callsign VL8T operated on 2325 kHz and 4910 kHz.

Each station comprised a Continental Electronics type 418D-2, 100 kW transmitter cut back to give 50 kW output. The modulator used two 4CV100000C type tetrodes while the power amplifier used one of the same type. These valves used a vapour cooling system which is superior in efficiency compared with a conventional water cooled system due to the exploitation of the latent heat of vaporisation of water.

The stations used a technique known as vertical incidence transmission or sometimes called 'shower' broadcasting. In this method the radio waves are transmitted upwards in a narrow conical beam and reflected back downwards by the ionosphere in a more dispersed beam for reception within a planned coverage area. Each station had an approximate range of 450 km in all directions.

Because of changes in the characteristics of the ionosphere not only on a daily basis but on seasonal and long term sunspot cycles each station had been allocated three frequencies. Only two of the frequencies were used on a daily basis when changes were usually made at 8 am and 5 pm. In 1996, allocated frequencies were VL8A, 2310, 3230 and 4835 kHz; VL8K, 2485, 3370 and 5025 kHz; and VL8T, 2325, 3315 and 4910 kHz.

Each aerial at the stations was a wideband broadcast type capable of handling 100 kW carrier power plus 100% modulation. The dipole elements were fabricated from alumoweld wire, a wire composed of a high strength steel core and an integral aluminium coating. The curtain was assembled on the ground and hoisted to its correct position by winching up the catenary.

Senior Engineer responsible for establishment of the three stations was Bruce McGowan with Wayne Croft being Project Engineer.

Operation and maintenance of the stations were carried out by Darwin based group Barrie Morton, Principal Technical Officer; Murray Fopp, Senior Technical Officer Grade 2; and Terry Wooster, Technical Officer Grade 2.

Barrie Morton began work in the Postmaster General's Department as Technician-in-Training in Adelaide in 1964. His first permanent posting was to 5AL Alice Springs with other responsibilities including operation of the HF Radio Telephone Subscribers Network.

After qualifying as Senior Technician, he worked at the Loxton TV station ABRS3 and in 1979 transferred to the Broadcasting Service Centre Adelaide as Assistant OIC. One of his major responsibilities at the Centre was construction of a Transportable Emergency Broadcasting Station for the Natural Disaster Organisation.

On formation of the NT Broadcasting District in 1984, he became OIC for operation and maintenance of all National broadcasting facilities throughout the Northern Territory.

In 1986, Barrie was appointed Section Manager Northern Territory with Radio Australia Cox Peninsula being added to his other broadcasting responsibilities.

Barrie subsequently held senior management positions in Queensland and Melbourne Head Office in the Telstra broadcasting organisation.

Murray Fopp joined the Postmaster General's Department in Adelaide in 1970 as Technician-in-Training. On completion of the course he was appointed to the Radio Section where he worked on the maintenance of broadcasting stations throughout South Australia and Northern Territory.

In 1984, Murray transferred to Darwin as Assistant OIC of the NT Broadcasting District being involved in the maintenance of some 34 stations including the three HF Inland HF stations. Murray later left Telstra, completed an MBA Degree and established Murray P Fopp and Associates Pty Ltd in Adelaide.

Terry Wooster joined the PMG's Department as Technician-in-Training in 1960 in Victoria and in 1965 joined the Radio Australia staff at Shepparton. He transferred to Radio Australia Cox Peninsula in 1971 and spent two years at the receiving station at the complex. After two years he transferred to the transmitting station. Following damage by Cyclone Tracy he was involved in rehabilitation work until 1984 when he transferred to the Northern Territory District maintenance staff.

Programs for the HF service generally originate in the Darwin studios of the ABC. For most of the time they are the same programs as broadcast over the medium frequency stations 8RN Darwin, 8AL Alice Springs, 8GO Nhulunbuy, 8JB Jabiru, 8KN Katherine and 8TC Tennant Creek. The Central Australian Aboriginal Media Association (CAAMA) also provide programs mainly for transmission over the Tennant Creek and Alice Springs stations. The service is known by the Aboriginal people as 'Bush Radio'. Seven Aboriginal languages are broadcast and they occupy 90% of the short wave program time. In 1990, with the formation of the Top End Aboriginal Bush Broadcasters Association based at Batchelor College, the Association provided programs for broadcast over the Katherine transmitter.

The future of short wave broadcasting has been subjected to several studies in recent years. Many major improvements have been made in transmitter technology, aerial systems and in receivers but only in recent times have in-depth investigations been undertaken to provide a means of transmission other than via the ionosphere.

For some years the Voice of America in conjunction with the US Jet Propulsion Laboratories have been developing a system employing digital satellite broadcasting technology using the HF short wave bands and which operate with relatively cheap receivers in the target areas. It is planned that the HF digital broadcasting system which would replace the analog modulation system would operate on a 10 kHz bandwidth. However, as at 1998, more developmental work needed to be done before the new satellite technology could replace the present system using the ionosphere to reach the target areas.

RADIO AUSTRALIA

Until the outbreak of the Second World War in 1939, there was no Government sponsored or operated service in operation in Australia for broadcasting to other countries. It became apparent with the commencement of hostilities that an overseas service was essential in order to transmit the Australian viewpoint, so officers of the Department of Information, the Australian Broadcasting Commission and the Postmaster General's Department met to discuss the early establishment of such a service

Following recommendations of the meeting, and Cabinet approval on 19 October 1939, an overseas service known as 'Australia Calling' commenced on 20 December 1939. Programs were broadcast from stations near Perth, Melbourne (Lyndhurst), and Sydney using transmitters of powers ranging from 2 to 10 kilowatts. The Perth and Melbourne stations had been established as part of the National Broadcasting Service for providing ABC programs to remote areas of the Commonwealth and two Sydney 10 kW transmitters were leased by the Department of Information from Amalgamated Wireless (A/Asia) Ltd. On 16 June 1941, a 10 kW outlet was provided at Lyndhurst to assist the service. The service operated with callsigns VLQ, VLW and VLG and transmitted to New Caledonia, North America, Central America, Middle East and South-East Asia target areas.

While the service was reasonably successful and reports encouraging, it was obvious that such low power transmitters could not keep abreast of services with the high power transmitters employed by other countries. Because of the low signal strength received, particularly in the USA, it was not practicable for local USA stations to rebroadcast the Australian programs.

Over the years, a number of transmitting stations were established to provide outlets for the Radio Australia service. They comprised:

* **SHEPPARTON**

In developing plans, the design for a high power station allowed for:

- Transmission to four Zones comprising South-East Asia, East Asia including Japan, North America and South America.

- Transmission on at least two channels simultaneously in each Zone.
- Broadcasting in several languages.
- Signal strength in the target areas to be of the same level and reliability as broadcasts from other nations.

It was realised that the cost of fully meeting the plans would be very high, and that there would be difficulty in obtaining the necessary technical plant, especially high power transmitters, but studies indicated that the most urgent requirements could be met with three 100 kW transmitters and adequate directional aerial systems.

In choosing the site for the station, the following considerations were taken into account:

- Far enough away from the coast to be reasonably free from sea and air bombardment.
- Reasonably clear of the major domestic air routes.
- At least 80 km from RAAF flying training centres.
- Close to high voltage power mains.
- Close to telephone trunk line circuits.

After taking these matters into consideration, a site was selected near Shepparton in north-central Victoria. Cabinet gave approval for establishment of the station on 15 September 1941.

Tenders were invited for the three 100 kW transmitters, but as the earliest date for Australian built equipment was some 18 months, it was decided to purchase a 50 kW transmitter from the USA to improve the service until the 100 kW units could be commissioned.

At the time, the estimated capital cost of the station including the 50 kW transmitter, three 100 kW transmitters, aerials, buildings and associated plant was £306000 with the annual operating cost, on the basis of 12 hours per day, being £89000. The final establishment cost was almost double the original estimate, with only two of the planned 100 kW transmitters being provided because of difficulties in obtaining critical component parts.

The 50 kW transmitter was manufactured by Radio Corporation of America and the two 100 kW units manufactured in Australia by joint contractors Standard Telephones and Cables Pty Ltd and Amalgamated Wireless (A/Asia) Ltd. The 50 kW transmitter began transmission at 3.30 pm on 15 May 1944 beamed towards the Philippines on 15315 kHz. The station was known as the Shepparton International High Frequency Transmitting Station, but later became known as Radio Australia. The first 100 kW transmitter began service on 14 August 1945 followed by the second 100 kW unit early in 1946, although final acceptance work was not completed until September 1947.

The RCA ML Series transmitter was designed to deliver 50 kW over the frequency band 6–22 MHz. It comprised two complete radio frequency channels from crystal to output and one Class B modulator which could modulate either of the RF channels at high power.

Each channel employed six stages. The crystal oscillator, which had six plug-in crystal units, generated oscillations at half the transmitter output frequency, followed by a doubler stage. The circuit also had provision for the use of an external oscillator source. Following stages were all push-pull arrangements and used valve types 828 pentode, 810 triode with cross capacitor neutralisation, 827R external anode air blast cooled tetrode and water cooled 880 triodes in the output stage with cross capacitor neutralisation.

Features of the output stage included ceramic water isolating helices, anode tuning and neutralising capacitors which comprised rectangular plates of the book leaf type, transmission line type tuning inductors and a balanced tuning capacitor with large plates, the spacing of which was performed by motor operation.

The audio frequency channel comprised two push-pull Class A amplifiers, the first stage employing two 1603 valves, the second stage four 828 types, a cathode follower stage of four 828 valves and a Class B modulator stage employing two 880 valves capable of producing 40 kW of audio frequency power.

Mercury vapour valves were fitted to rectifier circuits providing anode supplies of 1.5 kV, 5 kV and 10 kV. A spare 857B valve was provided with the 10 kV supply unit. Filament supply to all tubes was AC with two phase being used for the modulator and power amplifier 880 and 827R valves.

A water cooled artificial aerial employing woven wire and asbestos resistance mat immersed in circulating water was provided for transmitter test purposes.

The design of the ML Series transmitter with two 50 kW power amplifier stages and a single modulator and power supply made it possible to provide two separate transmitter outlets by installing some additional plant. In 1959, an additional modulator and power supply were constructed by local station staff, with the outcome being the availability of two separate 50 kW transmitters.

The ML Series was fitted with a Morse keying unit and this was used to advantage during the early 1950s to initiate successful pulse reflections from the moon using a local rhombic aerial system. A receiving site was established in New South Wales and received the Shepparton signals reflected down from the moon.

The transmitter was also used for successful 28 MHz propagation tests in the early 1960s.

The transmitter was taken out of operational service in late 1991 but in 1994 was still in situ at Shepparton exactly 50 years after being employed for the first transmission from the station.

The two 100 kW transmitters were identical, and manufactured jointly by STC and AWA, the two largest Broadcast Engineering companies in Australia at the time. They were made to the general design requirements of the PMG's Department. Guaranteed output was 100 kW up to 15.2 MHz, 95 kW at 17.8 MHz and 80 kW at 21.6 MHz.

STC supplied the four RF stages, with Dave Abercrombie being in charge of the work and AWA supplied two modulators, with Joe Reed being responsible for the AWA part of the project.

Each transmitter comprised an 8 kW driver for the high power channels; two high power channels either of which could be driven by the driver; a modulator unit which could modulate either of the high power channels and two high tension rectifiers. For further redundancy the driver unit included a modulator unit which could be employed in event of failure of the high power system, to feed program directly to the aerial system.

The driver unit consisted of crystal oscillator, separator, multiplier and three stages of amplification resulting in 8 kW drive power. The amplifier valves consisted of 813, 833 and 889R types with anode supply voltages being supplied by rectifiers of the 866A and 872A types.

The high power channels each employed four Federal type F124A valves in parallel push-pull configuration. The circuit was a conventional cross neutralised push-pull circuit with layout being designed to minimise stray inductance and capacitance. In the assembly of the components, a pair of parallel valves for one side of the push-pull circuit were mounted in a metal frame which supported the anode jackets of the valves. The frame was mounted on pyrex glass insulators and was metal covered forming one electrode of the anode tuning capacitor. The electrode comprised a number of parallel vertical tubes about 150 mm diameter and terminating at the top in hemispheres of their own diameter. This design minimised eddy current problems which frequently occurred with designs using solid plate electrodes. The capacitance was varied for tuning purposes by moving a central electrode up between the anode electrodes using a handwheel to provide the mechanical drive.

The anode inductance consisted of 100 mm diameter rods screwed to the anode framework. The rods were replaceable for frequency change purposes and were connected by bridging links to provide transmission line type inductors. They could be series or parallel connected as required for the necessary frequency. Coupling to the transmission line was inductive with the coupling arrangement using a truck mounted butterfly type variable air capacitor carrying an inductor similar to that used for the anode inductor. Movement of the truck varied the mutual inductance. The capacitor and inductor formed a parallel tuned circuit across the output transmission line.

The modulator design employed three amplifier stages using resistance and choke coupling, a fourth stage using six 4279A type valves operating in push-pull as a cathode follower and driving two 4030C modulator valves. The output of the modulator unit was fed through a modulation transformer and choke to the modulated amplifier. Feedback of the order of 16 dB was provided over the entire audio system. Spare modulator valves were provided with the filaments and grids being switched in circuit by changeover switches.

Two identical anode supply rectifiers were provided for the high power stages. The anode voltage was applied through oil cooled resistors in series with the rectifier transformer primaries and were short circuited after a suitable delay. Each rectifier employed six 857B valves in a six phase voltage doubler circuit. Two spare valves were provided. The two rectifiers normally supplied the working modulated amplifier and the modulator respectively.

Cooling of the facilities was carried out by air and water cooling systems. Two large blower units with spares, drew air through oil type filters for cooling each transmitter, with pumps and a water cooling system being provided for the anodes of the high power valves.

Many people were associated with the design, construction and commissioning of the station facilities and included among PMG's Department and Contractors staff were:

David Abercrombie, Joe Alexander, Ron Blades, Tony Brettingham-Moore, Drake Brockman, Rudolph Buring, John Champion, Fred Chapple, Jack Hargreaves, Alan Hart, West Hatfield, David Hutchinson, Phil Keon, Mal Kirkwood-Jones, Jack Kyne, Jack Laydon, Tom Lelliot, Bob Long, Bruce Mair, Alan McIntosh, Alec McKenzie, George Nolfe, Norm Park, Joe Reed, Roy Spratt, Bob Stainsby, Jack Tremlett, Tom Walsh, Bill Waterworth, Jim Wilkinson, Sid Witt, Bert Wood and others.

David Abercrombie of STC, as well as making a major contribution to the design of the two 100 kilowatt transmitters, was in post war years responsible for a novel cooling arrangement incorporated in the company's 50 kW transmitters provided in considerable numbers for the National Broadcasting Service in the 1950s and 1960s. He was granted a Patent for the system. The majority of the transmitters installed were still operational in 1992. During the period 1958 to 1959, he served a President of The Institution of Radio Engineers (Australia).

Tony Brettingham-Moore played a major role in on-site installation and commissioning work associated with the power amplifier and modulator stages and the valve water cooling systems. Following graduation from the University of Tasmania in 1937, he undertook Post Graduate Research work at the University in Communication Engineering. In 1939 he joined the Hydro Electric Commission in 1939 working as Junior Engineer until he transferred to Standard Telephones and Cables Ltd, Radio Transmission Division in Sydney in 1941.

On completion of the Radio Australia project, Tony worked on the design of AM and FM radio broadcast mobile radio equipment until about 1949 when he went to the UK to work with EMI for three years, returning to STC Radio Transmission Division in 1952.

David Hutchinson, Jack Tremlett and Bob Long were also STC employees. David and Jack served terms as President of The Institution of Radio Engineers (Australia) before it became The Institution of Radio and Electronics Engineers, Australia. David was still active with The Institution in 1998, being Honorary Treasurer for 1997–98 and a member of Council.

West Hatfield commenced work in the Victorian Branch of the Postmaster General's Department in February 1926 as a Junior Mechanic-in-Training. In 1934, he began a long association with the National Broadcasting Service when he transferred to the Drafting Section of the Central Office Research Laboratories. During that period he played a prominent part in the design and provision of tall radiators then being developed in conjunction with high power transmitters. On qualifying as Engineer in 1939, West was appointed to the Research Laboratories and his first assignment in association with Engineers Bruce Mair and Alec McKenzie, was the design and construction of the International High Frequency Broadcasting Station (Radio Australia), Shepparton.

He was later involved with early experiments with FM broadcasting, being responsible for the installation of the tower, aerial and transmission line and subsequent field testing of the original station at Jolimont.

With the creation of the Australian Broadcasting Control Board in 1949, West joined the new organisation as Sectional Engineer National Broadcasting Service, with responsibility for the development of plans for the further expansion of the service.

In 1950, he was the Board's representative on the Australian Delegation to the Extraordinary Radio Administrative Conference in Geneva. When West retired in 1977, he had been associated with Broadcast Engineering for more than 45 years.

Jack Hargreaves ISM transferred from Lyndhurst HF station in 1944 to become the first Officer-in-Charge. He retired after 18 years service at the station.

Bill Davidson joined the PMG's Department in 1939 as Lineman-in-Training and as part of the course attended the Linemen-in-Training School at Fisherman's Bend, Melbourne and evening classes at the Melbourne Technical College.

On completion of the course, Bill was promoted Lineman Grade 1 and joined the newly-formed Radio Lines Section in Victoria working on the construction of aerials and transmission lines at RAAF and US Army bases at Laverton, Point Cook, Werribee, Ballarat, Rockbank and Diggers Rest.

In 1943, Bill was transferred to the International High Frequency Transmitting Station (Radio Australia), Shepparton as acting Lineman Grade 2 where work was in progress to establish the station. It was a move that determined his career path for the rest of his working career in the Department.

The project included a large team of Linemen including many new graduates of the Linemen-in-Training School. They were under the control of Engineer Jack Kyne and Line Foreman Jack Laydon. Like other members of the external plant group, Bill was engaged on the construction of aerial arrays, transmission lines and line switching systems.

At the conclusion of the outdoor construction work in 1945, he joined the Transmitter Operation and Maintenance staff as Acting Technician.

In 1994, Bill was one of a small group still alive who witnessed the first transmission which took place 50 years ago on 15 May 1944 using the 50 kW RCA transmitter.

When he began work in the transmitter hall, three transmitters were in operation using callsigns VLA, VLB and VLC.

In 1948, he was appointed Technician, followed by appointment as Acting Senior Technician. Having qualified as Senior Technician in 1950, he was placed in charge of one of the Operation and Maintenance Shifts. Promotions to Supervising Technician level followed with appointments as Supervising Technician Grade 1 (Radio) in 1951, Supervising Technician Grade 2 (Radio) in 1952 and Supervising Technician Grade 3 (Radio) in 1956.

In 1957, major expansion began to increase the number of transmitters and to provide improved aerial switching facilities. Bill was appointed Acting Supervising Technician Grade 5 (Radio Installation) and spent the next five years in charge of local staff engaged on the project. On completion of the work, the largest transmitter upgrading work ever undertaken in Australia up to that time, the station transmitter capacity comprised four 100 kW, three 50 kW and three 10 kW models. A large matrix line switching system was also installed.

On retirement of Jack Hargreaves, Bill was appointed to the OIC position in April 1962 and remained in that position until retirement in March 1980. Shortly after retirement, Bill was awarded a British Empire Medal which he received at a ceremony at Government House, Melbourne.

Bruce Wilson took over the role of Officer-in-Charge in March 1980 and was subsequently involved in major expansion activities including new transmitters, aerials and line switching system.

In addition to his busy role in running the Shepparton complex, Bruce found time to be active in many local community projects and affairs. In 1990, he was presented with the Australia Day Medal sponsored by the National Australia Day Council. The Award was presented for his personal contributions to the development of facilities for the disadvantaged, disabled and sick; the promotion and development of the arts and service to charitable organisations. The presentation was made by Max Chadwick, Deputy General Manager of Telecom's Broadcasting Directorate.

As at mid 1998, station Officer-in-Charge was Doug Brodie. Doug joined the Postmaster General's Department in 1964 and began work in the New South Wales Broadcast Section the following year. He was associated with the installation and maintenance of many National stations throughout the State and in 1971 was appointed to 2NR Lawrence 50 kW station as Shift Leader. Doug transferred to Shepparton as STTO2 Maintenance in 1989 and promoted to Officer-in-Charge in 1995.

Over the years, many changes were made to improve performance and reliability, to make better use of redundant facilities and to change over to alternative valve types mainly because of supply problems.

During the 1950s and 1960s, major upgrading and additional installation work was undertaken, resulting in the station having transmitter outlets of four 100 kW, three 50 kW and three 10 kW. The original two 100 kW transmitters were converted into four separate 100 kW transmitters by using redundant equipment and adding other components, an RCA 50 kW type BH50B transmitter was commissioned in 1956, and two new STC 10 kW units were installed to supplement a 10 kW AWA model which went into service about 1946. Included in the upgrading works were replacement of the 4030C modulator valves with GEC air blast cooled triodes type BR189, and the HCMV rectifiers with silicon diode stacks.

Ian Hill, later Engineer with Australian Broadcasting Control Board, and in private enterprise, played a major role in the upgrading work.

The STC/AWA 100 kW transmitters were withdrawn from service on 10 October 1983, and replaced by six 100 kW vapour cooled Harris transmitters imported from USA. The new transmitters had capacity to change frequency bands and select preset tuning point in less than 20 seconds, a feature enabling better utilisation of the transmitting facilities. The transmitters comprised two Harris SW100 types installed during 1978–79 and four Harris SW100A types installed during 1983–84.

When the Radio Australia, Carnarvon transmitting site was closed down in July 1996, a 100 kW transmitter was relocated to Shepparton to become a standby unit.

During the period 1991 to 1996, about $9.6 million in capital expenditure was employed in upgrading the station facilities.

In 1997, the station was operated and maintained by a staff of 10 technical specialists.

Following reduced budget allocation for short wave transmission, the Cox Peninsula facility was closed down on 30 June 1997 leaving only the Shepparton and Brandon stations to provide an overseas service for ABC programs. The closure of Cox Peninsula station severely downgraded Radio Australia's coverage of Asia particularly, Thailand, Malaysia and Indochina.

In the initial design of the Shepparton station, an important consideration was the provision of a reliable electrical supply. This included the commissioning and operation of a large heavy diesel emergency generating plant.

Primary electrical power was supplied from the State Electricity Commission grid at 66 kV and stepped down to 6.6 kV within an on-site Zone Substation. Distribution was via a large paper insulated lead covered oil filled cable to the transmitter building Main Oil Circuit Breaker (OCB). Transmitter supply was then via individual 6.6 kV OCBs. In 1942–43, the new installation was one of the largest industrial electrical installations in country Victoria.

Emergency supply for the two water cooled 100 kW and one 50 kW transmitters, came from two PCT/6 six cylinder Crossley heavy engines operating as a synchronised pair and fitted with 6.6 kV/400 kW Brush alternators. Total power output from both sets was 800 kW which was ample to supply the three transmitters and ancillaries under full transmitter modulation conditions.

Each engineer was rated at 800 HP at a speed of 375 RPM and used heavy residual fuel oil at the rate of 28 GPH when operating at full load. Both engines were fitted with a Roots blower to improve engine aspiration and a 6 ton flywheel to improve regulation under high transmitter modulation.

In recent years the plant started to show signs of age. Water pumps, cooling towers, circuit breakers, internal wiring and engine cooling were the source of many problems. An engineering review of the total plant and ancillaries confirmed major deterioration. After 49 years of service, the difficult decision was taken. The plant was closed down.

Richard (Dick) Cox operated the plant up until 1955 when his assistant Brian Bingham took on the job. Brian retired in 1986 and Keith Dahlberg took over the helm. Keith commenced work at the Shepparton site in 1960 and was previously employed by the Victorian SEC. Keith retired after 32 years service at the station. He lovingly nursed the old plant along in its final years of service.

The days of low speed heavy engine plant as the motive force for the generation of emergency power at broadcasting stations have now gone. In addition to Shepparton, large engines sets were installed at MF stations at 3WV, 2CR, 6WA and 4QN in the 1930s where no commercial power was available Such large generating plant provided many years of sterling service and a link with the golden years of radio. They are fondly remembered and talked about whenever old time radio buffs get together.

Over the years, the Shepparton station has been an important centre for the training of broadcast transmitter staff and the development of high power Broadcast Engineering facilities. With the installation and operation of the Radio Australia transmitting outlets at Cox Peninsula and Carnarvon, many of the staff associated with the new stations were either recruited from Shepparton or had served there during their career. For many years, Rex Wales was responsible for Technical Training of staff at Shepparton.

Over such a long period of operation, a great many Technical, Radio Lines staff, other Specialist staff and Trainees passed through the station. Up to about 1988, these included:

Daniel Adams, William Adams, Bela Adorjan, Gunnar Anderson, Geoff Angus, Johnathon Ash, William Badrock, Leonard Baker, Harry Baldwyn, Gordon Bamford, Lindsay Bamford, Robert Bamford, Fred Barker, Laurence Batt, John Beanland, L Beech, Francis Beitzel, John Bell, Graham Billing, Brian Bingham, John Bingham, Doug Bisby, John Bishop, Myles Black, John Blackburn, Gordon Blythman, Howard Briant, Arthur Brighton, Tom Brown, Victor Bruce, Albert Buck, V Burden, Edmund Burrell, John Campbell, James Caroll, William Catchpoole, Walter Chamberlain, George Chandler, Ken Chaplin, Fred Chapple, Don Chilcott, Ralph Clarkson, Thomas Cole, Max Collins, George Cox, Richard Cox, Roy Crisp, William Cromarty, Thomas Crutchfield, Norm Currie, Sidney Curtis, Jack Carnell, William Daffy, John Daish, Ian Dalrymple, Robert Darling, Ray Davie, Allen Davies, Max Dawkins, George Decaux, Tony Dennis, Harry Dinham, Edwin Dodd, Frank Doncon, Allen Dobson, William Doyle, Norm Draper, Robert Ducat, David Edward, Bruce Edwards, Leslie Eliason, Robert Elkin, Bruce Emmerson, Brian Emmett, Francis (Keith) Esson, William English, Keith Ferres, Alan Finch, Murdoch Finlay, Robert Finlay, Alan Fisher, Lawrence Fitch, Thomas Fitzgerald, Ray Fitzsimmons, Bill Flatman, Stephen Fletcher, James Foley, Bryan Forbes, Robert Forbes, Max Fowler, Linton Furphy, James Gilmour, Ken Gilmour, Xavier Gledhill, W Greenwood, Alfred Griffard, Gordon Gullock, Ormond Guy, Peter Gordon, Raymond Graf, Ron Gray, E Heanel, Syd Hamilton, Robert Hansen, Harry Hare, Alan Hewlett, William Hilderbrand, Allan Hart, Robert Haverfield, Leonard Hearnes, Colin Heath, William Henderson, Fred Hill, George Hill, Fred Hird, Desmond Hocking, George Hogarty, Noel Hogg, Alan Holland, John Hollingshead, Donald Horsey, Albert Howell, Lewis Howell, R Hunt, Sylvestor Hyland, Alan Ireson, Douglas Jackman, John Jaffrey, Bruce James, Ian Jamieson, Peter Jarvis, F Jayet, Dennis Joel, M Kirkwood-Jones, Maxwell Johnston, David Joseph, L Keane, Ian Keenan, Ray Kelly, Lynton Kelly, L Kelly, Patrick Kelly, Malcolm Kennedy, Philip Keon, Jannes Keuken, Josef Keorcesi, Klaus Konieczny, John Laidlaw, Delmont Lees, Mark Lenevez, Herbert Lilburn, Miss G Ling, Rupert Livingston, Gary Long, John Long, Leigh McAuliffe, John McCarty, Alex McCormack, William McCullock, Edward McDonald, Eric McDonald, Robert McGregor, Francis McGurgon, Brian McKenzie, John McKenzie, Kenneth McLachlan, John McLay, Jim McLeod, Reginald McRae, Neville Maddern, Francis Markham, Stanley Marris, Kevin Mead, Edward Mellish, W Middleton, Alan Miller, Ian Miller, William Mingter, Arne Moller, Russel Morgan, Thomas Morris, John Morrissey, Joseph Morrison, Thomas Morton, Gerald Mulloy, Donald Murphy, G (Len) Myers, Steve Nankivell, Geoffrey Nelder, John Nicholas, Richard Nye, Arnoldus Nys, S (John) Oakes, George Ronald, Edward O'Brien, John O'Farrell, Dennis O'Flaherty, Peter O'Keefe, Victor O'Sullivan, Denys Parnell, Frank Papworth, Norman Park, Ivo Parker, Keith Parker, Graeme Parkinson, Andrew Paris, R Pether, John Ray, Wallace Read, Michael Reed, H Reynolds, Wallace Ritchie, Robert Rivett, Kenneth Robertson, George Robbins, John Robinson, Fred Robinson, Harry Rodway, Russell Rolls, William Royal, John Russell, Trevor Ryan, Lindsay Sage, Terence Said, Donald Schafer, Linton Schier, Earn Scoones, Arther Searle, Frederick Seligmann, Paul Serin, Allan Shacklock, Jack Shacklock, Leslie Shard, Neil Simmons, Aaron Sinclair, Brian Sinclair, Alan Slarks, Vincent Smith, Robert Speer, Stanley Spodar, Mervyn Spowart, John Stanley, Alex Stephanou, Hans Struve, Claude Sutherland, Joe Tamburro, Barry Taylor, Howard Taylor, Roy Teakel, Ronald Thomson, V Thomas, R Thomas, Aiden Torrance, Laslo Toth, Lawrence Tout, Ian Tremellen, William Triffett, Peter Turner, Jan Van Kerrwijk, Bob Van Merkesteyn, Eric Verran, Ronald Vincent, William Vines, Robert Wade, Rex Wales, David Walker, John Walker, Donald Wallace, Jack Walsh, James Warburton, Edward (Paul) Watts, Wilton (George) Welch, Evan Whatmough, W Wicking, John Williams, K Wilson, Victor Wodetzki, Gregory Woolstencroft, William (Terry) Wooster and Muir Wright.

As at mid 1998, staff at Shepparton comprised Doug Brodie, Technical Manager; Terence Fahey, Technical Specialist; Brian Milton, Shift Operative; William Chilcott, Shift Operative; Patrick O'Shannessy, Shift Operative; Francis Alford, Shift Operative; Gary Wilson, Shift Operative; Russell Young, Field Operative; and Gary Black, Field Operative.

Over the years, many Engineers in the Department's Head Office and Victorian Administration were involved in various aspects of installation, upgrading and maintenance of the Shepparton facilities. A short list would include Roy Badrock, Doug Brooke, Bob Brown, Doug Cliff, Gavin Dorr, Giff Hatfield, Ken Hamilton, Keith Harding, Ian Hill, Peter Holt, George Joosten, Jack O'Shannassy, Mike Stevens, Bob Slutzkin, Alex Valentine, Alan Varey, Jim Wilkinson and many others.

* **COX PENINSULA**

Although the International Shortwave Service had been operating through the Radio Australia Shepparton facilities since 1944, it was not until 1957 that a technical investigation into reception in the most important target areas was undertaken.

During the period 25 August 1957 to 5 October 1957, H W (Horrie) Hyett of the PMG's Department Central Office staff visited countries in the South Asia and East Asia areas to conduct a technical survey. The investigation revealed that, although a reasonably good service was being provided, there were periods when some transmissions were subjected to interference from other stations or from jamming activities.

To improve service, additional aerials were erected at Shepparton and improvements in operational techniques were implemented.

A further study was undertaken in 1959 by Doug Brooke who conducted detailed reception tests at Singapore, Rangoon, Bangkok, Saigon, Hong Kong, Tokyo and Manila.

After leaving school, Doug Brooke joined the Department of Civil Aviation, and in 1943 joined the Postmaster General's Department as Cadet Engineer whilst on War service with the Royal Australian Air Force. He subsequently graduated Bachelor of Science from the University of Melbourne in 1949.

In 1950, Doug became Engineer for MF stations in Victoria at the time of refurbishing and renewal of NBS transmitters. The following year he transferred to the HF stations group with responsibility for Radio Australia Shepparton and Lyndhurst. Doug moved to the Department's Central Office in 1954 with responsibility for the oversight and performance of National transmitters and sound studios. At that time, the Department was responsible for the technical facilities at the ABC studios.

Doug was Australian Post Office representative in London from 1967 to 1969 and on return to Australia took up duty in the Central Office Planning Branch where he worked until his retirement in 1985.

As a result of the overseas investigations by Horrie Hyett and Doug Brooke, plans were developed to establish a high power 'Booster' station in the Northern Territory near Darwin, to rebroadcast the transmissions from Shepparton, in order to improve the signal levels in South East and East Asia.

Following extensive on-site examinations in a number of areas including Howard Springs, Berry Springs, Adelaide River and Cox Peninsula for suitable sites on which to establish a transmitting station and associated receiving station by Cliff Savin, Divisional Engineer Headquarters Radio Section and Jack Ross, Divisional Engineer Radio Section South Australia, two sites on opposite ends of Cox Peninsula were selected as being suitable for the two stations. Cliff made a major contribution in preparation of technical documentation when seeking approval for construction of the stations on the chosen sites. He was also involved in other aspects of the project implementation.

The proposal to establish the broadcasting complex was referred to the Parliamentary Standing Committee on Public Works on 22 April 1964.

Site works commenced in 1965 with the first test transmissions taking place during December 1968. Two regular transmissions were introduced in December 1969, and installation work completed in 1970. However, because of problems with the transmitters and aerial systems which took considerable investigation effort to correct, regular and reliable transmissions using full 250 kW power from three Collins transmitters were not realised until September 1971.

Many Engineers and Technical support staff were involved in planning, development, installation, commissioning, equipment procurement, contract supervision and associated activities for the project from the Department's Central Office, the South Australian Radio Section and Contractors. Up to 1971, when full transmissions began, they included Don Beames, Bill Beard, Reg Boyle, Bob Brown, Ross Burbidge, Werner Busch, Max Chadwick, Oleg Chichoff, Forrest Cummings, Lawrie Derrick, Ken Endacott, Jim Finch, Des Fulton, Jack Furze, Alan Gibbs, Dave Giovanazzi, Bill Gold, Ralph Gurner, Frank Henschke, John Innes, Ted McGrath, Jim McLellan, Frank Mullins, Lionel Parker, Charlie Pierce, Les Pridham, Max Rieper, John Robertson, Don Rodini, Jack Ross, Cliff Savin, Bill Shapley, Graham Shaw, Bob Slutzkin, Kevin Templeton, Alec Valentine, Frank Wilkinson, Jim Wilkinson, Brian Woodrow and others. Ralph Denison was in charge of Drafting Services.

Don Beames and Les Pridham were Senior Technical Officers who provided extensive assistance during the design, development and installation stages of the project. Don Beames, an experienced Radio Lines Inspector had many years experience in the construction and maintenance of radio line plant and provided valuable input into the design and preparation of specifications for transmission lines, aerial switching equipment and transportation co-ordination in shifting the huge amount of material to the remote Cox Peninsula site.

Les Pridham had been associated with broadcasting transmitter and studio installation and maintenance work from early days. He had been Shift Supervisor at the ABC Adelaide studios and the 5CL Brooklyn Park transmitter for some years and had worked on modifications and installation of new plant. Les also had wide experience in radio telephony particularly in HF subscriber equipment and was seconded to the ITU to provide assistance in the establishment of HF facilities at the Maldives, a small independent country comprising some 2000 small coral islands about 600 km south of India.

Programs were provided by off-air pick-up of transmissions from Shepparton with a receiving station also on Cox Peninsula, but some 15 km from the transmitting station. In 1974, the receiving facilities were closed down and the programs provided over Telecom broadband landline circuits from the ABC Radio Australia Melbourne studios.

The three Collins 821A-2 model transmitters each delivered 250 kW of output power at any frequency in the band 3195 to 25600 kHz and were capable of continuous sine wave modulation at 100 %. They also accepted 9 dB clipped sine wave modulation with less than 5 % overshoot in the flat top of a clipped 100 Hz sine wave.

They were the first transmitters to be installed in Australia using vapour cooling techniques and capable of operation under full computer control and supervision. They were fully self-protected and included a fast acting crowbar circuit to dump all energy from the high power valves on the detection of an internal valve arc. Operational frequencies were provided by a solid state synthesiser which, under computer control, could be tuned to any frequency in the required band in steps of 100 Hz.

The RF unit was fed by a digitally controlled remote frequency synthesiser and included input amplifier with 4CX350A valve, an intermediate driven amplifier with 4CX350A valve, an RF driver amplifier employing a 4CX3000A valve and RF power amplifier using two 4CV100000C vapour cooled power tetrodes in parallel. Grid bridge neutralisation and direct screen connection to ground were employed to ensure stable operation of the third stage and the power amplifier. 100 % modulation was applied to the anode and screen of the power amplifier and 80 % applied to the grid. The output from the RF power amplifier was fed to a bandpass filter and balun transformer, TVI filter and directional coupler and then to a 300 ohm balanced transmission line.

The RF unit could be tuned to any frequency within its operating range in 12 seconds or less by automatic tuning circuits under the control of digital commands from the control computer. This was accomplished by use of eight servo-motor driven controls, the servo-motors being initially commanded to coarse tuning positions through conversion of digital frequency information into an analogue signal. Fine tuning was automatically directed by the servo control unit in response to error signals supplied to it by a phase discriminator in each case.

The AF unit included an input amplifier which was a four stage solid state unit, an AF drive push-pull Class A amplifier using two 4CX350A valves, and a Class B push-pull modulator employing two 4CV100000C vapour cooled tetrodes.

The modulators provided 12 kV peak for 100 % modulation. The audio stage used two forms of feedback to lower distortion. Above 3.5 kHz, 6 dB of feedback was applied from the anodes of the modulator to the cathodes of the AF driver. Below 3.5 kHz, 6 dB of RF envelope feedback was applied to the second stage of the AF input amplifier.

The 15.35 kV power supply for the modulator and power amplifier anodes was provided by a 12 phase bridge rectification network. Other supplies included 2000 V screen supply for the modulator valves and 750 V negative for the RF power amplifier screens and 4250 V for the RF driver anode.

On 24 December 1974, Cyclone Tracy almost completely destroyed five aerial systems and associated transmission lines. Damage to the main transmitter building was not extensive but ingress of water caused considerable damage to the three transmitters and associated equipment.

Engineers on site responsible for operation of the facilities up to this point included Bill Shapley, Max Chadwick, Graham Shaw, Rodney Thompson and Chris Soutter. Supervising Engineer was Jack Ross.

Technical staff who worked at the Cox Peninsula facilities from commissioning in 1969 until temporary closure in December 1974 included:

Geoff Adams, Dick Adey, Colin Anderson, Graham Baker, Dick Baker, John Berry, Bill Binns, M Bradley, Barry Burns, Doug Butler, Ken Bytheway, Don Carter, Mal Chamberlain, Warren Charlton, Trevor Chapman, Peter Coombe, John Cowell, Dick Deland, Neil Dick, Brian Dodgson, B Donavan, Bob Durand, Ray Dunchue, Gary Earnshaw, Bill Edwards, Jim Elmsley, Bob Fricker, Bruce Gardener, Bob Gilliland, John Glossop, Syd Heinrich, Frank Henschke, Alex Heywood, Darby Hill, Graeme Hillgrove, Frank Horne, Fred Hosking, Ted Hurn, Dennis Joel, Kev Johnson, Laurie Keen, Bob Lane, Ken Leader, Carl Leopold, Kev Leopold, Doug MacArthur, John MacIntosh, Mike MacIntire, Pat McCall, L McKay, Kev Menzel, Trevor Martin, Glenn Miller, Cliff Milowic, Brian Milton, Eric Newmann, Ted Notley, Gary Nolan, Laurie Oakes, Brian Oatway, Jim Parkes, Brian Pennefold, Murray Pennefold, Bob Randall, Warren Richardson-Johnson, S Shanko, Gary Shubert, Jim Sinclair, Brian Smith, Ian Smith, Doug Stevens, Mal Stewart, Barry Stoyel, John Stuchbury, Peter Swan, Hayden Tremethic, Ron Warden, Peter Wilson, Fred Wimmer, Terry Wooster and Evan Wyatt.

It was 10 years before the station went back on air to resume regular transmissions.

Following investigations by the Standing Committee on Public Works in 1980, Parliament approved rehabilitation work at an estimated cost of $10 million. Major works included repairs to the access jetty and provision of a new wharf head; repair and upgrading of buildings and services; repairs to an existing submarine power cable and installation of a new cable; provision of transmitting curtain arrays, transmission lines and switching facilities; and replacement of the computer control facility.

One of Telecom's Head Office Engineers who played a major role in the rehabilitation was John Webb. John joined the Telecom Broadcasting Branch in 1981 after having worked in the Department of Civil Aviation on major works including MF, HF and VHF stations and on taking up duty with Telecom was immediately involved in the Cox Peninsula rehabilitation. The involvement took up the major part of his time for three years. John was also involved in the provisioning aspects for the three HF Inland services in the Northern Territory.

The station resumed transmissions on 2 September 1984 and was officially opened by the Minister for Communications, the Hon. Michael Duffy on 30 October 1984.

South Australian Radio Section Engineers involved in the rehabilitation activities and subsequent operation included Jack Ross, Graham Shaw, Ron Falkenberg, Len Som de Cerff, John Wilkins and Chris Cooper. Ralph Denison was responsible for drafting activities.

Officers-in-Charge of the station to 1994, except for the period when it was not operational during the rehabilitation phase, included Ken Bytheway, Ross Kearney, Terry Said, Graeme Wilmot and Bob Gilliland. In 1996, Graham Quinell was Acting Officer-in-Charge.

Technical staff who were responsible for operation and maintenance activities since recommissioning in 1984 up to mid 1993 included:

Peter Baddeley, Mike Beall, Peter Becker, Bruce Berry, Allan Borrick, Peter Cathery, Bill Chilcott, Robin Clarke, Robbie Coleman, Bill Collins, Peter Coombe, Jack Davis, Steve Dearle, Les Denison, Mike Ditoro, Vic Dzieciol, Nguyen Phuoc Dzung, Gary Earnshaw, Dave Edwards, Bob Gilliland, Ray Henley, Des Hocking, Alan Holland, Allan Hubbard, Ted Hurn, Chris Jarvis, Kev Jeffery, Denis Joel, Dave Joseph, Mike Jury, Ross Kearney, Mario Klauzer, Ray Lawrence, M Lih, Alf May, Eric Newmann, Bruce Pine, Terry Said, John Scharpel, Ian Smith, Vern Taylor, George Wallace, Neil Williamson, Graeme Wilmot and Brian Wilson. Veronica Patterson attended to the station switchboard and administration duties.

Although the station as originally designed, allowed for the installation of 5 x 250 kW HF transmitters, it was not until 1991 that the Government decided to provide funds for two additional transmitters to complement the three already installed.

The project resulting from this decision involved the purchase of two 250 kW transmitters, a 2 x 10 extension of the Brown Boveri matrix switch, revision of the matrix switch control software, construction of transmission lines, rearrangement of the program input equipment, extension to the mains power supply system and replacement of the main station computer control system. The work involved Telecom Broadcasting SA/NT and National Office staff until early 1994 when the new facilities were put into full operation.

Central to the project were the two transmitters. The transmitter contract was issued on 18 October 1991 to Thomson-CSF, France which later became Thomcast, a company formed by the merger of the high power Transmitter Divisions of Thomson-CSF, France and ASEA Brown Boveri, Switzerland.

The National Transmission Agency invested $9.5 million in the upgrading of the station including $7.6 million for the two transmitters. Both transmitters were air freighted from Paris to Darwin by Russian Aeroflot Ilyushin 1L76 cargo planes.

Program input equipment and control room upgrade work was completed during April/May 1993 prior to arrival of the two new transmitters on site. Because the station had to maintain an operational schedule the work had to be done with minimum disruption to transmissions.

The existing PIE racks were fully occupied and it was decided that the most expedient course of action was to install new racks and migrate the existing equipment to them.

Because of the existing control room equipment layout, it was necessary to relocate control and monitoring functions for the aerial selector switch matrix and AC power supply from a control desk to a new rack and the new PIE racks were installed in place of the redundant control desk.

The PIE racks consisted of eight racks, one each for the five 250 kW HF transmitters, a program selection rack, a monitoring and testing rack and a rack for spare equipment.

Program selection was normally computer controlled to meet schedule requirements through an audio matrix switch, program to each transmitter was fed through a CRL MBL 100 limiter and audio processor, monitoring was arranged through Harris AM 90 modulation monitors and the transmitted waveform displayed on a CRO screen.

Input program fail alarms were provided, as were output program and carrier fail alarms.

A new control desk housed the station alarm system computer, field arc detector interfaces, CCTV monitoring and fire alarm mimic. In addition, an emergency 'off' button, demodulated output VU meter, status indicators and feeder isolate switch controllers were provided for each transmitter on the desk. Facilities to select audio to monitor speakers were also provided. On either side of the desk was a computer terminal for the display and selection of station transmitter alarm summaries and schedule control. A dynamic station overview was displayed on a large computer screen above the desk.

Each transmitter had a dedicated computer terminal in the control room which displayed detailed transmitter status information and provided facilities to control the transmitter when it was not operating under automatic schedule control from the main station computer.

The installation and commissioning of the program input equipment and control room facilities was undertaken by Greg Kinnear, Alan Mattiske, Peter Tsuolous, Paul Pyatt and Bruce Combe under the supervision of Engineer Graham Baker.

The Thomson-CSF TRE2326 transmitters installed at the station were the first of a new range of high power broadcast transmitters produced by the newly formed Thomcast company.

The transmitters were capable of producing 250 kW carrier output in the range 5.95 to 26.1 MHz and operating in the AM, Dynamic Carrier Control and Reduced Carrier SSB modes.

Only one valve was employed in the transmitter, this being a 500 kW rated Thomson-CSF TH558 type located in the final stage. The 2 kW drive power required by the valve was produced by a multiple device broadband solid state amplifier.

The mains power supply requirement was 3 phase 400 volt with the transmitter having a 50 ohm unbalanced output. On site, the transmitter was supplied with a balun to convert the output to 300 ohms symmetrical to suit the existing balanced transmission lines and aerial selector matrix switch.

A feature of this new generation transmitter was the method by which modulation was produced.

The main high tension supply to the valve was synthesised by connecting in series up to forty-eight separate 700 volt DC power supplies. These power supply modules were controlled by a dedicated microprocessor system through individual fibre optic links.

The main power transformer consisted of 3 phase 400 volt primary winding and forty-eight individual three phase secondary windings feeding the power supply modules.

The incoming audio modulation was digitally sampled and converted into high speed control strategy to turn 'on' and 'off' switches in each power supply module.

Each module was fault protected and the transmitter could continue to operate with up to seven of the modules out of service. A major advantage offered by the transmitter was the improvement in overall efficiency of the system with a guaranteed efficiency of 73% being obtained.

Cooling of the transmitter was a combination of closed cycle water employing the patented Hypervapotron system and air. The air system included provision for minimising the high humidity problems common in Darwin during the 'wet' season.

The transmitter was normally tuned automatically. There were fourteen tuned elements in the transmitter and each was controlled by a servo motor and an optical coupled absolute position indicator which provided digital feedback to the control system.

A second group of frequencies were memorised as the transmitter operating frequencies and frequency change was normally accomplished by selection of these memory channels.

The transmitter was controlled through a number of dedicated microprocessors having individual responsibility for various functions within the transmitter.

A video colour display module was incorporated in the transmitter control panel which indicated the transmitter status. Alarm messages appeared as part of the display. Alarm events were logged in the controller memory and could be scrolled through for maintenance purposes. In the event of a fault, plain language messages were displayed in conjunction with faults to assist in fault resolution.

Equipment provisioning associated with the two transmitters was handled by Terry McManus of Telecom Broadcasting Melbourne Headquarters with on-site Project Engineer Graham Baker being responsible for oversighting the Contract on behalf of Telecom Broadcasting. Thomson-CSF staff who carried out the installation of the facilities were Marc Moreau, Guy Pellett and Didier Thomas. Local Radio Australia staff and staff from Telecom Broadcasting Adelaide including Greg Kinnear, Peter Tsuolous and Alan Mattiske assisted with the provision of support services associated with the installation.

A brief ceremony was held at the station on 20 May 1994 to mark the inauguration of the new facilities. Included among those in attendance were Bob Collins, Federal Member for Primary Industries and Energy who acted on behalf of Michael Lee, Minister for Communications and the Arts; Vic Jones, General Manager, National Transmission Agency; Derek White, General Manager ABC International Broadcasting; Les Rodgers, General Manager, Telecom Broadcasting; Greg McAdoo, Assistant General Manager, National Transmission Agency; Terry McManus, Telecom Broadcasting Melbourne; Graham Baker, on-site Project Engineer; Bob Gilliland, Station Officer-in-Charge and others.

Following closure of the Radio Australia Carnarvon station in July 1996, the Thomson–CSF 300 kW transmitter was relocated to Cox Peninsula at a cost of $1.7 million.

Because the station was located on the other side of Darwin and remote from Darwin where staff normally lived and power was provided via a submarine cable, the staffing originally included a number of different disciplines to operate the facilities and provide support. The number of people involved in 1970 was about 110 and included Technical, Radio Lines, Electrical Fitter Mechanics, Diesel Mechanic, Bus Driver, Office Assistant, Storeman and Marine staff.

The Marine Service was unusual for a broadcasting station in Australia. They provided transport across the Harbour for all shifts using the public wharf at Darwin and a jetty specially constructed at Mandorah on Cox Peninsula. A bitumen road linked the Mandorah jetty terminal to the receiving and transmitting stations. The first launch was named the 'Charles Todd' and was later followed by another named 'Sky Wave'. Both boats were lost during Cyclone Tracy in 1974 with one member Ron Marshall, losing his life when the 'Charles Todd' sank. By 1992, marine transport had been provided under contract and the total station staff reduced to about 16 people.

Some 28 boat crew were on the staff list over the years when the Department operated its Marine Service. Those associated with operation of the service during the installation and early operation days of the station include Murray Cubillo, Phill Delacruz, George McCubbin, Ray Nurton and Bill Pringle (Senior Master of Launch).

Others who later joined the service include A Arabina, Terry Bushell, J Connell, A Cribb, Stemmy Edwards, Syd Gebert, Ian Jordon, E Kerr, Mo Logan, Ron Marshall, Barry Martin, Darby Morris, Owen Morris, Ron Morris, Vic Morrison, Franz Ocker, Kenny Payne, P Renwick, Jim Rosewear, Nigel Townsley, Mike Verral, Ken Walters and Mike Wright.

Electrical Fitter and Mechanic trades staff responsible for Electrical Services at the time of commissioning the station were Ron Beaumont, Ainsley Britian, Kev Gilbert and Rod Laver. Others who joined the group later included R Burns, Neil Grimm, Bob Henness, Steve Opperman, John Murphy and Jimmy Roberts.

Transmissions from the Cox Peninsula station ceased on 30 June 1997 following Federal Government announcement that the facility was no longer required for the Radio Australia service.

The station was placed in a caretaker mode by staff of the maintenance contractor Broadcast Communications Ltd while future uses of the facility were being explored. A skeleton staff remained on site to attend to ongoing maintenance and security tasks.

Following announcement of the closure, the press reported that German, Dutch, USA and other overseas broadcasters were interested in leasing the facilities in order to extend their reach and raise their profiles in Asia.

* CARNARVON

With the extensive damage to the Cox Peninsula station as a result of Cyclone Tracy, particularly the aerial system, and anticipated delays in restoration work, urgent action was taken to establish a temporary station at Browns Range Carnarvon on the site of the former NASA tracking station in Western Australia to maintain a high signal strength for Radio Australia in South East Asia, and also to keep active, the allocated transmission frequencies.

The Carnarvon site, like Cox Peninsula, was also subject to cyclonic conditions and this factor had to be taken into account in the design of the external plant facilities.

Tenders were called for a high power transmitter, with a contract being subsequently award to Brown Boveri for a 250 kW HF transmitter. A 100 kW transmitter originally ordered for installation at the Cox Peninsula site for the HF Inland service was directed to Carnarvon to provide for two operational units at the station.

The 250 kW Brown Boveri transmitter was the first to be commissioned, with a six hour schedule being maintained from 20 December 1975. With the commissioning of the 100 kW Harris/Gates transmitter on 15 February 1976, two transmission schedules were implemented.

With the completion of all major site works, a full schedule of 20 hour daily transmissions commenced on 7 March 1976 using the four curtains provided.

Staff associated with establishment of the station included Terry Sellner, Giff Hatfield, Murray Little, Trevor Chapman and many others.

Terry Sellner began work in the PMG's Department in Western Australia as Cadet Engineer prior to graduation with First Class Honours Degree from University of Western Australia. He was involved in a number of projects in the Perth and North Western areas before transferring to the Radio Section in Perth to work in the broadcasting area. One of his early projects was the high priority Radio Australia Carnarvon station where he spent most of 1976 on testing and adjusting feeder lines, aerial systems and construction of a safety fence around the aerial farm. He was appointed Engineer Class 2 in 1979 and was Project Engineer for the establishment of some 28 stations under the RATV program. In 1982, Terry was promoted to a position of Engineer Class 3.

Giff Hatfield joined the PMG's Department in 1957 as Cadet Engineer and completed his Degree studies in the same year. He then worked on final testing aspects of metropolitan television stations and establishment of regional stations before going overseas in 1966 for two years to complete a Masters Degree.

On return to the Department's Central Office in Melbourne he worked on a number of MF broadcasting and radiocommunication projects including passively cooled shelters for the East/West radiocommunications link.

Giff became involved with the computer based fault recording system later to be known as BORIS and shortly after, was put on the project to establish Radio Australia Carnarvon in short time.

As Supervising Engineer Operational Studies, he finalised the Broadcast Engineering Manual and associated Engineering Instructions and also undertook investigations into RF radiation safety issues.

Following retirement, Giff was a Consultant on radiation safety aspects mainly related to broadcasting stations and aerial systems.

The 250 kW Brown Boveri transmitter type SK53F3 which had capability to accept clipped signals to raise the average level of modulation used a single valve drive stage, a single grounded cathode tetrode as the modulated power amplifier and a pair of valves in push-pull configuration for the modulator. The modulator stage employed conventional high level modulation technique with a modulation transformer and choke. Additional modulation was applied to the screen of the RF power amplifier.

The main tank inductor of the final tuning stage was formed around the final amplifier valve and tuned by three parallel variable vacuum capacitors motor driven in synchronism.

The operational control panel had all the required features to bring the transmitter to full power and included a mimic diagram with associated metering, digital logic monitoring and diagnostic system for status indication and for rapid fault isolation.

In line with current design trends for high power short wave transmitters, broadband amplifiers were employed in order to keep the number of tuned stages to a minimum. All elements which were switched or varied in the course of tuning operations were motorised. The switchable elements were automatically positioned merely by operation of a band selector switch, whereas the continuously variable elements were controlled by flip-flop switches.

The operating frequencies could be supplied by either high stability crystal oscillators or a decadic frequency synthesiser.

Valve types employed were type CQL5, an air cooled ceramic tetrode in the driver stage, type CQS200 vapour cooled ceramic tetrode in the final RF stage, and two type CQS50 ceramic tetrodes in push-pull in the modulator stage.

The 100 kW Harris transmitter used a pulse duration system of modulation. The modulation valve was connected in series with the RF power amplifier valve and driven with 70 kHz duration modulated pulses.

The transmitter employed five valves. They were RF driver, type 4CX1500A; modulation driver, type 4CX1500A; modulator, type 4CV100000E; RF power amplifier, type 4CV100000E; and damper diode, type 2C10000E. The damper diode was placed between the modulator valve and the output amplifier to ensure the 70 kHz pulse frequency was not radiated.

The output tuning inductor comprised a number of coils which were switched in and out of circuit as required to cater for the required operational frequency. In this way, moving coil contacts which are a major problem with high RF currents were avoided.

A vapour phase cooling sub-system cooled the modulator and power amplifier valves. The vapour phase cooling system consisted of valves with a specially designed anode immersed in a boiler filled with distilled water. When power was applied to the valves, anode dissipation heated the water to 100°C and further applied energy caused the water to be changed to vapour. The vapour was passed through a heat exchanger where it was cooled and converted back to the liquid state. The water was then returned to the boiler where it repeated the cycle.

The power amplifier tetrode power valve type 4CV100000E operated with fixed bias of −600 volts. A screen operating potential of 800 volts was provided by the PA screen supply rectifier diode. A voltage proportional to screen current appeared across a rheostat with the voltage being returned to the base circuit of RF driver transistor. It reduced the RF drive to keep the screen grid within its dissipation limits with various conditions of power amplifier tuning and without anode voltage. With this arrangement, the anode of the power amplifier could be tuned without concern about over-dissipating the screen grid.

Normal anode voltage for the PA was about 13 kV. About 20 kW was dissipated by the PA valve at 100 kW output. Broadband neutralisation was employed to reduce phase modulation of the carrier.

The transmitter was equipped with an external high voltage power supply. This supply provide the operating potential for the PA anode. Nine internal power supplies were included in the transmitter. These supplies provided bias, screen, and anode potentials for the power stages. They also provided operating potentials for the servo sub-system and RF section low level stages. The transmitter was equipped with a number of metering circuits for monitoring current, voltage, and power at important points in the transmitter.

On 3 April 1984, a Thomson-CSF TRE2320 300 kW transmitter was commissioned. At the time, it was the most powerful transmitter in the Radio Australia service.

Operational frequencies were provided by a synthesiser and fed through a wide band solid state amplifier and two high power tetrodes operating in Class AB and Class C respectively. The first RF stage transistor amplifier provided 100 W to the second RF stage tetrode type TH362 which in turn supplied 3 kW output to the final RF amplifier using TH573 Hypervapotron tetrode to produce the 300 kW output. The RF chain contained a cavity filter as well as a matching stage. These stages were fitted inside the transmitter enclosure. The output circuit included a VHF filter, a reflectometer and feeder-protection box.

The audio frequency section comprised one transistorised and two valve amplifier stages. This provided amplification including amplitude and phase correction to produce 180 kW of audio power for high level modulation purposes. The valves employed were self cooling QE08/200 types in the second AF stage and two Hypervapotron cooled TH581 type tetrodes in push-pull in the modulator stage.

The transmitter had a microprocessor controlled tuning system employing series 4000 CMOS ICs capable of 50 frequency memory storage.

Cooling of the high power valves was achieved by the Hypervapodyne hydraulic cooling system comprising three separate pressurised water circuits.

Operation and maintenance people who staffed the station when it began operational transmissions in 1975 included Eric Anderson, Bob Broun, Brian Clarke, Jack Clugston (Officer-in-Charge), Peter Coulthard, Jim Cregan, Ken Gillian, Phil Dickinson, Bob Green, Harry Hermans, John Scott, Niel Sims, Greg Soudure and Mike Templeman.

At mid 1993, the staff included Alf Blackley, Peter Castlehow, Steve Donohue, Richard Errey, Les Fancote (Officer-in-Charge), Steve Farrall, Ted Hewitson, Phil Leaney, Jim Lofts, David Minchin, John McKernan, Trevor Mosel, Lindsay Pond, Dave Richter, Niel Sims and Mike Templeman.

Officers-in-Charge at Carnarvon as at mid 1996 since commencement of first Radio Australia operations included Jack Clugston, Ron Bennett, Ross Kearney and Les Fancote.

Following an agreement made between the Government and the ABC, in order to assist in funding the ABC's Australia Television service, the Radio Australia Carnarvon transmitting facilities were closed down with operations ceasing on 31 July 1996. The Thomson–CSF 300 kW transmitter was subsequently relocated to the Cox Peninsula station and the 100 kW transmitter relocated to Shepparton. The 250 kW Brown Boveri unit was scrapped. Operational staff on duty at Carnarvon when it shut down were Les Fancote, Mike Templeman and Steve Donohue.

* BRANDON

The most recent of the Radio Australia outlets was established at Brandon in North Queensland on the site occupied by 4QN, with the first scheduled transmission taking place on 7 May 1989 on 6020 kHz beamed to Papua New Guinea using a log periodic aerial system.

The service commenced operation with three STC type 4-SU-48B transmitters transferred from Lyndhurst after closure of that station in 1987. Although the transmitters had been in service since the 1960s, some upgrading work was undertaken and they were expected to provide reliable service for many more years. The station operated in an unattended mode.

The output impedance of the transmitters was 300 ohms and they fed into 300 ohm two conductor boxed lines inside the building to the outside lines. To match the 120 ohm aerial input impedance, the outside lines were of tapered construction. The first six spans were of 2.8 mm copper four wire square configuration of 300 ohm impedance, then tapering to the final section within the mast framework with 20 mm copper tubing.

The service commenced operation with a rotatable type log periodic aerial transferred from Lyndhurst, but by the end of 1989, two curtain types HR 2/2/0.4 and HR 2/2/0.6 consisting of four horizontal half wave broadband folded dipoles with aperiodic reflecting screen to produce essentially, a unidirectional beam were installed.

Two transmitters were utilised in a day/night frequency change configuration for the Papua New Guinea service and the third unit operated for the Coral Sea service. Transmitters covered the frequency range 3–28 MHz and employed A3 high level Class B modulation. Modulator and PA used 3X2500A3 type valves. Rectifiers were solid state circuits with HT being 4800 volts.

The short wave broadcasting stations of Radio Australia were expensive to operate and maintain. Mains AC power consumption was high and efficiency of a transmitter played a major part of power costs particularly with the top of the range 250–300 kW models. As an indication of costs involved during 1991–92 the cost of operating and maintaining the Shepparton, Cox Peninsula, Carnarvon and Brandon stations totalled $13.6 million which included $4.4 million for power.

As at 1992, all transmitters of 100 kW and above in the Radio Australia service featured automatic tuning mode. It is of interest that on 8 December 1942, Engineer Bill Gold while employed with Standard Telephones and Cables Ltd Radio Division in England lodged a Patent Specification concerning 'Improvements in or relating to tuning arrangements for thermionic valve circuits'. Basically, the invention concerned an automatic tuning arrangement for high power medium wave and short wave broadcast transmitters. The complete Specification was accepted on 13 June 1944,and British Patent Number 561977 issued.

Although equipment forming part of the invention employed electromagnetic devices adapted to vary a reactance forming part of a tunable circuit and controlled directly by a current derived from a thermionic valve or rectifier, may appear outdated by today's solid state technology, it was state-of-the-art technology 50 years ago, and like many inventions, did not receive widespread acceptance and application until many years later. Today, a high power broadcast transmitter which did not incorporate automatic tuning would not sell. The advantages of a high power short wave transmitter carrying out tuning automatically at high speed are so great that there is now no place for human intervention in transmitter tuning when changing frequency for a new transmission schedule.

Bill Gold migrated to Australia, and commenced work with the Adelaide PMG's Department in 1956. He retired 10 years later, and during the period worked on a number of design and development projects for the 5CL/5AN Pimpala Transmitting Centre and the Radio Australia Cox Peninsula project involving three 250 kW transmitters. He made a significant contribution to the development of high power HF transmission lines and hardware for aerial systems particularly with strain insulator design.

As at mid 1996, Radio Australia programs could be heard through many outlets including:

- Daily short wave transmissions from Australian based stations to Asia and the Pacific region in English, Indonesian, Standard Chinese, Cantonese, Tok Pisin, French, Khmer and Vietnamese.
- Via satellite in South East Asia through the Australian Television signal on the Palapa Satellite Channel 5H, 3880 MHz C Band. Programs could be received on 7.20 MHz for English and 6.48 MHz for other languages.
- Via satellite in Europe on the World Radio Network (WRN) service via ASTRA 1B Satellite on Channel 22 on the 7.38 MHz audio sub carrier.
- Via satellite in North America on the Galaxy 5 Satellite Channel 6, 3820 MHz with sub carrier 6.8 MHz.
- Via cable in Europe where WRN relays were carried on cable services in Dublin, Amsterdam, Berlin, Brussels, Bonn, Cork, Galway, Rotterdam, Strasbourg and Vienna as well as many provincial services in United Kingdom.
- Via cable in USA and North America where WRN relays were carried by Cable Vancouver, University Cable in Omaha and Oregon State University Cable.
- Via cable in Japan via Cable Audio Network.
- In Canada, Radio Australia programs were broadcast daily on stations of the Canadian Broadcasting Corporation.

On 1 September 1995, Thai language broadcasts via Radio Australia ceased after some 53 years of continuous transmission due to limited interest in Thailand to the short wave broadcasts. A replacement service was made available by direct satellite feed for rebroadcast by local stations if they wished to take advantage of the programs.

* REVIEWS INTO THE RADIO AUSTRALIA SERVICE

Since its establishment, Radio Australia has been subjected to many reviews, debates and inquiries into administration, program policy, financial and technical aspects as well as its independence, by individuals, Department and ABC staff, and bodies set up by the Federal Government.

Since 1980, major inquiries have included:

- The Dix Report 1981 in which one of the recommendations was for the ABC to have control of its radio transmission facilities.
- The Revill Review 1989 in which Stuart Revill noted that the Radio Australia transmission equipment and plant needed immediate upgrading and that the ABC should control the transmitters.
- Radio Australia Review 1995 in which Dr Rod Tiffen expressed concern that, although earlier investigations had recommended that the transmission facilities be transferred to the ABC, this had not taken place. He observed that the ABC had been locked into a tightly controlled three corner arrangement with Telecom Australia and the National Transmission Agency. This resulted in the ABC being denied any effective control of financial and technical aspects of the Radio Australia transmitting facilities.
- Review of ABC's International Broadcasting Services 1995, undertaken by an Interdepartmental group. The Report was completed in October 1995. The team examined the status and funding of Australia Television and Radio Australia and in commenting on the Radio Australia service, the group was of the opinion that the lack of control by the ABC over the transmission facilities and the budget associated with these facilities, the ABC could not advance into other contemporary broadcasting media such as AM/FM and satellite broadcasting to cover for a predicted decline in short wave broadcasting into overseas target areas.
- Senate Inquiry 1997. This inquiry was conducted by the Senate Foreign Affairs, Defence and Trade References Committee which tabled its Report 'The Role and Future of Radio Australia and Australia Television' in May 1997.

The inquiry was undertaken following concern by some Senators about recommendations by Bob Mansfield in his Report 'The Challenge of a Better ABC', December 1996. Mr Mansfield recommended that Radio Australia be closed.

Important factors revealed during the inquiry by the Senate, relative to technical aspects of the service included:

- In the 40 year period 1950 to 1990, major overseas short wave transmitter manufacturers including Marconi Communications (UK), AEG Telefunken AG (Germany), Asea Brown Boveri (Switzerland) and Thomson CSF (France) between them produced more than 580 transmitters with a total carrier output power exceeding 162 megawatts.
  The high power transmitters (250 kW and above) for Radio Australia had been supplied by Asea Brown Boveri, Thomson CSF and Collins (USA).
- In addition to upgraded transmission facilities, Radio Australia had replaced some terrestrial studio-transmitter program links with Delta satellite distribution system, developed a Radio Australia Internet site making news bulletins available on World Radio Network, and Internet audio.
- During 1995-96 Radio Australia received about 100000 unsolicited letters for listeners and an additional 35000 letters in response to a competition conducted during this period. The Committee was told that it is difficult to estimate the total number of listeners in target areas due to the absence of reliable survey data in many areas. However, programmers estimate the figure to be close to 18 million listeners in surveyed areas.
- Because of the lack of control of the budget associated with the transmission facilities, the ABC cannot itself upgrade the transmission facilities or to fund the introduction of alternative broadcasting technology.
- The ABC is confined to the operation of short wave transmitters based in Australia to reach overseas target areas and are at a disadvantage compared with its major competitors who can construct or lease transmitters on sites to provide more effective signal coverage of target areas.
- During the period 1991 to 1997, expenditure on upgrading Radio Australia transmissions equipment and plant

amounted to $23.2 million. The majority of the expenditure was associated with the Cox Peninsula station which included the addition of two transmitters of French manufacture, upgrade of the station computer system, upgrade of the aerial systems, and relocation of a 300 kW transmitter from Carnarvon which had been closed down. The Cox Peninsula station was the largest broadcasting station in Australia and was operated by a staff of 14 Technical experts.

- Radio Australia also broadcasts programs via the Indonesian Palapa C2 satellite covering target areas of South East Asia, India, Southern China and part of the Pacific area including Fiji. Two programs are available via audio sub-carriers attached to the Australia Television signal. However, the service does not have a large body of listeners mainly because of the high cost of receiving systems capable of utilising the service. Rebroadcasters using terrestrial AM/FM transmitters are the main users of the satellite service.
- In addition to the provision of programs via the transmission system, Radio Australia provides audio transcription tapes to a number of overseas based stations for rebroadcast purposes, and in May 1996 it commenced placement of program material on the Internet.
- The Committee was told of the relative merits of new technologies being considered by a number of overseas broadcasters for improved short wave broadcasting. They included digital short wave broadcasting and satellite aided digital broadcasting.
- The cost of operating the transmission facilities of Radio Australia by the National Transmission Agency during 1996-97 was nearly $7 million. The ABC Radio Australia budget for the same period was nearly $10 million, involving a staff level of 144.

TRANSMITTING FREQUENCIES

Frequency bands for short wave broadcasting were first allocated in 1927 at an International Radiocommunications Conference held in Washington, USA. Six bands were allocated:

6000-6150 kHz (49 metre band); 9500-9600 kHz (31 metre band); 11700-11900 kHz (25 metre band); 15100-15350 kHz (19 metre band); 17750-17800 kHz (17 metre band) and 21450-21550 kHz (14 metre band). The channel separation in each of the bands was 50 kHz. By modern standards, this is a highly inefficient use of the spectrum but at the time, this was considered appropriate due to the poor frequency stability of receivers in use.

When the PMG's Department Research Laboratories established its VLR experimental service in 1928, it chose to broadcast in the 31 metre band on 9580 kHz. The AWA experimental service through VK2ME in 1931 operated in the same band on 9590 kHz.

During 1937, there were 245 short wave broadcasting stations operational in the world and a Plenary Conference of the CCIR was held in Bucharest to consider in detail the need for a World Plan for short wave broadcasting activities. Among the many agreements was the allocation of a new band from 25.6 to 26.6 MHz.

With the outbreak of the War in September 1939, co-operation between overseas broadcasting organisations ceased, and it was in this atmosphere that the Radio Australia service was established.

The selection of operating frequencies for both the Inland and the Radio Australia services was undertaken by Post Office staff and this arrangement continued until 1990 when the Radio Frequency Management Unit of the ABC took over the responsibility for Radio Australia. Those involved included Hugh Murray, Telecom Broadcasting and Nigel Holmes, ABC.

Radio Australia has daily short wave broadcasts in English and other languages. Focus is on Asia and the Pacific with some transmissions directed to these regions reaching the Middle East, North East Africa, United Kingdom, Europe, Canada, USA and South America.

Frequencies employed in the Radio Australia transmissions vary with day/night, seasonal and sunspot situations and the distance of the target area from the transmitter, but the following in operation as at March 1994 for the English Language Service was typical at the time:

- South Asia, Bangladesh, Bhutan, India, West Malaysia, Nepal, Pakistan, Singapore, Sri Lanka and West Indonesia.
  21725 kHz, 21595 kHz, 17880 kHz, 17695 kHz, 15565 kHz, 15510 kHz, 11660 kHz, 9770 kHz, 7260 kHz and 6080 kHz.
- Brunei, Cambodia, East and Central Indonesia, Laos, East Malaysia, Burma, Thailand, Vietnam.
  21725 kHz, 21595 kHz, 17880 kHz, 17750 kHz, 15415 kHz, 15240 kHz, 13755 kHz, 13605 kHz, 11855 kHz, 9645 kHz, 9510 kHz, 7260 kHz and 6080 kHz.
- China, Korea, Japan, Hong Kong, Taiwan, Philippines.
  17750 kHz, 17715 kHz, 17670 kHz, 15170 kHz, 13605 kHz, 11855 kHz, 11660 kHz, 9510 kHz and 6150 kHz.
- Papua New Guinea, Federated States of Micronesia.
  15240 kHz, 13755 kHz, 13605 kHz, 11880 kHz, 11695 kHz, 9710 kHz, 7240 kHz, 6080 kHz, 6060 kHz and 6020 kHz.
- Nauru, Kiribati, Tuvalu, Cook Islands, Fiji, Tonga, Samoa.
  17860 kHz, 17795 kHz, 15365 kHz, 11910 kHz,, 11880 kHz, 11800 kHz, 11695 kHz, 9860 kHz, 9580 kHz and 5995 kHz.
- Coral Sea, New Caledonia, Vanuatu, Solomon Islands.
  15240 kHz, 13755 kHz, 11720 kHz, 9860 kHz, 9580 kHz, 6060 kHz, 6020 kHz and 5995 kHz.

Other countries in which transmissions could be received, subject to propagation conditions and frequency congestion included:

- Middle East and North East Africa.
  21725 kHz, 21595 kHz, 15565 kHz, 15510 kHz, 11660 kHz, 9770 kHz and 7260 kHz.
- UK/Europe
  21725 kHz, 21595 kHz, 15565 kHz, 13755 kHz, 11660 kHz, 9770 kHz and 7260 kHz.
- USA/Canada
  17860 kHz, 17795 kHz, 15365 kHz, 11910 kHz, 11880 kHz, 11695 kHz, 9860 kHz, 9580 kHz, 6060 kHz, 6020 kHz and 5995 kHz.

FREQUENCY MODULATION TRANSMITTERS

Parliamentary Committees had examined the matter of the introduction of frequency modulation (FM) broadcasting in Australia as early as 1942, but because of more important factors in relation to the War effort at the time, investigations were deferred.

In November 1944, the Postmaster General requested the Parliamentary Standing Committee on Broadcasting to investigate and report as to the manner in which frequency modulation broadcasting should be incorporated in the domestic broadcasting system.

Following consideration of the Report, the Postmaster General announced that the Government had decided to carry out trials in the VHF band to obtain experience in FM broadcasting technology. The technical aspects were put in the hands of Post Office Engineers who set up experimental transmitters in Sydney and Melbourne in 1947 and Adelaide in 1948, all on 97.3 MHz.

Details of the original transmitter provided at Sydney for the experimental transmissions are not readily available but a former member of the PMG's Department Sydney Radio Section understands that it was a 250 W model made in the Department's Melbourne Workshops together with the Melbourne transmitter which was installed at Jolimont, the Central Office Radio Section

Headquarters. Horrie Hyett was Supervising Engineer in charge of the Group and Jim Wilkinson was one of the Engineers associated with the FM experiments.

In Sydney during 1952, a locally constructed 1 kW transmitter was put to air from the Department's Radio Laboratory at 24 West Street, North Sydney with the aerial system being mounted on top of an existing 39 m high tower.

The rig caught fire during 1958 and was badly damaged. Useable material was transferred to the Gore Hill TV station where staff under guidance of Senior Technical Officer Charlie Youngston rebuilt it. A new exciter was constructed based on the Marconi Frequency Modulated TV transmitter sound exciter.

The service was recommissioned at Gore Hill during 1959 feeding a series of vertical dipoles on a 27 m high pole on top of the ABN2 tower using a rigid copper feeder.

The transmitter was taken out of service during 1960 and the equipment used at the North Sydney Technical College for training purposes.

In Melbourne, as early as 1955, part of the then newly constructed National TV tower at Mt Dandenong included a Marconi bats wing 30 kW FM aerial but was not used for some time. With the introduction of colour television at Mt Dandenong the old Marconi TV transmitter was scrapped and the 3 kW sound section was converted by local staff to broadcast Melbourne's first National stereo FM programs on an experimental basis. Technical staff provided the program material during these test transmissions.

The Adelaide facilities comprised a 250 watt AWA transmitter installed in July 1948 at Mt Bonython and operating on 97.3 MHz. It fed into a four element halo type aerial. Ted McGrath was in charge of the installation, with those assisting including Roy Buckerfield, Bert Lampe and Arthur Capel. Operating staff included Jim McLennan, Jack Lester, Arthur Capel, Alby Smith, Ian Gilett, Cliff Linke and Len Radford. Late in 1951, a 17 metre pylon type aerial replaced the halo type.

On 2 November 1953, a 3000 watt AWA transmitter replaced the 250 watt unit with Eric Craig, Bruce McGowan, Dudley Field and Bill Gold being associated with the installation. The equipment was subsequently relocated at Mt Lofty and commenced operations from the new site on 11 August 1960. Ted McGrath supervised the activities.

Ted McGrath who was closely involved with the early FM experiments and later, with the establishment of the permanent stereo service commenced with the PMG's Department in Adelaide in May 1926 as a temporary Junior Mechanic.

When the Government acquired the A Class station 5CL from Central Broadcasters Ltd to form the National Broadcasting Service in 1930, Ted was transferred to the station as shift operator, alternating on transmitter, studio and pick-up duties.

In 1931, he worked on the installation of 5CK Crystal Brook, the first regional station in South Australia, and when it went to air in March 1932, Ted stayed there for a while before returning to Adelaide. He qualified as Senior Mechanic in 1935, and was put in charge of Long Line and Broadcasting Installations including major alterations to the 5CL transmitter and the provision of new studio equipment.

Ted qualified as Engineer in 1937, and during the 1950s and 1960s played a key role in the expansion of broadcasting and television services throughout SA and NT including new stations at Port Lincoln, Penola, Mount Gambier, Alice Springs, Berri, Pimpala, The Bluff, Mt Burr, Mt Lofty and Radio Australia Cox Peninsula.

In 1966, he visited USA, Italy and Portugal in connection with the design of the Cox Peninsula station.

Ted retired from the Commonwealth Public Service on 31 January 1968 and in January 1969, was awarded an MBE for pioneer work in broadcasting and radiotelephone communications in SA and NT.

In Brisbane, when regular FM broadcasting began on 6 October 1953, a 1000 watt REL 518D/DL transmitter manufactured by Radio Engineering Laboratories was employed on 91.1 MHz. It fed into a halo aerial mounted on a 30 m high wooden tower at Mirrimbul on the Taylor Range overlooking Brisbane. People associated with the installation and subsequent field strength measurements included Doug Sanderson, Ted Dennis, Maurice Palmer and Ken Holson.

All the experimental stations were shut down on 30 June 1961 when, following the recommendations of the Huxley Committee on radio frequency allocations, the VHF channels used for the FM experimental broadcasts were allocated for use in connection with the extension of television services to country areas.

However, following continued interest and representations from FM enthusiasts, and inquiries by the Australian Broadcasting Control Board and later, an Independent Inquiry headed by Sir Francis McLean, a former Director of Engineering of the BBC, FM broadcasting recommenced on 7 January 1976 using the Pilot Tone stereo system. Transmissions began from transmitters installed at Canberra, Sydney, Melbourne and Adelaide with programs originating on a 24 hour basis from new ABC stereo studios at Collinswood, Adelaide with program circuits having a bandwidth of 15 kHz. The Brisbane, Perth and Hobart transmitters were commissioned during August 1980. By mid 1991, the ABC-FM Stereo network had grown to comprise 48 transmitters catering for a listening audience approaching one million.

Stereo transmissions had in fact commenced well before the official 7 January 1976 date. On the initiative of the staff of the PMG's Department Victorian Radio Section at Mt Dandenong, an old TV sound transmitter was converted to stereo operation in July 1975 on 105.7 MHz. It broadcast stereo records on a nightly basis for several months. The first record played was 'The Road to Marrakesh' by Enoch Light.

The Public FM stations were among the first to provide stereo transmissions. The Music Broadcasting Societies in New South Wales and Victoria had been pushing for special AM licences outside the broadcast band under the Wireless Telegraphy Act for some time but in a change in Government policy, the Sydney and Melbourne groups were invited to apply for licences in the FM band.

Station 2MBS transmitted stereo programs on 25 January 1975 using a 400 watt transmitter at West Street, North Sydney while the Melbourne station 3MBS went to air on 1 July 1975 with a 200 watt transmitter. Experimental licences were first granted under the Wireless Telegraphy Act but licences were subsequently granted under the Broadcasting and Television Act.

The stations were later upgraded and joined by other Public stations.

During 1980, a number of Commercial services began operation. They included 2MMM Sydney, 2DAY Sydney, 4MMM Brisbane, 3EON Melbourne, 3FOX Melbourne, 5SSA Adelaide and 6NOW Perth. The majority of the stations employed RCA FM transmitters.

The most widely used transmitters employed throughout Australia for both the ABC Classic FM service and Commercial services were designed and manufactured by NEC Corporation Tokyo. The model FBN-7150E, a transmitter of 10 kW output was typical of transmitters still in operation at 1994, although it was later superseded by more advanced models.

The transmitter which employed only one valve was designed to provide a high quality FM stereo or mono service. It provided rapid checking of equipment operation by using LEDs in addition to meters to indicate voltage, current and output power at principal points throughout the transmitter. A control unit gathered information from various points and displayed these on a mimic diagram.

The unit had been constructed to give front access so simplifying accommodation design and layout. It was a fully self-contained cubicle housing all parts of the transmitter including air blower, high tension transformer, rectifier and harmonic filter.

The modulated oscillator circuit of the FM exciter employed direct carrier frequency modulation (DCFM) and required no multiplication. The carrier frequency could therefore be changed very easily by changing the crystal oscillator giving the reference frequency and setting the dial to the desired frequency range. The transistorised power amplifier was made wideband so as to cover the band 87.5 to 108 MHz and required no adjustment should it be necessary to change operating frequency.

The power amplifier used a simple circuit enabling easy adjustment. Input tuning, anode tuning and neutralisation were carried out by the adjustment of a few semi-fixed tuning elements.

The transmitter was fully protected, enabling safe operation by staff and minimising damage to equipment should a fault condition develop. The transistorised power amplifier was provided with an output circulator and any reflected power due to mismatching was dissipated in the dummy load through the circulator, thus protecting the final stage transistor from damage. In the high power valve amplifier, current sensors were provided in the power supplies of the screen grid and anode which provided protection to the power supply circuit and the valve. Reflected power due to mismatching was detected by a reflected power meter.

Audio signals from the two channels were applied to the stereo modulator. Although this unit was designed for stereo broadcasting, it was possible to provide mono broadcasts by operating a switch on the front panel. The modulator was based on the Pilot Tone AM-FM system. The right and left audio signals were added to the switching circuits using diodes after passing through the level adjusting pre-emphasis and low pass filter and phase equaliser circuits and then passed via the amplifier circuit. The switching circuits were operated by a 38 kHz square wave signal. The 38 kHz square wave produced a 19 kHz pilot signal by means of a frequency divider and this signal was added to the switching circuit output signal after adjustment of its phase and level.

The output of the stereo modulator was applied to the FM exciter where the audio (composite) signal was amplified to 150 watts by the transistorised power amplifier. This amplifier had a wideband frequency characteristic with no readjustment of the RF matching networks being required to cover the entire 87.5 to 108 MHz range. All transistors operated in Class C mode.

The final amplifier was a high gain power amplifier employing a grid drive system using a 4CX15000A tetrode valve. The amplifier operated in Class AB mode with an efficiency of about 60%. It comprised four circuits, viz:

- Input matching,
- Anode tuning,
- Neutralising, and
- Output coupling.

The RF output of the final amplifier was passed through a harmonic filter resulting in spurious components above 160 MHz being attenuated more than 40 dB. The filter employed a low pass type consisting of two derived-M and four constant-K filters and no readjustment was necessary should the operating frequency be changed.

In subsequent development of the transmitter, the Company produced an all solid state version. The transmitter incorporated many new and advanced technologies including high efficiency high power transistor amplifiers, low loss RF combiners, high efficiency switching regulators and a high performance exciter.

The transistor power amplifiers eliminated the need of high tension voltages so reducing operating hazards to staff. The amplifiers also eliminated the necessity of a warm-up period before commencing transmission.

In addition to the 10 kW model, NEC provided transmitters varying from low power up to 20 kW for Australian FM stations. In addition to the large ABC Network, NEC transmitters in service in 1989 included 2ROC-FM Canberra, 2 x 10 kW; 2KIX-FM Canberra, 2 x 10 kW; 2MMM-FM Sydney, 1 x 20 kW; 2DAY-FM Sydney, 1 x 20 kW; 2VM-FM Moree, 1 x 10 kW; 2NEW-FM Newcastle; 3MMM-FM Melbourne, 2 x 10 kW; 3BAY-FM Geelong, 2 x 10 kW; 3GL-FM Geelong, 2 x 10 kW; 4SEA-FM Gold Coast, 2 x 10 kW; 4GGG-FM Gold Coast, 2 x 10 kW; 4MMM-FM Brisbane, 1 x 10 kW and 6NOW-FM Perth, 1 x 10 kW.

In the 1987–88 sales period, NEC Australia had 95% share of the local market and when a 20 kW model was supplied to 2MMM-FM Sydney, it was the 300th FM transmitter supplied by the company.

To meet the Australian demand and to reduce the delivery time, their Broadcast Engineering Centre at Mulgrave near Melbourne was expanded in 1990 to cater for 10 kW and 20 kW transmitters to be assembled locally from imported sub-units and components and locally sourced items. One of the features of the facilities was a large screened test room big enough to cater for transmitters up to 30 kW output.

When NEC supplied 2ST Nowra with an 11K series 10 kW transmitter for a supplementary FM licence in early 1991, it made a total of 100 units sold in Australia. The 11K series accounted for more than 70% of sales of the 350 transmitters supplied up to March 1991 for Australian FM broadcasters.

Among later NEC transmitters provided for the ABC Classic FM and JJJ FM networks was the FBM11K20E model, a 20 kW transmitter installed at Mt Dandenong near Melbourne and Mt Coot-tha near Brisbane. Of the lower power FM transmitters manufactured by NEC Corporation, the type FBN-9030E produced in the early 1980s was installed at a number of stations including ABC Classic FM at Broken Hill and Geraldton on 1 September 1984 and 1 May 1984 respectively.

The transmitter was one of the FBN-9000 series produced by the company. The series was fully transistorised up to 5 kW output rating with only one valve being employed even with the 20 kW model.

The FM exciter accepted the audio signals of the two channels from a limiting amplifier provided to prevent over modulation of the exciter due to excessive input. The audio signals to the exciter were directed to a Stereo Modulator Card for conversion into a stereo composite signal. The FM modulator used Direct Carrier Frequency Modulation (DCFM) system to provide an RF signal of carrier frequency. A synthesised Phase Locked Loop (PLL) circuit was employed for carrier frequency regulation. This enabled the carrier frequency to be set by digital switches.

The RF output of the exciter was amplified to 100 watts by a transistorised power amplifier. The Class C amplifier had wide-band frequency characteristics over the 87.5 to 108 MHz range and required no readjustment of RF matching networks should station frequency change be required.

The power amplifier employed a grid drive system using a 4CX3000A tetrode valve. The amplifier operated in Class C mode and had a single tuning system for anode tuning.

A harmonic filter designed to attenuate spurious components above 160 MHz was a low pass type consisting of two derived-M and two constant-K filters.

The transmitter had been designed to provide speedy checking of equipment operation by using Light Emitting Diodes (LEDs). A Mimic/Control Panel gathered information from many points and displayed it on the Mimic Board.

Manager of NEC Australia Pty Ltd Broadcast Systems group for many years and who still occupied the position in 1998 was Roger Greenwood.

When Australian Commercial FM station broadcasters began operation during 1980, USA manufactured RCA FM transmitters of 10 or 20 kW rating were employed at many of the capital city stations. The 20 kW transmitter circuitry differed from the 10 kW unit only in regard to production of increased power output.

The 10 kW model designated BTF-10E1 was designed to cover the standard FM band 87.5 to 108 MHz. Except for the high voltage power supply, the transmitter was housed in a single double door cabinet. The principal sections of the transmitter comprised FM exciter, driver and power amplifier together with associated low voltage, high voltage and grid bias power supply units.

For stereo transmission, the exciter system consisted of an RF exciter module and a stereo generator module with all circuitry being solid state. The frequency modulated oscillator operated at carrier frequency and a buffer stage plus a three stage RF power amplifier, raised the power level to suit the input requirements of the driver stage. The carrier centre frequency was controlled through the use of a phase locked AFC circuit which employed integrated circuit frequency dividers. No tuned circuits or adjustments were required with the circuitry used.

Two single ended Class C amplifiers followed the exciter. The driver stage included a ceramic 7203/4CX250B tetrode. The stage had tuned pi-network input and output circuits. Variable vacuum capacitors were used to tune the RF tank circuits.

The final PA stage, which employed a type 4CX10000D valve, also used pi-network circuitry. Tuning of the stage was accomplished by variable inductors operating at earth potential. The power output was controlled by means of a motor driven variable transformer connected in the primary of the low voltage anode power supply for the driver amplifier. The same variable transformer controlled the driver and PA screen voltages.

A three and one eighth inch diameter harmonic filter was provided to reduce spurious emissions to a minimum. The filter consisted of a series of transmission line elements with a uniform outer diameter conductor, a stepped inner conductor and a shunt stub. Attenuation of harmonic radiation above channel limits was accomplished in an 'M-derived' section and a series of 'constant-K' T sections.

Included amongst the other brands of FM transmitters provided at a number of stations was the Harris HT–10FM model. The transmitter featured the THE–1 FM exciter and two SCA inputs for external generators. The transmitters had RF patch-around capability to remain operational on reduced output power during emergency situations. Three modes of operation were available for use with the transmitter automatic switcher. They were manual, semi-automatic and full-automatic.

In 1992–93, Harris model PT5FM 5 kW Platinum Series solid state transmitters were being employed at a number of stations. They included 2KOFM, WAVE-FM, IN98, ONE-FM and others. All these services were previously in the AM band. In addition to PT5FM 5 kW as main transmitter, the stations employed Harris HT-1 one kilowatt units as standby.

When the owners of 2WS developed plans to change to the FM band in June 1993, they selected the Harris Platinum Series PT20FM transmitter for the service located at Willoughby. This model was one of the first solid state 20 kW FM transmitters developed for the FM market. It consisted of a pair of 10 kW solid state units combined by Harris' switchless combining system. The broadband design of modules eliminated all tuning or adjustment requirements.

The operators of 2WS-FM also employed a Harris transmitter for its back-up transmitting site on Optus Tower, North Sydney feeding into a Jampro aerial system. The transmitter was a Platinum 10 kW PT Series which worked with a Digital 'THE-1' exciter.

During the first six months of 1993, the Australian agent Comsyst Pty Ltd supplied about 20 Harris solid state FM transmitters to Australian broadcasters.

Among the stations which were equipped with Collins FM transmitters was Christian Radio Hobart 7HFC-FM commissioned on 30 March 1980. The 2.5 kW Collins transmitter was derated to meet licence requirements of 1.5 kW ERP using a Phelps Dodge aerial system located at Mt Nelson. A driving force behind the establishment of the station was Neville Brown former ABC Technical Services Director, Radio and Television. Technician Wes Carpenter also assisted with installation and operation of the facilities.

Another series of new generation FM transmitters introduced to the Australian market were manufactured by Broadcast Electronics Inc., of USA during 1992–93 and distributed by John S Innes Pty Ltd. The series included FM-100C with power output of 100 watts employing MOSFET RF amplifier; FM-500 with power output capability to 500 watts with fully solid state circuitry; FM-1C with power output to 1000 watts with dual RF power modules to provide for soft failure; FM–10B with power output capability to 11 kW and employing a single 4CX7500A type valve and FM-20B with power output up to 22 kW and employing a single 4CX12000A type valve. Other models have since been added to the series.

Commercial FM stations at Townsville, Bowen, Sydney (MIX-FM), Deniliquin and Shepparton (SUN-FM) were equipped with BE series transmitters.

Telefunken brand transmitters were in service at some stations including 4ABCFM Mt Isa with a 500 watt S3169/3 model installed on 2 July 1984, Koolan Island where 100 watt transmitters were put into operation for 6ABCFM and 6ABCRN on 24 June 1987, Kalgoorlie where a 500 watt transmitter was commissioned on 2 December 1983 for 6ABCFM, Queenstown/ Zeehan with a 500 watt model installed on 12 June 1987 for retransmission of 7QN programs, Argyle Mine installed on 24 June 1987 for retransmission of 6KW programs.

The FM radio service is expanding rapidly particularly since the implementation of the Government scheme to convert some AM services to FM at mainland capital cities to enable AM channels to be released for Radio for the Print Handicapped and Parliamentary Broadcasting services. One of the first Print Handicapped stations to convert to the AM band was 3RPH which began transmission on 1179 kHz from 19 August 1990. The frequency became available when 3KZ moved to the FM band. Another was 4RPH which in September 1990 moved from 1620 kHz just outside the AM band to 1296 kHz.

The frequency had previously been used by Commercial station 4BK which moved to the FM band.

In parallel with the establishment of new FM services in regional areas, the Government is allowing single AM stations which face competition from new Commercial FM services to convert to an FM frequency concurrently with the commissioning of the new service. The first AM station to convert, was 4GG on the Queensland Gold Coast which began operation with new callsign 4GGG on 20 March 1989.

Even some National service AM stations have been closed down and replaced by FM stations notwithstanding the very large network of FM stations provided specifically for broadcast of ABC programs. In Queensland, stations so effected included 4SO Southport, 4QA Mackay and 4QY Cairns as at mid 1992.

By early 1991, there were 456 FM stations in operation. They included 237 for ABC, 67 for Commercial and 103 for Public broadcasting services. Additionally, there were 49 stations licensed to carry ABC programs under the Self-Help Broadcasting Reception Scheme (SBRS). By early 1992, a milestone was reached when the 500^{th} FM transmitter was commissioned at Mission Beach, Queensland.

The expansion of television to remote areas using the satellite system has also resulted in expansion of the radio service. Although the use of the satellite has proved to be somewhat expensive — annual cost $20.5 million in 1989 — it has been a major technical breakthrough in providing television and radio services to areas which otherwise may not have been served for many years.

The service for distribution of ABC programs was known as the Homestead and Community Broadcasting Satellite Service (HACBSS) and the Commercial equivalent was the Remote Commercial Television Service (RCTS).

HACBSS provided in addition to ABC television, three radio services comprising two mono and one FM. The programs multiplexed in a B–MAC system were frequency modulated by four high power transponders providing four zone beams over western, central, north eastern and south eastern regions of Australia.

Australia was a pioneer in the use of the B–MAC (variant B-Multiplexed Analogue Components) standard for TV and radio broadcasting. The system was developed in Canada.

The audio channels in B–MAC were specially designed to be compatible with the best hi-fi available. The system was designed with variable pre-emphasis and a delta modulation system. With variable pre-emphasis, the signal was sampled before it was retransmitted and the amount of pre-emphasis set accordingly. The result was good quality sound from what was effectively a low quality channel.

People wishing to receive the programs direct, installed a small earth station system with dish antenna typically 1.5 m diameter. The service was widely used with retransmission terrestrial stations both as community or Government provided installations.

The HACBSS facility also proved useful for the ABC in operation of its Regional studios. During 1986–87, the ABC installed earth stations at Broken Hill, Albury, Newcastle, Orange and Tamworth. The stations provided for both up and down links to interchange circuits so that the Regional studios could be fully integrated into the national program exchange and compilation network. Other installations followed.

In 1990, the Department of Transport and Communications carried out a review to consider the impact of the introduction of AUSSAT's second generation satellites — the B series. The satellites were capable of offering new capabilities compared with the A series satellites.

In order to make more FM channels available the Government developed a plan to shift some VHF television services to other bands. Stage 1 of the plan began in 1989 and 33 VHF stations were shifted. Stage 2 which took effect from 1991, involved another 33 services. All of the services were moved to the UHF band.

Of the six categories of broadcasting services, the Subscription Narrowcasting service was very popular particularly amongst ethnic market operators. The Narrowcast FM service operated with encryption in the 150 MHz range with a bandwidth up to 15 kHz and was intended for niche markets too small for the major AM or FM operators. With the limited bandwidth, stereo broadcasts were not practicable.

One successful station was Hellenic Radio in Melbourne which in 1992 after one year of operation had 2000 subscribers, mostly among the Greek community. Subscribers paid an installation fee of $199 or $299 if they wanted to receive a second music-only channel. An annual subscription fee of $55 applied.

The Hellenic Radio receiver/decoder which was necessary to receive the service was manufactured by GSA RanData of Hawthorn. It could accept sixteen 150 MHz range narrowband frequency transmissions using crystals.

In light of the success of the station in Melbourne, other entrepreneurs particularly Chinese, Spanish and Vietnamese entered the market with a Chinese operator attracting 500 subscribers in the first few months of operation.

Although many FM broadcast transmitters have been manufactured in Australia for some time, nearly all FM broadcast receivers have been imported from overseas sources. During the days of the experimental broadcasts many of the receivers were imported from USA but in more recent times the major import sources are China, Japan, Taiwan and Singapore.

THE WAVELENGTH CONTROVERSY

When the Government agreed to the establishment of a broadcasting service, the planners had some major problems to solve, not the least of which was how best to serve the scattered population over such a large continent. In addition to the problem of how best to cover the populated areas with adequate signal strength, the country from about Sydney northwards extended into semi and full tropical zones with their atmospherics which, particularly in the summer season, caused severe interference in the form of noise in broadcast receivers.

To cover large areas, long wavelengths had some important advantages, but atmospherics were more troublesome in this band. Medium waves did not give as large coverage as long waves, but were superior as a reception mode.

Unlike the USA, where broadcasting took off like a steam train giving planners little time to carry out studies and lay down a well-thought out plan for the service, and also Europe where there was the matter of many nearby countries with different languages and different Governments which wanted to have control over broadcast signals within their boundaries, Australian planners had the advantage of being able to choose equipment and operating wavelengths to suit its own particular requirements, without being governed by expediency and without necessity to avoid interference with neighbouring countries. There was a golden opportunity to devise a broadcasting network on a scientifically planned basis.

However, the broadcasting service was established and allowed to expand while advisers and those in authority argued about the plan for nearly 10 years before the Post Office officials made their own decision on the matter, based on technical considerations.

The development of long wave technology for radio-communications had reached an advanced stage by the time the Australian broadcasting system was approved, and it was natural that designers should turn to the employment of long waves for a new system. Ernest Fisk of AWA had indicated that long wave transmissions would be ideal for Australian conditions.

Three of the transmitters designed and constructed by AWA for the A Class stations were commissioned on long waves. Station 2FC transmitted on 1100 metres, 3LO on 1750 metres and 6WF on 1250 metres. However, there was a strong lobby for the use of medium waves, and the other early stations, 2BL, 3AR, 4QG, 5CL and 7ZR operated on medium waves. The long wavelengths used by 2FC, 3LO and 6WF did not last long, and about May 1925 it was announced that all existing stations would operate on a wavelength below 500 metres. The last station to change from long wave transmission was 6WF. It changed from 1250 metres to 435 metres soon after transfer to the PMG's Department. At the time of the changeover, some attempt was made to increase the efficiency of the plant which, through the rapid advances made in broadcast transmitter technology, had become more or less obsolete.

The Radio Research Board which was established in 1927, from the start, undertook an active role into broadcast technology. The Postmaster General's Department on taking over the A Class stations in 1929 to form the National Broadcasting Service used its own Research Laboratories, which had been set up in 1926 to assist in designing, planning and constructing the system's facilities.

By the end of 1932, some progress had been made in the expansion of the NBS to country areas using medium wave transmitters and plans were developed for further expansion.

The Radio Research Board concluded that long wavelengths would generally be more suitable for southern States, whereas the PMG's Department officers were inclined to favour medium wavelengths.

The Radio Research Board during late 1932 began extensive investigations into the use of long waves, particularly into fading in the 1500 metre band. Using Navy long wave transmitters at Flinders Naval Base in Victoria and Garden Island, Sydney, reception tests were carried out in southern New South Wales and eastern Victoria. The tests successfully filled an important gap in the quantitative information available on long wavelength transmissions. It put a good case for the scientific argument of using long waves in combination with medium wave stations in selected areas.

Post Office technical experts who were keen advocates of employing medium wavelengths for the Australian broadcasting service pointed to the USA model as an example. Although the licensing policy left much to be desired, there was considerable merit in using the wavelengths (frequencies) that they had decided to use. The country was about the same size as Australia, and their plan had suited the coverage requirements very well.

Initially, the USA authorities licensed stations indiscriminately, without regard to resultant interference. The operating wavelength was at first 360 metres (833 kHz), designated 'A' range. When the number of stations mushroomed from one in 1920 to 600 in 1922, the authorities included a 400 metre (750 kHz) channel designated 'B' range for high power stations.

Even though stations were separated by long distances, there was very great interference, particularly after sunset, the peak listening period. It became common practice among station Engineers to slightly off-set the assigned wavelength to minimise interference to listeners.

By 1923, the broadcasting plan had been changed to cover the band 200 to 550 metres (1500 kHz to 545 kHz). In 1924, by which time broadcasting had already begun in Australia there were some 1400 stations in operation in the USA, and medium wave technology for both transmitters and domestic receivers, had reached an advanced stage of development.

Arguments by scientific and lay people on long waves versus medium waves for broadcasting purposes continued for a long time. Meeting after meeting resolved nothing, primarily because of hostility between staff of the Radio Research Board and the PMG's Department Research Laboratory.

It was not until the end of 1934 that the PMG's Department decided that only medium waves would be employed for the Australian broadcasting network. The Department was the licensing authority, so discussions were put to rest.

A major technical factor influencing the decision, was the advent of the half wave vertical radiator which had the important property of emitting only a small proportion of the transmitted energy in a vertical direction. Most of the energy travelled nearly horizontally.

Since long waves would require very tall and expensive radiators of the half wavelength type, they were ruled out as an alternative.

It was thus a simpler procedure to upgrade and supplement the existing medium wave network than to face all the innovations and imponderables inherent in a long wave plus medium wave network.

Also, the PMG's Department had been giving consideration to the use of short waves to feed the more remote inland areas. The Research Laboratories had established an experimental short wave station at Lyndhurst, out from Melbourne in 1928 and in 1934 put the transmitter into regular service. With the combination of medium wave and short wave stations there was no role for long wave stations in the Australian broadcasting service.

This policy continued for many years. However, modern technology has seen the introduction of broadcasting services via satellite and terrestrial FM stations to supplement the MF service, with the short wave stations being closed down, except for three stations in the Northern Territory.

OSCILLATORS

Before the widespread employment of quartz crystals as a means of generating a stable carrier frequency, there were many different types of oscillator circuits in use. These included the Hartley with several variations, Colpitts, tuned-anode-tuned-grid, tuned anode, Meissner and others.

Except for a few of the early low power B Class transmitters which had previously been operated as Amateur stations, the early transmitters employed a system termed a 'master oscillator, power amplifier', or MOPA system. The oscillator was a conventional type with the amplifier being a single valve, several in parallel or push-pull, or several in cascade. The chief difference was in the fact that considerable power was being handled and so the circuits were made up of heavy conductors and large valves.

Typical examples are the 3AR/7ZL — 1500 watt transmitter which employed a Hartley circuit with a 203A valve of nominal 50 W rating with frequency being controlled by a variable inductor, 5DN which used a modified Hartley circuit with a 5 W valve, and the early 5 kW AWA transmitters of 2FC, 3LO, 4QG, 5CL and 6WF which employed two MT7A valves in parallel in a circuit employing variometer control for fine frequency adjustment.

The Hartley circuit was by far the most popular circuit with broadcast transmitter designers. The popularity was due mainly to the fact that the criterion of oscillation was not at all critical as was the case with Meissner and tuned-anode-tuned-grid circuits. The amplitude of oscillation was easily controlled by adjustment of the tap on the oscillator coil.

In the basic Hartley design the anode high tension was connected in series with the anode coil and this meant that the terminal of the capacitor, as far as DC was concerned, was at the same voltage as the anode voltage. This was exceedingly dangerous to the operator who might be standing on the ground to which mains negative HT was connected. Contact with the plates or shaft of the capacitor would mean contact with the full anode HT. To prevent trouble of this nature, the practical circuit arranged for the anode voltage to be fed to the valve anode through a separate path by means of a choke coil and blocking capacitor. The design of this shunt-fed Hartley oscillator had to ensure that the reactance of the blocking capacitor was low compared with the reactance of the choke at the operating frequency so that the anode coil was not short-circuited so far as RF was concerned.

The Meissner design was employed with the 5 kW AWA transmitters provided for 2FC, 3LO, 4QG, 5CL and 6WF during 1923–25. The circuit was a number of important inventions of Alexander Meissner a leading scientist of the Telefunken Company in Berlin. He patented the oscillator which bears his name in April 1913.

The circuit configuration included three mutually coupled inductances. The anode circuit high voltage could be connected in series or in parallel, with the parallel arrangement being employed with the AWA transmitters. The high voltage was supplied to a pair of MT7A valves in parallel through an RF choke to prevent the oscillations leaking through the HT supply circuit. A high voltage blocking capacitor was installed to prevent the inductor in the anode circuit from short circuiting the HT. To provide for circuit tuning, the anode and grid coils were shunted by variable capacitors in some designs but the AWA Engineers chose to provide tuning by varying the inductances. The grid circuit was adjusted by physical movement of the grid coil while the anode circuit was adjusted by means of a variometer.

Even though the employment of quartz crystals for generation of the transmitter carrier frequency was widely employed by the late 1920s, most of the AWA transmitters were still operating with the original Meissner circuit when the A Class stations were taken over by the PMG's Department staff in 1929.

The Colpitts oscillator was employed by several Engineers who designed and constructed their own MF transmitters in the 1920s. In 1927, a Colpitts oscillator was employed with an experimental short wave transmitter operating on 100 metres (3 MHz) to transmit 4QG Brisbane programs into north Queensland areas.

There were a number of modifications to the fundamental circuit but the difference between the Colpitts circuit and others was mainly in the method utilised to obtain the requisite grid alternating voltage. The Colpitts circuit depended for its operation upon the voltage changes (called voltage drop) obtained across the grid excitation capacitor when alternating current was flowing. This capacitor was connected between grid and filament. An important advantage of the Colpitts oscillator was that the tuning elements were in the grid circuit where no high voltages were present.

In 1948, many years after the Colpitts oscillator had lost favour with transmitter designers, James Clapp an Engineer with the General Radio Company in USA developed a new version known as a series tuned Colpitts oscillator. Clapp added a variable capacitor in series with the tank inductance to permit an increase of 400 times the frequency variation of the conventional Colpitts.

Many station Engineers had a wavemeter in their test equipment cupboard to regularly check on the transmitter operating frequency. They ranged from a simple instrument using a coil and calibrated capacitor with a pea lamp to indicate resonance, to a heterodyne model. The coil/capacitor or absorption type had an accuracy of about 1 per cent for a well-designed unit with a rigid coil soaked in beeswax to prevent physical movement of the wires. However, it would often drift with temperature changes. Some models used a plug-in coil arrangement allowing the wavemeter to be used on more than one band. A typical unit sold and made by AWA in the 1920s had three plug-in coils, and covered the MF, LF and VLF bands. It was housed in a handsome highly polished wooden box. Imported models included Igranic, De Forest, General Radio and Marconi brands.

The heterodyne wavemeter was a much more accurate instrument with an accuracy of about 0.02 per cent. However, by today's standards, this would not be acceptable for frequency measuring purposes. A typical model employed a single valve auto-heterodyne receiver tuned for zero beat using a pair of headphones to monitor the signal tone.

With rapid growth in the number of broadcast transmitters, it soon became evident that a more accurate means of generating the carrier frequency was required. The lumped coil and capacitor components were subject to physical changes due to vibration and temperature resulting in frequency change to the transmitted carrier.

The US Navy had been conducting research into the employment of quartz crystals for the generation of transmitter carrier from about 1918, and by 1922, had produced one of the world's first crystal controlled transmitters giving long term operation stability.

Investigations in 1922 by Dr W G Cady, credited with being the inventor of the crystal oscillator, and Professor George Pierce in 1923 created a lot of interest in the employment of quartz crystals for broadcast transmitter applications.

By 1926, a number of Radio Engineers were active in Australia in converting transmitters to quartz crystal operation. One pioneer was Harry Kauper, Chief Engineer of 5CL, and well-known operator of Amateur station 5BG. He roamed the Adelaide Hills collecting crystals and built equipment for cutting and grinding crystals to suit radio transmitter operations. By early 1926, he had a 250 watt transmitter in operation with the crystal oscillator section using a receiving type valve. However, he apparently had not changed the 5CL transmitter to crystal operation as the original Meissner oscillator was still in operation in 1929 when he left and the PMG's Department took over the station for the NBS.

One of the early broadcasting stations known to be equipped with a quartz crystal controlled transmitter was 2GB Sydney operated by the Theosophical Society and licensed on 13 May 1926 to the Theosophical Broadcasting Station Pty Ltd.

The transmitter commissioned on 23 August 1926, and operating on 326 meters (920 kHz) was located in the grounds of the Bishop's Manor at Mosman and fed a cage wire type aerial. The studio was located in the Society's office in Bligh Street in the city.

The transmitter was constructed and installed by United Distributors Ltd, one of the largest distributors of radio components, as well as manufacturers of receivers. The company Chief Engineer, Ernest Beard designed and commissioned the transmitter assisted by Len Schultz who later joined the station staff during 1927 and became Chief Engineer in 1928. Len carried out a great deal of upgrading work at the transmitter and also the studios over many years, incorporating state-of-the-art technology. Prior to working with Ernest Beard on the 2GB project, he had been in Europe and USA looking at developments in Broadcast Engineering technology and noted the efforts being put into the application of quartz crystal to the generation of carrier frequencies, particularly in the USA where there were hundreds of transmitters on air.

Although Beard and Schultz had worked together in constructing the 2KY transmitter before the 2GB installation, there is no record of the original 2KY having a quartz crystal oscillator fitted at the time.

The employment of a quartz crystal controlled oscillator meant that the transmitter carrier frequency could be maintained to within ±0.5% under normal operating conditions and within ±0.001% with a crystal mounted in a temperature controlled oven.

The two most widely used oscillator circuits are those developed by Cady and Pierce. Many variations were subsequently developed from these two original designs. In Cady's original circuit, the crystal acted as a selective element in the feedback path of the oscillator permitting feedback only at the crystal frequency. In the Pierce circuit, the crystal was connected between anode and grid or between grid and cathode of the valve. The Pierce arrangements are the most widely used with broadcast transmitters.

The crystal oscillator supplied with the 2NC, 4RK, 5CK and 2CO transmitters installed in the early 1930s employed three crystals with two on standby. They were contained in an electrically heated oven maintained at 50°C. After modifications to the master oscillator, the frequency drift was maintained within 0.008% or ±100 Hz. The master oscillator together with two stages of amplification were housed in a brass lined box for screening purposes and was located away from the high power parts of the transmitter.

In contrast with crystal controlled oscillators, records of 5CL which was still using an oscillator without crystal control in 1932, show that the carrier frequency was maintained within 800 Hz during long term operation. When a new valve was fitted in the oscillator circuit, some adjustments had to be made over a period of time to get the stability back to normal.

Commercial station operators also soon realised the merits of crystal controlled transmitters. Early conversions included 4GR, 4BC, 2UE, 2WG, 2SM, 2MO, 2KO, 2WL, 3BO, 3BA, 3YB, 5DN, 5AD, 6PR, 6ML, 7HO, 7UV and others.

However, not all station Engineers converted their transmitter to quartz crystal operation. Some were completely happy with their L-C oscillator circuits and considered the quartz crystal simply 'gilded the lily'.

In early 1935, AWA produced one of the first designs to meet the demand for broadcast station equipment capable of maintaining the carrier frequency within ±50 Hz at any desired carrier frequency in the broadcast band — then 550 to 1500 kHz. The equipment was known as Frequency Control Unit R662. Facilities for a typical broadcast transmitter comprised two frequency control units, each consisting of temperature-controlled crystal, oscillator and buffer amplifier. The two units were mounted on a single rack with power supply and a switch box, so that either crystal could be selected for operation.

The crystal oven was an aluminium casting in which was placed the crystal holder with its heavy brass base in close thermal contact. The crystal oscillator used a Radiotron 76 valve in a simple Pierce circuit with grid-cathode connection of the crystal. A small capacitor provided fine adjustment of the frequency over a range of about ±30 Hz. There was a huge demand for the equipment. During September 1935, eighteen units were put into service at broadcasting stations throughout Australia. Subsequent investigations indicated that the average divergency from the designed frequency was less than 10 Hz for 85% of the stations and less than 50 Hz for 99.7% of the stations.

The success of the unit and the desire to produce a unit of even better performance resulted in the subsequent development of the R3357 unit about 1937. The unit employed two crystals, either of which could be selected by a switch to be used with an oscillator using a type 42 pentode valve in a Pierce circuit with anode-grid connection of the crystal. The oscillator load was loosely coupled to an 807 buffer amplifier to minimise any frequency change. The crystal was mounted in a small bakelite holder which was mounted on bakelite supports in a heavy metal isothermal chamber consisting of a base, a casing and lid. A well in the chamber wall carried an Edison bi-metallic regulator switch mounted in a sealed glass tube containing hydrogen. A 12 ohm heater was wound on the outside of the isothermal chamber with as little insulation from the chamber wall as possible. The equipment was designed to maintain a frequency stability within ±0.001% with crystals of temperature co-efficient less than two parts per million per degree centigrade.

Improvements have been made over the years in the manufacture of the crystal elements but the basic construction and temperature control arrangement have changed very little. In the Master Oscillator of the Philips 2 kW transmitter type 1656 manufactured in 1953, a 6V6GT valve was arranged as a Pierce oscillator with the crystal effectively between screen grid and control grid. The anode circuit was electron coupled to the oscillator section. A split stator capacitor was adjustable from the front panel to permit small adjustments of the carrier frequency and to compensate for crystal tolerances. The crystal oven assembly was enclosed in an aluminium can and designed as a plug-in unit for five pin valve socket mounting. The oven heater was supplied with 12 volt AC from a winding on the oven transformer. When the oven temperature reached 60°C the thermostat opened and heating ceased. After cooling slightly,the thermostat closed again and heating recommenced. After about one hour of operation, the thermostat followed a cyclic ON/OFF action.

Modern techniques used for preparation of quartz crystals have eliminated the need for controlled heating of crystals to ensure their stability.

It is very infrequent that a change in transmitter frequency is required for an MF station but in November 1978, following decision to change Australian broadcasting station channel spacing from 10 kHz to 9 kHz, many stations had to change frequency. The majority of changes were relatively small and involved only minor changes to facilities and tuning. The major changes were associated with the carrier frequency generating equipment.

In the case of the National stations, basic crystal units in service at the time of change, included AWA 7 pin type R3535 with crystal oven, Philips 5 pin type SP220 similar to the AWA unit, D style crystals housed in crystal ovens and operating at 2 to 4 times the required carrier frequency and some special units.

Rather than regrind or purchase new crystals, decision was made to employ a commercially available package to replace the AWA and Philips units. The unit used a D style crystal operated at a frequency several times that of the desired carrier frequency. It included a transistor oscillator with frequency divider operating without an oven. The facility had a frequency stability of better than ±5 parts per million over the temperature range -10°C to +60°C and better than ±2PPM over 12 months. The unit allowed for frequency adjustment of ±20 Hz.

High frequency broadcasting stations also employed crystal units until recent times. For example, the Radio Australia Shepparton 100 kW transmitters commissioned during 1945–46 each used a crystal oscillator of the Pierce type employing 10 plug-in crystal units each incorporating its own crystal oven. The crystals were selected by means of a 10 position switch. The crystals varied in frequency between 3.1 MHz (half the lowest transmitter output frequency) and 5.4 MHz (one quarter of the highest transmitter output frequency). Multiplier stages followed the separator or isolator stage. The transmitter was also provided with a Master Oscillator of the Colpitts type which could be used for frequencies not immediately available from crystals. A variable tuning inductor was employed comprising a copper wire helix having a rotating tapping arm driven by a lead screw operated by a dial. Capacitors were selected by a three position switch.

With the installation in the late 1960s, of the Collins 250 kW high frequency transmitters for Radio Australia Cox Peninsula near Darwin, operating frequencies were provided by a solid state synthesiser which under computer control was capable of being tuned to any frequency in the required band in steps of 100 Hz. The output frequency was held constant to 0.8 parts per million per day. The use of synthesisers later became normal practice with all Radio Australia high power transmitters.

In a specification prepared in 1991 for the manufacture of two additional 250/300 kW transmitters for the Cox Peninsula station, the requirements for the RF source included the following:

- The source to be synthesised type normally controlled by the transmitter and capable of generating a carrier within all the transmitter operating frequency bands and be capable of adjustment in increments of 100 Hz or less.
- The source to be capable of accepting an external reference of 10 MHz, in this case the stations 10 MHz rubidium standard oscillator.
- When operating without the external reference, the frequency source is required to have a frequency stability equal to or better than + or - 10 Hz at all operating frequencies.
- The frequency instability due to ageing to be no worse than $1x10^{-6}$ per year.

From early times, the Postmaster General's Department maintained Frequency Measuring Centres for checking that each station maintained its authorised frequency. The responsibility for providing a frequency standard was given to the Department's Research Laboratories.

Initially, frequency measurements were made using known inductance and capacitance but early in 1928, a Sullivan 1000 Hz valve maintained tuning fork was ordered and brought into operation in 1930 at the Laboratories in Melbourne. The accuracy was a few parts in 10^6.

The instrument was put into immediate use to check the frequency of every broadcasting station in Australia.

In 1936, an improved Sullivan model was obtained giving an accuracy of a few parts in 10^7. The new standard was transmitted to line to the Frequency Measuring Centre at Mont Park to provide a reference for Radio Inspectors responsible for measuring the frequencies of broadcasting stations.

In 1939, an Essen quartz ring 100 kHz Z-cut crystal was obtained from the National Physical Laboratory in England, giving a frequency capability of a few parts in 10^9.

By 1941, there were frequency measuring stations located in all capital cities except Hobart and Canberra. At that period, the permissible tolerance was plus or minus 20 Hz of the authorised frequency. A station was subsequently established in Hobart only to be destroyed by the bushfires which swept through southern Tasmania in 1962.

Further improvements have been carried out to Laboratory frequency equipment in recent years by taking advantage of highly accurate atomic oscillators.

Another service provided by the Laboratories, was provision of time signals for a variety of purposes, such as hourly time signals broadcast by radio stations. In the early days of broadcasting, some stations had a microphone installed in the bell tower of the GPO or City Hall clock connected to the studio by a landline.

The operation of frequency measuring stations to check on broadcast transmitter frequencies later became the responsibility of the Department of Communications.

NEGATIVE FEEDBACK

One of the major advancements in transmitter design in the 1930s was the introduction of negative feedback. The technique was developed by H S Black in the US, as a means of reducing distortion and noise. It was originally called stabilised feedback in the US, and was incorporated in Western Electric Co., transmitters about 1935. It was known as inverse feedback when first used in Australian built transmitters.

Many designers were cautious about incorporating it in their transmitters, and when the first BBC transmitters were constructed with negative feedback circuitry, facilities were provided so that if the feedback proved unacceptable, the transmitter could be operated with the modulator in Class A mode without feedback.

From 1937, most transmitters designed for broadcast purposes incorporated negative feedback. STC transmitters supplied at that time included units for 4QS, 3LO, 3AR, 2FC and 2CY.

The incorporation of negative feedback made it possible to achieve less hum modulation and lower distortion than was possible without feedback for a standard design. It allowed reduction in the overall cost of the transmitter as the designer could sacrifice some linearity of modulation and of amplification in order to obtain increased anode efficiency, to reduce filtering requirements of the power supplies and to employ AC power for valve filaments. However, it was not a cure all, as some station

Engineers who built their own transmitters found out. It could not be relied upon to compensate for bad design or improper operation. For example, negative feedback could not prevent distortion resulting from overmodulation of the transmitter. This was a major problem before the advent of peak limiters and volume compressors.

Commissioning tests of the 4QS transmitter which went to air on 17 October 1939, indicate that with the gain reduced by approximately 16 dB of feedback, the frequency response over the band 30 Hz to 10 kHz was within ±1 dB of the 1 kHz figure, the distortion at 96% modulation was less than 5% and the signal-to-noise ratio was 60 dB below the full modulation level. In this transmitter, the feedback rectifier used a type 6A6 valve connected as a diode and operating as a linear detector. The rectifier was so proportioned that it gave an accurate image of the modulation envelope at all frequencies from 30 to 10000 Hz. The output from the rectifier passed through a tuned radio frequency filter to an amplitude control rheostat where it was coupled to the cathode resistance of the first speech amplifier valve through an electolytic capacitor. A high resistance voltmeter connected across the feedback rheostat served as an indication of the amount of feedback being used.

In a typical modern day all solid state transmitter similar to the 50 kW model installed at 3WV in 1988, the frequency response is ±0.5 dB over the band 30 Hz to 10 kHz, harmonic distortion is better than 2% at 95% modulation, and signal-to-noise ratio is better than 60 dB (unweighted) at 100% modulation.

Two major advantages with the application of negative feedback were that it eliminated the need for direct current generator and commutator ripple filter equipment for the filament of the high power stages and it enabled transmitter efficiency to be increased by obtaining greater output from the main valves.

The generating equipment was expensive to install and operate and in most cases was provided in duplicate. The use of alternating current to heat filaments was a major breakthrough in reducing station maintenance and operating costs.

Harmonic distortion was caused mainly by non-linearity of the final amplifying stage. The input-output characteristics of the valves were not linear up to the limits of their power output and Engineers had to incorporate sufficient valve capacity in the final stage to keep the distortion within tolerable limits. This resulted in high initial and operating costs. As standards of performance for transmitters were increased, the problem of low distortion for high power stages was difficult to solve. Negative feedback solved the problem by allowing the employment of valves only large enough to carry the modulating peaks.

MODULATION TECHNIQUES

It would appear from a superficial reading of the technical magazines and daily press of the early 1920s, that the layman knew more about transmitter modulation than the Radio Engineers responsible for designing and operating the equipment.

Nearly every issue contained complaints about performance of the local transmitter, and there was no shortage on advice as to how to fix the problem. Everything from poor frequency response, noise, hum, whistles etc, was put down to improper modulation.

One Adelaide listener was moved to put pen to paper and state: 'If the 5CL transmitter was fully modulated, we would have a top rate service. When the station started at the Grosvenor Hotel with its 350 watt transmitter we could hardly hear the signal. We were promised with the 5000 watt transmitter at Brooklyn Park that the signal would be 15 times louder. I am still waiting for the deafening signals. My friends tell me that the trouble is with the modulation. Why don't the Engineers do something to fix such a simple problem?'

Another Adelaide listener writing in a magazine commented that, 'If the transmitter was fully modulated, Berlin would be ringing up to know where the earthquake was in the antipodes'.

The 'South Australian Wireless Weekly' carried an article in which the writer said, 'If all the power was modulated the inhabitants of the North Pole, if any, could listen in comfortably to 5CL every night'.

Articles in the press and local technical magazines by experts had little effect. All their efforts to explain the workings of the modulator in the transmitter chain brought little comfort to listeners who had been led to expect 'deafening signals' from the station. The situation in Adelaide in particular, was made worse following the arrival in the city of an Interstate Engineer who had been asked to look at the transmitter to isolate a problem associated with drop-out of the circuit breaker on high levels of modulation.

When the unsuspecting Engineer arrived at the Adelaide Railway Station he was met by a huge crowd of reporters and disgruntled listeners. The crowd fired questions at the expert and next day a paper ran a story saying that the Engineer had said that, 'The soil in Adelaide was perfect for radio propagation and there was no reason why 5CL should not be easily heard in New York and London'.

It was normal practice at the time, even with overseas stations, to operate the transmitter with a low level of modulation. The reason was, because the Technical staff were often caught off guard by sudden changes in program level from pianissimo to fortissimo in an orchestra or voice coming from the studio. This overloaded the transmitter, sometimes causing the main circuit breaker to drop out. This resulted in the Chief Engineer banning certain records, and for studio control Operators to closely monitor most live broadcasts. Automatic level control amplifiers or limiter devices were not part of the program input facilities in the early 1920s. In fact, few stations had equipment which could allow accurate measurement of modulation depth.

The two most common methods of modulating a broadcast transmitter in the early days of broadcasting were the choke and grid methods. The choke method could be adapted to employ high power choke modulation or low power choke modulation techniques.

The choke method had wide acceptance in Britain, with the majority of USA station designers, and on the Continent, except Germany, where the Telefunken Company favoured the grid modulation technique. The choke method was also favoured by Australian transmitter designers. The choke method frequently called the Heising or constant current method was developed by R A Heising of the USA and described by him in a publication in 1921. In the system, the anode voltage of the oscillator, whose frequency was the carrier, was varied in sympathy with the audio frequencies. Since the oscillation current, and hence aerial current, was proportional to the anode voltage, the current varied with the audio variations. In practice, the oscillator and modulator valves were connected in parallel and the anode current for them both passed through a choke. The choke had such a large inductance that it blocked the passage of speech currents through it.

In high power choke modulation, the control valves dealt with power equal to the power expended in the main oscillation generator. Thus if the oscillation generator dealt with 10 kW, then 10 kW had to be lost at the anodes of the control valves. In the low power choke method, the oscillations were modulated at low power and then magnified by a high frequency magnifier until raised to the required value. This did away with a control system designed to handle high power.

With high power modulation, the anodes of the final high frequency magnifying valves had applied to them a voltage which varied according to the voltage of modulation whereas in low power modulation the anode voltage was constant while the mean high frequency grid voltage was varied according to the impressed modulation.

Extensive studies by transmitter designers indicated that there was no superiority in either method, with regard to overall power efficiency. For example, in the case of a transmitter producing 10 kW into the aerial, the total power consumption for a high power choke modulated transmitter by the high frequency magnifiers, drive, control valves high tension, sub-control valves high tension, valve filaments plus miscellaneous requirements was 41 kW giving a power conversion efficiency of 24.5%. For a low power choke modulated system, total power consumption by final amplifier, first power amplifier, modulation amplifier, modulators, master oscillator, separator, power amplifier filaments and other filaments was 39.1 kW giving a power conversion efficiency of 25.5%.

The lower power modulation technique was widely employed with MF transmitters designed and manufactured by STC for the National Broadcasting Service during the 1930s. This practice was also adopted by the British Broadcasting Corporation for its transmitters. However, American designers at the time, preferred high power choke methods for their installations.

Notwithstanding American preference for the high power modulation system, it was considered by both British and Australian designers that low power modulation produced a better frequency characteristic. The technology of large audio frequency transformers and chokes was not sufficiently advanced, and the possibility of obtaining good quality from Class B audio frequency amplifiers was not fully realised. The Engineers also considered that the low power arrangement had a greater stability and a greater factor of safety, as voltages did not rise above the continuously applied state.

With low power modulation, the modulated carrier was amplified in a chain of linear amplifiers, with the final or power amplifier being connected to the aerial.

With some early transmitter designs, it was standard practice to use oscillator and modulator valves of the same power ratings. This arrangement restricted the depth of modulation because it was not possible for the modulator valve — an amplifier — to draw the same power from the power supply as the oscillator without overloading the anode.

The next development was to use more modulator valves so that the combined anode current times the anode voltage was equal in power to that taken by the oscillator. Even then, 100% modulation of the oscillator was not possible because such a condition would imply that the anode voltage on the modulator would be reduced to zero in some instances. This was impossible without serious distortion. This led designers to operate modulator valves at a higher voltage than the oscillators. The 3AR/7ZL transmitter was typical, with modulators being fed direct from the EHT supply and the oscillator via a bank of carbon filament lamps to reduce the applied voltage.

Further developments led to the employment of a transformer to increase the depth of modulation without increasing distortion. However, the transformer was difficult to design as it had to, not only carry both oscillator and modulator valves currents without saturation point being reached, but it had to handle the wide audio frequency band being broadcast. The cost of producing such a transformer to meet these specifications was very high.

In the 1930s, emphasis was being placed on high fidelity of sound reproduction and other methods of modulation came under scrutiny. Among the techniques studied and tried by designers were grid modulation and series modulation. Grid modulation was not favoured by some designers as it was difficult to adjust so that amplitude distortion remained low over the full frequency band from low to high levels of modulation. However, a design produced by STC which covered an output range from 50 to 2000 watts and installed at a number of National and Commercial stations was reasonably successful. One of the 500 watt models was installed at 5AN in 1937. It employed 4242A valves in the modulator, buffer and modulated amplifier stages and two 4279A types in the final amplifier.

A lot of study was put into the series modulation arrangement. The Marconi Company in Britain had used series modulation in the early 1930s even with high power transmitters. They were able to achieve a distortion factor of less than 4% up to 90% modulation and a frequency response of ±0.5 dB over the range 50 Hz to 10 kHz.

In Australia the technology had been employed much earlier than in England. A 600 watt series modulated transmitter was designed and built by Amalgamated Wireless (A/Asia) Ltd and employed as a temporary transmitter for A Class station 4QG Brisbane pending the installation of an AWA 5000 watt transmitter. The 600 watt transmitter began transmission of programs from 27 July 1925 and remained operational until 22 April 1926 when the main transmitter took over program transmission function. It then became a standby unit until later sold to the owners of Commercial station 4BK Brisbane. It was put into operation in 1930 following some modifications including the provision of more efficient high power valves. The transmitter was subsequently transferred to 4AK Oakey as a standby unit.

Other stations which employed series modulated transmitters included 2SM, 3XY, 2UW, 2GZ and 2CH.

In series modulation, the modulating valve was connected in series with the anode potential supply of one or more of the valves in the high frequency amplifier circuits of the transmitter. The signal to be modulated on to the carrier was impressed on the grid of the modulator and the consequent variation in its anode resistance caused a variation of the anode supply to the modulated amplifier. Provided the modulator valve was operated on the straight portion of its characteristic curve, the resultant modulation was linear and virtually distortionless.

One of the disadvantages of the system was the high voltage requirements. The anode voltage required was the total of the voltages required for each valve operating separately under optimum conditions. When using water cooled valves such as CAT6 and CAM3 for a 4 kW transmitter, the total anode potential requirement was 16 kV.

Suppressor grid modulation was a feature of some Philips transmitter designs of the 1930s. Colville Wireless Equipment Co., manufactured Philips transmitters under licence in Australia with installations including 2BE, 2TM, 3CV, 4AY, 4IP, 2KM and others.

When 2KM Kempsey was commissioned on 20 September 1937 it was fitted with a KVFPH 500/11b model providing 100 watts into a T type aerial. Chief Engineer was W T Grant.

The suppressor grid type of modulation had a number of advantages including:

- Only low audio frequency power was required.
- It provided high linearity of modulation up to about 80%.
- No capacity neutralising circuit was necessary.
- The RF and AF circuits were completely separate and circuitry of one had no effect on the other.

Efficiency of the carrier condition was about 35% since the anode voltage swing was only half the swing at 100% peak modulation.

Post war transmitter designs concentrated on the high level or anode modulation system which remained the main modulation system for over four decades. It is only now being replaced with other systems following the introduction of solid state transmitters.

The anode modulation system was basically a modified form of the Heising system employed with transmitters of the 1920s. It involved the use of a Class C amplifier and a Class B or Class AB modulator. The anode modulated Class C amplifier was a typical Class C amplifier in which the modulating voltage was superimposed upon the DC anode supply voltage. The effective anode voltage therefore consisted of the sum of the DC anode supply voltage and the modulating voltage. This resulted in the production of the desired modulation envelope. The modulator which was a Class B or Class AB power amplifier delivered its output to a load having an impedance equal to the ratio of DC anode voltage to AC anode current of the Class C valve. For complete modulation, the peak value of the modulating voltage had to equal the DC anode voltage.

Faithful reproduction of the program material fed to the audio stage was heavily dependent upon valve linearity characteristics of the high power audio stages. Feedback was incorporated in the system to correct for deficiencies in linearity.

The major components required to produce an anode modulation system — a modulation transformer and a modulation choke — were difficult to design and were bulky and heavy, sometimes causing installation problems. Performance of the system was limited at low modulating frequencies by the iron content of the modulation transformer.

With early high power systems, care had to be exercised to avoid lengthy periods of maximum modulation, particularly during testing periods using tones, in order to prevent damage to the transformer. Because of the size and weight of components, oil filled units were located in a vault or a separate enclosure. However, notwithstanding these problems, a well-designed and adjusted anode modulated Class C amplifier produced a modulation envelope with very little distortion.

A method of modulation employed with NEC transmitter type MBN 7237B installed at 2NX Bolwarra and 2ST Nowra about 1980, was designated the High Efficiency Anode-Screen Modulation System. It had been used with NEC transmitters since the late 1960s. It was basically the same technology as the conventional high level anode modulation system but differed in that modulation was applied not only to the anode but also to the screen. The anode-grid circuit of the PA was provided with a high efficiency circuit tuned to the third harmonic in order to improve the operating efficiency. By making the voltage waveform of the anode nearly square, the anode efficiency was raised, theoretically close to 90%. The designers of the transmitter claimed that advantages in employing anode modulation and screen modulation in combination, ensured that should one of the types of modulation deteriorate, the other type of modulation would operate to compensate for, or reduce the deterioration, thereby lessening the overall characteristic deterioration. Another advantage was that for a good design, negative feedback was not essential for obtaining good performance.

Low power Gates transmitters employing pulse duration modulation (PDM) technique were installed at some stations including 2CP Cooma in 1966 and 6BE Broome in 1967. Dual 50 watt transmitters were employed at each station.

In PDM, a power amplifier and modulator were connected in series to the transmitter power supply unit and the conduction of the modulator valve was controlled by the modulating signal so as to apply modulation to the PA. Although somewhat like the principle of series modulation technique, it differed in that a pulse amplifier was used instead of the conventional modulator. The modulating signal was first converted to a pulse signal of about 75 kHz by a driver. This was amplified to the required level in the modulator stage and passed through a filter to restore the original sinusoidal signal waveform. A damper valve was used for feeding the energy of undesired waves and reflected waves caused by the filter, back to the power supply.

Although some overseas manufacturers built high power units employing PDM, the technique was phased out with low power models due to a number of operational problems.

Harris 100 kW transmitters employed at Radio Australia stations at Shepparton and Carnarvon used the Pulse Duration Modulation with a Harris patented system.

In this system, the audio input was converted to a pulse duration form with the amplitude of the audio input directly proportional to the pulse duration of 75 kHz pulse train. This PDM signal fed a modulator in series with the PA. This modulation technique was unique in that it provided conventional high level anode modulation of the RF carrier at an efficiency of approximately 90 per cent without the need for an anode modulation transformer and reactors. The modulator section consisted of an audio input stage, redundant PDM generators and amplifiers, modulation driver, an auxiliary driver and the series modulator. Audio frequency feedback was provided to improve modulation linearity, response and noise figure.

In the fully solid state Nautel transmitters, the first of which in Australia was installed at 2WS Sydney in 1983, the RF driver module generated a square wave carrier and the modulator driver module accepted the audio input and generated a pulse width modulated drive signal for the modulators of the power amplifier stage. The modulator module of each power block accepted the pulse width modulated audio signal from the modulator driver and provided a modulated DC supply voltage to the power amplifier module.

A form of modulation employed with RCA transmitters provided at a number of Commercial stations in Australia by John S Innes during the 1970s was designated 'Outphasing Modulation' or 'Ampliphase Modulation'. The system had been developed during the 1930s. Stations equipped with these transmitters included 2BS Bathurst, 2GZ Orange, 2WL Wollongong, 2OO Wollongong, 3BA Ballarat, 3MP Melbourne, 3UL Warragul, 4BU Bundaberg, 4GY Gympie, 7BU Burnie, 7SD Scottsdale, 2BS Bathurst, 3MP Mornington, 2VM Moree and others. In the system, the modulated RF energy to the transmitter load was produced by two Class C power amplifiers working into a single load. The impedance of this load was changed by varying the phase angle of the RF into the power amplifiers in step with the audio intelligence. A simple output network was adjusted to produce a resistive impedance to the PA valves at the carrier output level. Drive to the final amplifier was regulated in accordance with their drive needs which, in turn, depended upon the power they were required to supply to the load at any given instant in the modulation cycle.

The technique provided good linearity and so the transmitter operated with only small amounts of feedback.

An advantage of this system of modulation was that modulating components did not represent large investments in iron and copper as for high level modulation systems. Changes in high power valve characteristics did not radically affect the system linearity and by its very nature, the system was relatively insensitive to reasonable load impedance characteristics.

During 1993–94, two Thomson-CSF TRE2326 250 kW HF transmitters were installed at Radio Australia, Cox Peninsula near Darwin and a distinguishing feature of the design was the method of modulation. The main HT supply to the PA valve was synthesised by connecting in series up to forty-eight separate 700 volt DC power supplies. These power supply modules were controlled by a dedicated microprocessor system through individual fibre optic links.

The incoming audio modulation was digitally sampled and converted into a high speed control strategy to turn 'on' and 'off' Insulated Gate Bipolar Transistor (IGBT) switches in each power supply module. The principal advantage offered by this system was the improvement in overall efficiency of the transmitter when compared with other modulation techniques, with an efficiency of 73% being obtained in practice.

At the time of establishment of the first broadcasting stations in Australia 1923–25, the Experimental or Amateur station operators were just as confused as the professionals in regard to the best method of modulating a transmitter.

The design of Experimental station OA5BS for the Bedford Park Sanatorium illustrates how one group of designers handled the technology at the time.

The Bedford Park Sanatorium, Adelaide was owned by the Repatriation Department as part of medical facilities and institutions for Returned Service Personnel. Through the efforts of Hugh Cooper, £2000 was raised from public contributions to enable the installation of transmitting and receiving facilities as an amenity for the patients.

A contract was let to Newton, McLaren Ltd of Adelaide for design and installation of a top class transmitter. The company manufactured radio receivers even before broadcast stations were on air in the State. Two of the company's most talented Engineers, Ern Gunner and Ted Ashwin were put in charge of the project. The design was unique in that three systems of modulation were provided for telephony transmission and two for telegraphy operation.

The three systems for speech and music were Heising, grid and absorption methods. In the Heising method, a Class C modulated amplifier and a Class A modulator were fed through a common iron core choke made by staff on the premises, of sufficient inductance to offer a high impedance at the lowest modulation frequency, assumed to be 150 Hz, so it was able to pass the DC current but impede the audio frequency current. With the grid method, the modulator was connected in the grid circuit of the modulated amplifier. In the absorption arrangement, modulation was effected by shunting the aerial circuit with a speech controlled absorption valve.

In the telegraphy mode, Morse code was transmitted by either continuous wave or interrupted continuous wave techniques.

All controls and meters were mounted on a large panel well-lit by a reading lamp. To simplify operation of the station, only two switching operations were necessary to put the transmitter to air.

To change modulation methods, special changeover switches were provided. The transmitter was powered by a 250 watt motor/generator set with the motor being powered from the AC mains. The generator provided 500 volts DC for anode circuits and 10 volts DC for valve filaments.

The station operated in the 200 metre band and was officially opened by the Governor of South Australia, Sir Tom Bridges on 21 June 1924, the same month that B Class station 5DN began operation.

Mr W J Davey was responsible for operation of the station. Messrs Gunner and Ashwin were also associated with the installation of the first A Class station 5CL when it began operation on 20 November 1924.

TRANSMITTER COOLING SYSTEMS

Transmitter components such as valves, transformers, inductors, chokes, resistors, capacitors, contactors, relays and others, as well as wiring, all give off heat which has to be removed from the transmitter enclosure to reduce temperature build-up. The greatest amount is produced by valves and for high power valves it has been normal practice for many years to provide an enclosed system for heat extraction purposes. This is easily arranged for water cooled valves, but not so easy for air cooled types. The most widely employed practice where air cooled types are employed is to treat the valves like all other components and cool the whole cabinet internal area by either blowing air into the cubicle or extracting the air in such a way that the air is drawn at high velocity over the valve surface or through the fins.

Very few transmitters built locally by station staff in the 1920s had an integrated cooling system designed into the transmitter to deal with the heat problem. Typical treatment was to place standard fixed or oscillating fans near the transmitter and blow air through the wire mesh into the room.

As transmitter powers increased and the enclosure of transmitter components in sheet steel cubicles or modules became standard practice in the late 1930s, the need for an integrated and properly designed cooling system became apparent.

Factors which the designer had to consider — and indeed still needs to consider in today's design — included the following:

- The rate of air flow.
  This was related to the amount of heat which had to be removed from the cubicle in order to reduce compartment temperature rise.
- The static pressure.
  This was determined by the total system resistance that had to be overcome in order to maintain the required rate of air flow over the components and through air filters.
- Atmospheric contaminants.
  Dust, sand and sometimes corrosive elements in the atmosphere had to be removed to prevent deterioration and breakdown of the transmitting equipment by high voltages.
- Space requirements.
  Large blowers and associated ductwork occupied a large space and this aspect had to be taken into account in the building dimensioning, design and layout.
- Noise and vibration.
  The noise level was an important factor where staff were concerned, and vibration had to be sufficiently small to have negligible affect on the long term performance of the equipment.
- Power consumption of the blower motor.
  This had a bearing on overall transmitter efficiency and operating cost.
- Environmental specifications.
  The blower motor frequently had to operate in a hostile environment. In many installations, because of mounting problems the hot air being extracted from the transmitter passed over the motor unit.
- Mounting methods.
  Space restrictions within cubicles often determined whether mounting would be in a horizontal or vertical position.
- Reliability.
  Long trouble-free continuous service was an important requirement. Cooling equipment reliability had to be matched in reliability to other critical components of the transmitter.
- Utilisation of waste heat.
  In cold climates it was often desirable to put the waste heat to a useful purpose in heating the building. Hot air was sometimes directed into the transmitter hall or staffed areas. Station 5CL/5AN is a typical example. The first 50 kW transmitter was installed in 1961 and provision made to direct heat into the transmitter hall during cold weather.

Most blowers used in transmitter cooling systems included an impeller, a housing to govern the flow of air and a direct or belt driven motor. They were broadly categorised as axial or centrifugal types.

Axial flow types which included propeller fans, tube axial fans, and vane axial fans were distinguished by the fact that pressure was proportional to life produced by the rotating airfoils of the impeller. The vane axial had the highest pressure characteristics and the highest efficiency of these types.

The most widely used centrifugal blowers were forward curved, backward curved and multi-stage types. Generally, they were superior to axial flow types. They developed static pressure through the action of centrifugal force as the air was thrown from the inlet to the impeller periphery. There was little to choose between the forward and backward curved impellers. The multi-stage blower consisted of two or more centrifugal impellers attached to a common shaft. The air was channelled from the outlet of one to the inlet of the other. Centrifugals gave stable performance at low flow rates, had a built-in 90 degree turn from inlet to outlet and they developed the highest pressure.

At one 10 kW station, the blower system was accommodated in a cubicle or rack which could be mounted at the rear of the transmitter, or in a space beneath the floor. Filter mats were provided in the door of the cubicle, with the cooling air being taken from the transmitter hall. Alternatively, the cooling air could have been taken from a chamber or from the outside of the building via an air duct.

With some National service multi-transmitter installations, an automatic air filter was installed in a plenum chamber with all transmitters drawing their cooling air from this chamber. The filter used a large roll of glass fibre bonded to fabric which was supplied on a spool. A second spool drew the fabric off the loaded spool. When the dust had built up to the point where pressure increased to a predetermined level, a pressure differential switch closed the circuit to the take-up spool drive motor causing the roll to move on until equilibrium was restored. Station 3LO/3AR with two 50 kW transmitters used this arrangement.

With the increasing employment of all solid state transmitters in the medium and high power ranges, some equipment configurations returned to rack mounted methods. Although individual solid state components produce less heat than valves of equivalent output, the density of packaging can result in high heat build up unless efficient methods of heat removal are used. Free convection is not suitable for most transmitter applications as heat removal is limited to about 2 W/litre of air within each shelf of equipment.

For a typical rack with five shelves of equipment, axial fans at the base draw room air through a filter and into a duct behind the shelves. Each shelf receives cool air from the duct and exhausts it outside the room. This approach restricts access to the backplane and therefore requires front cabled system modules.

The most popular designs cater for airflow paths through the shelves in a parallel arrangement. Each shelf has a separate entry and exit, so thermal interactions between shelves are minimised. With the parallel feed system it is much easier to distribute the air flow to optimise cooling than for a series flow design. Also, a parallel flow system has a lower overall airflow impedance and hence a higher total flow than a series design using the same design.

In the case of high power high frequency transmitters, the heat dissipated may be considerable. In one Radio Australia 250 kW unit operating at full power, heat dissipated was about 230 kW from the vapour cooling system, 30 kW from transmitter cubicles, 20 kW from vault transformer components, 10 kW from high tension rectifier unit, 2 kW from modulator cubicle and 2 kW from power amplifier cubicle.

Heat dissipated by vapour cooling of valves was removed by a heat exchanger system and heat from the transmitter cubicles and vault components removed by air exhaust and scavenger systems.

SYNCHRONISED TRANSMITTERS

The number of transmitters which can operate in the band allocated for medium frequency broadcasting is limited by interference considerations. With 9 kHz channel spacing which has been in force since 1978, the number of clear channels available is 120. Channel sharing is therefore essential to cater for the number of transmitters now licensed. In 1991, frequency 1584 kHz was shared by eight stations all operating with omnidirectional aerials.

As shared stations are usually located at wide geographic separations, no problems of interference occurs during daylight hours, but after sunset, interference is generally widespread.

Some years ago, many transmitters had to be reduced in output power during night-time broadcasts to minimise interference, but in more recent times, directional aerial systems have helped to minimise the problem.

The first MF directional aerial was commissioned in 1957 by AWA for Commercial station 4BH Brisbane. By early 1991, 17 National, 63 Commercial, 2 SBS and 3 Public broadcasting stations employed directional aerial systems.

Another means of providing for stations to share a common channel is the use of synchronised transmitters. The usual technique adopted is for two or more broadcast transmitters to be modulated with the same program, and for carriers to be synchronised.

Although very little use has been made of the technology in Australia it has been widely used overseas with considerable application in the USA as early as 1931. It was also being used by the BBC in the mid 1930s when two stations were equipped with Elinvar tuning forks to provide long term frequency stability. At the outbreak of the Second World War in 1939, synchronised transmissions involved seven stations. During the War, MF stations were divided into two groups with one group of four being synchronised on one frequency and another group of four synchronised on another frequency. In this way enemy aircraft were prevented from identifying transmitters for radio navigation purposes.

It was not until the 1950s that investigations into the possibility of employing synchronised transmitters in Australia was undertaken. Frank Brownless, a former BBC Engineer working in the PMG's Department Research Laboratories was involved in the work.

About 1950, equipment was installed at 4QN Clevedon preparatory to synchronisation experiments involving 4QS Dalby using the 4QN frequency of 630 kHz. Unfortunately, 4QN equipment was destroyed by fire on 26 May 1951 and the experimental activities delayed until new equipment had been manufactured.

In late 1953, a rack of equipment was installed at 4QS and the station frequency changed. A loop aerial was installed on the building to allow reception of 4QN signals and comparison with the 4QS oscillator. The frequency generating equipment at both stations comprised high stability oscillators using DT cut quartz crystals.

As part of the experiments, field strength surveys were carried out at a number of centres using a specially prepared van. People participating in the survey included West Hatfield of the ABC, Frank Brownless and Doug Sanderson.

Station 4QS reverted to its assigned frequency following completion of the experiments.

With the establishment of 4QO Eidsvold on 29 November 1965, the station operated in a synchronous mode with 4QB Pialba. Delay and equalising equipment was installed to provide for program audio phasing to minimise distortion in equal signal strength reception areas. Station frequency generating equipment comprised glass vacuum ovenless crystals using Sulzer 5A Laboratory Frequency Standards.

The services which were still operational in 1992, were not strictly synchronised but achieved pseudo-synchronisation by employing independent exciter oscillators of high stability better than 1 in 10^7 per day.

The extensive work undertaken in this area by the Department's Research Laboratories is well documented in a number of Departmental Reports.

Another application of synchronised operation with NBS stations was the provision of a synchronised repeater at Bendigo for Melbourne station 3AR. Frank Brownless undertook most of the design work for the project.

From a listener point of view, synchronised operation of transmitters has not been entirely satisfactory for those listeners residing in the 'mush' area because of non linear distortion problems with the received signals.

REDUNDANCY

Prior to the Second World War, a standby transmitter was a luxury that few broadcasters could afford. Reliability of equipment was poor compared with modern standards and an examination of the log shows the difficult problems the Operators had to cope with to keep the transmitter on air.

Maintenance was time consuming, and for a 6 am transmission schedule it was not unusual at some stations, particularly those with water cooled valves, for staff to start work at 4 am in order to perform all the necessary preventative maintenance chores. The NBS Radio Centre at Bald Hills near Brisbane with four 10 kW 4QG, 4QR, VLQ and VLM transmitters without any standby units was one station where staff commenced duty at this hour.

When standby facilities did become available, it was usually in the form of retention of an early model transmitter following installation of a new unit, often at another site. There still are today, a few cases where a transmitter is located on the roof-top of a city building with an emergency aerial to cater for instances of loss of program line or transmitter at a remote site.

When a standby transmitter became an accepted operational facility, it was normal practice to use a main and standby configuration with, in the case of high power transmitters, the standby unit a fraction of the main transmitter power. For example, a 10 kW main transmitter would have a 2 kW standby and a 50 kW main transmitter would have a 10 kW standby unit. Examples are 5CL 50 kW main and 10 kW standby, and 4QL 10 kW main and 2 kW standby. When 4QL first went to air in 1947, it employed two 200 watt transmitters with one operational and the other spare. It was the first National station in Queensland to have a standby transmitter. Earlier stations 4QG, 4QR, 4QS, 4QN, 4AT and VLQ all operated without standby transmitters.

The major advantage with this main/standby arrangement was that it allowed transmission to be restored quickly in the event of failure of the main unit and it also allowed the main transmitter to be taken out of service for maintenance routines at a time that was convenient to the station staff. The disadvantages were that signal strength to the listeners was reduced during operation of the standby unit and two sets of maintenance spare parts had to be held.

Reduction of power and loss of transmission time were not acceptable to programmers and advertisers, so policy changed to the provision of twin transmitters of equal power operating in parallel. Examples of National stations in the 1980s included 6BE with 2 x 50 W, 6AL with 2 x 200 W, 8DR with 2 x 1 kW, 4AT with 2 x 2.5 kW and 4JK with 2 x 5 kW units. Many Commercial operators adopted a similar policy.

The failure of one transmitter did not put the station off air. Transmission continued at about half power until the fault was rectified. As the transmitters were identical, spare parts provisioning was simplified. However, from an installation cost viewpoint, the provision of twin transmitters with a combining unit was greater than the main/standby configuration using high and low power transmitters. Also, it did little to satisfy programmers and advertisers.

With the advent of round-the-clock broadcasting and the need to maintain uninterrupted high signal levels, some broadcasters installed two identical transmitters operating at the authorised power level in a main/standby configuration with fast changeover facilities in the event of failure of the on-air unit. This was an expensive arrangement as it required a high power transmitter to remain idle for most of its service life. Stations operating with this configuration in the mid 1980s included 4QY with dual 2 kW and 5SY with dual 5 kW units.

The availability of solid state transmitter technology with its high order of redundancy has introduced the concept of providing only a single transmitter unit. These transmitters employ duplicated exciters with auto changeover facilities, multiple driver and power amplifier modules as well as multiple power supplies. Low power, power amplifier modules are used in sufficient numbers to make up the required output power. When two or more modules are used, the individual power outputs are hybrid-combined to give the full rated radio frequency output in such a way that failure or removal of any one does not interrupt the performance of the others, except as to total output. This is referred to as 'soft failure' characteristic.

The extent of redundancy in transmitting equipment is linked to the most important requirement of any transmitter, its on-air availability.

Principal variables in determining on-air availability include:

* Mean time between failure (MTBF) — the expected reliability of the transmitter over time.
* Mean time to repair (MTTR) — the average time needed to return the transmitter to full operation.
* Mean preventative maintenance time (MPMT) — the average time required for the operator to perform routine maintenance activities.

With these variables, the on-air availability of the transmitter can be calculated using basic formulae.

The method of calculating the on-air availability, shows that a transmitter with a low MTBF is of little significance if the MPMT is inordinately high. This means that the time required to effect repairs and to carry out routine maintenance significantly affect the transmitter on-air availability figure.

Designs employing solid state technology are able to provide greater on-air availability compared with thermionic valves because the highly redundant modular architecture used, greatly increases the MTBF and at the same time the system architecture enables less off-air time for restoration of service and for routine maintenance.

Important factors which make solid state technology the best available approach in achieving high on-air availability include the following:

- Because solid state devices require low voltage, regulated power supplies can be used ensuring reduction in possible damage due to over voltage, surge etc. Also, there is not the trouble experienced with EHT circuits required for valve equipment.
- A transistor has a very much greater life expectancy than a thermionic valve.
- A solid state transmitter runs cooler than a valve unit of similar RF output.
- Cold start-up for a solid state transmitter is only a few seconds compared with many minutes for a valve model.
- A solid state transmitter requires only a small percentage of the maintenance time required by a valve transmitter.
- Much of the maintenance and repair work with good solid state architecture can be carried out without interrupting transmission.

Although the performance of the transmitter plays a major role in the reliability of the transmission network, there are many other factors which have an impact, some of which are not directly related to the transmitter. These include:

- interruptions to the incoming program caused by problems at the studio or the interconnecting program line or circuit.
- lightning strikes, particularly to the aerial system.
- commercial power supply interruptions.
- shut down of equipment for maintenance purposes, commissioning of new facilities and for safety considerations.

Notwithstanding these factors, broadcasting networks in the main generally provide a service with high reliability. For example, the National network overall reliability defined as total hours transmitted divided by total hours scheduled for 1995–96 was 99.76%. Of the total transmission hours lost, 14% were due to incoming program faults, 28% to commercial power failure, 19% to planned outages and 37% to equipment failures.

TRANSMITTER MEASUREMENTS

Performance measurements on transmitters have been a necessary part of the licensing condition from early days. In addition to regular measurements of specific parameters it was usual practice for comprehensive performance measurements to be carried out, typically on an annual basis, by representatives of the licensing authority. The original licensing authority was the Postmaster General's Department and the inspecting representative was the local Radio Inspector.

For many years, all transmitters were staffed during transmission hours and it was normal practice for the Operator to complete a log to record readings at the metered points of the transmitter. The readings were often undertaken at hourly intervals and for many transmitters, particularly those of 10 kW and above, the log sheet might record up to 50 readings.

In modern times, transmitters are rarely staffed and hourly meter reading exercises are a thing of the past. With some transmitters, very few meters are fitted to the transmitter, the parameters being printed out on demand.

Some of the early stations had very few test instruments for commissioning or day-to-day maintenance purposes. Ted McGrath a member of the 5CK installation team during 1931–32, recalled that there were no oscilloscopes or distortion measuring sets available in those times and during the station commissioning tests, Sid Witt from the PMG's Department Research Laboratories stood on a set of steps with a magnifying glass watching movements of the anode current meter of the low level modulated amplifier stage while tones were applied to the transmitter.

Even as late as 1935, test instruments were scarce at broadcasting stations. Records indicate that at 7ZL Hobart, the only portable instruments held at the transmitter were a Megger and a Post Office No. 4 Detector which was a fairly insensitive meter used to test batteries employed with the transmitter. This was an exceptional case, as many other stations by that late stage of broadcasting had a well-equipped test equipment cupboard containing in some cases, such items as decade resistance box, attenuation boxes, calibrated variable capacitor, calibrated variable inductor, audio frequency meter, wavemeter, impedance bridge, cathode ray oscillograph, modulation monitor, distortion and noise meter, vacuum tube voltmeter, megohm meter, electrostatic voltmeter and a range of high quality components for substitution or comparison purposes.

By the mid 1930s, transmitter manufacturers provided a recommended list of test equipment which should be held at the station, and the suggested methods of carrying out measurements. With the 10 kW STC transmitters installed at 6WA, 3WV and 2CR in the period 1936 to 1937, the parameters to be measured, the instruments to be used and the hookup details were set out in some detail in the handbook.

Briefly, the parameters measured and instruments employed were as follows:

- Anode and Grid Voltages — high resistance voltmeter.
- Audio Input Voltage — metal rectifier type voltmeter.
- Peak Radio Frequency Voltages — electrostatic voltmeter in conjunction with thermionic diode and series capacitor.
- Percentage Modulation — cathode ray oscillograph.
- Frequency Characteristics — cathode ray oscillograph.
- Audio Harmonics — oscillator, filters, attenuator and an amplifier with output voltmeter.
- Carrier Noise — thermionic diode, attenuator and amplifier with output voltmeter.

One of the well-known names in the test equipment field in the 1920–30s was General Radio Co., of USA, usually referred to as 'GR'. The company had been set up in 1915 by Melville Eastman and O Kerro Luscomb who in those early days of radio, even before broadcasting, envisaged a future market for high quality test instruments and specialised components. In 1917, the company had 30 employees and 20 years later, they had increased to several thousand with activities being carried out in a large three-storey building complex. Operations in the manufacture of GR test equipment was undertaken by many specialist groups and sections within the factory. For a typical product, such as a new signal generator design, would include drafting, assembly of experimental model, engineering test of experimental model, forming of main wiring cable, winding attenuator resistances, assembling attenuator housings, winding oscillator inductances, winding power transformer coils, assembling slide wire attenuators, testing slide wire attenuators, wiring slide wire attenuators, assembling modulation coils, wiring amplifier shelf assembly, finishing panels, engraving main panel, forming oscillator shelf ends, inspecting switch contacts, assembling frequency change switches, wiring frequency change switches, assembling oscillator shelves, assembling oscillator tuning capacitors, final oscillator assembly, main assembly, copper lining of cabinet, calibration of completed instrument and packaging equipment ready for despatch.

Although carried out on a smaller scale, test instruments designed and manufactured in Australia by such firms as Amalgamated Wireless (Aust.) Ltd, Slades Radio Pty Ltd, Paton Electrical Pty Ltd and others, followed similar procedures.

One of the Australian distributors of GR test instruments and components in 1920–30s was Newton, McLaren Ltd, Adelaide. They mounted an extensive display of GR products at the Radio and Electrical Exhibition held in Adelaide in December 1925. The high quality components, particularly transformers, faders, volume controls, capacitors, inductors, rheostats, coil formers, dials, knobs, plugs and jacks found a ready market amongst receiver constructors, while test equipment was employed at broadcasting studios and transmitting stations.

Test equipment and major components held by one Sydney Commercial station in the late 1930s included:

- Resistors — decade resistors, resistance units, attenuator boxes, volume controls, rheostat-potentiometers.
- Capacitors — air and mica capacitance standards and general purpose types with air, mica and paper dielectric.
- Frequency and Time Measuring Equipment.
- Oscillators — beat frequency, tuned circuit and electromechanical types.
- Amplifiers.
- Bridges — resistance, capacitance and inductance.
- Signal Generators — receiver testing, field intensity measurement and general purpose use at all radio frequencies.
- Waveform — oscillograph, modulation monitor, noise and distortion meters, wave analysers and wave filters.

The versatility and accuracy of test equipment to measure and check on transmitter performance as well as receivers, has improved considerably over the past 50 odd years. However, costs are very high and a full set of instruments to cover the transmitter, aerial, link and studio equipment form a sizeable proportion of the initial capital and subsequent operating charges.

With the modern tendency of continuous transmitter operation and the requirement to maintain a high level of technical performance, systems are being introduced to carry out regular audits of service performance. This requires new and specialised testing techniques in order to minimise interruptions to program content.

Television Engineers employed Vertical Interval Test Signals (VITS) to establish video system performance without interrupting service but the Radio Broadcasting Engineers wrestled with their problem for many years.

In the early 1960s, trials were conducted with some National stations using automatic program monitors constructed to BBC specifications. However, after a long period of trial, and the introduction of several modifications, the concept did not prove satisfactory and was abandoned in the 1970s.

With advancements in solid state technology, attempts were made to develop another system in the 1970s. AWA in Sydney produced a short interval audio tester (SIAT) which formed the basis of a range of SIAT systems available throughout the world. The principle of the SIAT system was to limit the listener annoyance factor by sending a short burst of tone information and then analysing the result with equipment at the output of the transmitter. Equipment introduced into the National service during 1990, performed a wide range of tests on both mono and stereo systems including frequency response, harmonic distortion, intermodulation distortion, cross talk, phase/level difference between stereo channels, weighted and unweighted noise and channel transposition.

The test results were presented in the form of an instant hard copy printout of all results, an LCD display of individual test results, via a data line to a remote point or in conjunction with a computer to be stored and displayed as and when required.

In early 1995, the National Transmission Agency which had responsibility for Government funded transmission services for broadcast of programs provided by ABC, SBS and the Parliamentary Broadcasting Network, awarded a contract to Fujitsu Australia for development and provision of a new computerised fully automatic monitoring and remote control system for the transmission network throughout Australia.

The system was designated Transmission Operating and Supervisory System (TOSS) with the monitoring and control base being located at Belconnen in the Australian Capital Territory and staffed on a 24 hour basis.

The Agency considered that the system in use as at 1995 did not provide adequate information for analysis of faults, network performance and maintenance contractor performance. The new system not only informed the NTA and its maintenance contractors of any change of equipment status but allowed Controllers to interrogate equipment and remotely control some of the key functions.

For many years, the Minister for Communications was responsible for administration of the Broadcasting Act and for determining technical standards and practices for Australian broadcasting services.

Departmental publications dealt with technical performance standards for radio broadcasting stations including associated transmitting, studio and program link facilities. These publications set out procedures for establishing and maintaining equipment in accordance with the technical conditions relating to the station, specified the minimum technical performance of the equipment together with the applicable methods of measurement and set out procedures for the installation or alteration to equipment.

The standards were based on fundamental technical standards which defined the MF and VHF broadcasting systems.

Transmitter manufacturers continue to provide a Recommended Test Equipment Schedule in their handbooks as a guide for proper maintenance of the equipment. Recommendations for the RCA BTF-10E1 FM transmitter installed at some Commercial stations during the early 1980s is typical with the list comprising PA Dummy Load and Truline Wattmeter, Exciter Dummy Load and Wattmeter 0–15/60 watts, Audio Frequency Generator, Noise and Distortion Meter, Oscilloscope, Senior Volt-Ohmist VTVM, Volt-Ohm Milliammeter, Grid Dip Meter, Step Attenuator 1 dB and 10 dB steps, and a specified list of coaxial components required for PA neutralising.

Additions to the Radio Australia service in mid 1994, included two 250 kW Thomson-CSF TRE 2326 transmitters installed at the Radio Australia, Cox Peninsula station. The following outlines the principal acceptance tests undertaken with modern high power high frequency broadcasting transmitters:

Tests on HF broadcast transmitters used for International broadcasting are in many ways unique because of the operational requirements of the transmitters and their limited production numbers. The transmitters are required to be frequency agile with short tuning cycle times, they operate at very high power and use modulation techniques to minimise power consumption while maximising recovered audio in the receiver.

* POWER OUTPUT MEASUREMENT

Conventional in-line wattmeters are generally not used in testing high power HF transmitters. Typically, the output power is confirmed at the dummy load by calculating the rate of heat transfer.

High power dummy loads consist of a load resistance made from metal tubes in a conductive liquid of water mixed with soda ash. The liquid temperature is controlled in order to provide a constant load impedance and excess heat is dissipated through a heat exchanger into a separate cooling water path connected to a cooling tower. By measuring the temperature differential across the heat exchanger and the rate of cooling water flow, the rate of heat transfer in kilowatts can be calculated.

Transmitter power conversion efficiency is normally determined at factory testing where the dummy load heat exchanger instrumentation is calibrated by applying power to the RF terminals and the input power is measured using precision AC mains power wattmeters. On site, the output power is measured using the calorimetric method without calibration and the accuracy of the transmitter output power indicators is established at a couple of frequencies usually, the highest and lowest used by the transmitter. Subsequently, output power is read only on the transmitter instruments.

Tests indicated that the Thomson-CSF transmitters delivered in excess of 250 kW on all International broadcast band frequencies in the range 5.95 to 26.1 MHz.

* EFFICIENCY

Considerable emphasis is placed on the overall efficiency of high power transmitters because the cost of electricity is by far the most significant operating cost. In Darwin the cost of electricity for a conventional 250 kW transmitter operating 24 hours a day would be about $750000 per year. In selecting transmitters, a key factor in the final decision is operating cost.

Efficiency is determined by comparing the output power into the dummy load against the input power to the complete transmitter, including all auxiliary loads such as cooling fans, pumps, heat exchangers and power transformers. Definitive tests are normally conducted at the factory where the dummy load has been calibrated, and precision mains power metering is available. On-site tests are normally used only to confirm the factory test results as their accuracy cannot be assured.

The overall efficiency of the Thomson-CSF TRE2326 transmitter was measured at better than 75 % and this represented a potential saving in operating costs in the order of $250000 per year over conventional Class B anode modulated transmitters of the same output power.

Power consumption can also be reduced by using dynamic carrier controlled modulation techniques and reduced carrier SSB.

* TUNING TIME

In International short wave broadcasting, the operating frequency needs to be changed regularly to take into account diurnal variations in ionospheric characteristics and changes in target areas. In order to minimise disruption to programs, the time taken to change frequency needs to be limited. Typically, a maximum time in the order of one or two minutes is allowed in programming for frequency changes.

Limits of 10 seconds for frequency changes within the same short wave broadcasting band, and 45 seconds between bands is normally specified.

Testing of change times between frequencies and bands in both upward and downward directions is undertaken as part of the acceptance testing program. Worst case tests between maximum and minimum operating frequencies are normally used.

Generally, this tuning is between frequencies at which the transmitter has been pre-tuned and servo positions memorised. Often tuning to non-memorised frequencies is required and tune times are generally longer as automatic matching is required.

* HEAT RUN

In order to test the long term capability of the transmitter to produce its rated output power, a heat run test at extreme levels of average modulation is normally conducted. The test is typically for 24 hours and would consist of 12, two hour periods. During the first period the transmitter is run for 50 minutes at rated output power and modulated at 60 % with tone, then for the next 10 minutes, the modulation is increased to 100 %. During the second one hour period, the transmitter is run at rated output power with processed audio peaking at 100 % modulation. This is equivalent to about 30 % average modulation.

This test is in fact more strenuous than normal operation and is intended to heat stress the transmitter components in an attempt to ensure by a short duration test, that the transmitter can perform adequately in the longer term under normal operating conditions.

* PERFORMANCE TESTS

Other performance tests include audio frequency and amplitude response, total harmonic distortion, intermodulation and spectral purity and carrier harmonics. These are generally similar to tests carried out on other transmitters.

* COMPUTER CONTROL TESTS

Most major HF transmitters are now normally capable of remote computer control and monitoring, and this function needs to be tested by fully exercising all controls remotely.

* SAFETY

Inspection of safety features to ensure compliance with operational safety standards such as IEC 215 are required.

Similarly, testing of overload and over-temperature protection devices is required as part of the site acceptance testing procedure. Graham Baker was on-site Telecom Broadcasting Project Engineer oversighting the tests, assisted by the local Technical staff, and Thomson-CSF staff Marc Moreau and Guy Pellett.

CONSTRUCTION PRACTICES

Transmitter construction practices have changed considerably over the years. They may be grouped into the following types:

* **OPEN CHASSIS**
  Many of the early B Class or Commercial stations went on air using equipment previously used by Amateur operators. Although the construction varied widely, the open chassis type was typical, even as late as 1932.
  The original 1924 5DN Adelaide transmitter was previously Amateur transmitter VK5BQ and comprised a number of open chassis units with bakelite front panels on which meters, switches, rheostats, tuning controls etc, were mounted. It employed two valves in the oscillator circuit and two in the modulator.
  Power was supplied by a transformer for filaments and a motor generator for high tension DC.
  When 5PI Port Pirie commenced operation in 1932, it used the transmitter of Amateur station VK5WH. It had an input to the final stage with a Philips valve of 20 watts. It too, employed an open chassis type of construction.
  The 3UZ Melbourne transmitter using two 5 watt oscillator valves and two similar modulators was constructed on an open chassis with a vertical bakelite panel when it began operation in 1925.
* **RACK CONSTRUCTION**
  Typical of this practice was the original 5CL Adelaide transmitter which began service in 1924. Two racks were employed made of angle iron and bakelite front panels. One rack contained the transmitter, and the other the speech input amplifier. Two Marconi 250 watt valves together with meters and switches were mounted on the front of the transmitter rack with the main tank circuit being fixed to the top. The high tension generator and filament batteries were mounted on the floor behind the rack.
* **OPEN BOX FRAME CONSTRUCTION**
  This method was popular with Commercial transmitters constructed in the early 1930s. Stations 5AD Adelaide and 3WR Wangaratta are examples.
  In the case of the 5AD installation of 560 watt input, there were three box frame units housing separately the power supply unit, the oscillator/modulator unit and the power amplifier. Meters and controls were mounted on a bakelite panel on the front of the unit and a removal of the heat was assisted by external oscillating fans. The sides of the box frames were not covered or screened.
  The 3WR transmitter of 50 watts, had all equipment mounted on four shelves in the box frame with the main tuning coils being located on top.
* **SCREENED BOX FRAMES AND FRONT PANELS**
  This technique was adopted by AWA when it produced its 500 watt transmitters in the mid 1920s. One of the first transmitters to go to air was installed as a temporary service at 4QG Brisbane pending the installation of its licensed 5000 AWA transmitter. The 500 watt transmitter which began operation at 8 pm on 27 July 1925 was installed by AWA Engineer Syd Newman. It comprised three separate units comprising a rectifying unit, an oscillator unit and a modulating unit. Construction of the frame and enclosure employed steel angle frame covered by steel lattice mesh panels. Control and meter panels were of bakelite and glass. The arrangement provided good safety for operating staff and also minimised interaction between stages.
  In some locally constructed designs at other stations, brass or copper were also employed as well as steel for the mesh material.
  Other transmitters which employed this method of construction included the AWA 50 watt 3BA transmitter in 1930, the 1000 watt Telefunken 2CH transmitter in 1932 and the 250 watt transmitter at 7UV which employed four screened box frames.
  As the power output increased, designers had to take account of mounting methods for the larger components and heavier chokes and transformers.
  Whereas lightweight transmitter units were often mounted on removable trays or arranged as units mounted in the channel steel frame, this was not suitable for larger components which required strong rigid welded or bolted metal frames provided with access doors to the sides and rear for maintenance purposes.
  The preferred construction of the larger transmitters was welded steel as it gave greater rigidity and could accommodate the stresses during transport from the manufacturer to site. Welding also ensured good conductivity, an important factor with high voltage RF stages.
* **CAGE CONSTRUCTION**
  Many of the larger components such as high tension transformers, power filter capacitors, tuning coils etc., had to be mounted external to a cubicle requiring that the whole of the transmitter be protected by a suitable cage or enclosure with gate access being tied in to the transmitter control circuitry. Usually, the enclosure was fronted by slate or bakelite panels on which the meters and controls were accommodated, followed later by sheet steel panels.
  With the 4QG, 2FC, 3LO, 5CL and 6WF 5000 watt installations of 1923-25, the transmitter was made up of a number of separate units with each unit being protected by special steel panels which were guarded on all sides by perforated metal doors which gave access to the high tension circuits. The doors were associated with switches which turned off the high tension in the event of the doors being opened.
  By the late 1930s with 10 kW transmitters installed at 6WA, 3WV and 2CR, the transmitter consisted of two separate units both of which were constructed of a metal framework faced with polished slate panels, the two units lining up to present a continuous facing of panels. The first unit, the oscillator-modulator, had each of the individual items enclosed in dustproof duralumin boxes. This provided complete electrical shielding between the various stages. The boxes were supported on runners allowing easy withdrawal from the main rack framework for maintenance purposes. Meters associated with each stage were mounted on the front of its shielding box and could be viewed through windows in the front panel. Control spindles were extended through the panel. The second unit housed the final linear power amplifier and was of the same dimensions as the oscillator-modulator unit. The entire unit was completely shielded with duralumin.
* **STANDARDISED CABINETS**
  During the late 1940s, AWA introduced a form of standardisation in cabinet designs for a range of transmitters it produced to cover the range of output powers 200 watts to 60 kW.
  The approach adopted, was to design a structure which could be assembled from a number of standard parts. The basic components of the structure were the base plate, vertical members and top members.
  The base plate consisted of a standard rectangular frame of welded channel iron. One unit formed the base of a 2 kW transmitter, two units were assembled for a 10 kW transmitter and eight units for a 60 kW transmitter. For smaller sizes the dimensions varied but the construction was the same. The vertical member was a rectangular frame of welded iron complete with gusset plates at top and bottom. One vertical member was required for each end of the cabinet and one for each subdivision.
  The cabinet was completed with a sheet metal cover panel at back, ends and top. The cabinet front was a welded assembly built up from a number of folded sections and fitted with access doors and control panel doors. Meters and safety switches were the only equipment mounted on the front assembly.
  Inside the cabinet, vertical components were mounted inside the vertical framework members. Large items such as

transformers and blowers were mounted on the floor of the cabinet.

The advantage of the technique was that transmitters of all powers could be built as sub-assemblies, with final assembly being straightforward. Units could be readily dismantled for shipment.

* **OUTDOOR POWER EQUIPMENT**

  In the 1960s, manufacturers of high power transmitters introduced the concept of mounting large components, such as high tension supply transformer, filter inductor, high tension supply starting resistor, modulation transformer and inductor, and exhaust fan, out of doors. The STC 50 kW MF transmitter installed at many National stations and the Collins 250 kW HF transmitters at Radio Australia, Cox Peninsula, Darwin are examples.

* **LAYOUT**

  In the STC 50 kW transmitter, the transmitter cabinet was divided at the front into three units, the rectifier unit, the modulation unit and the RF unit. At the back of these units a passage was provided down the middle of the transmitter with an access door at the left hand end of the front panel.

  Against the rear wall of the enclosure opposite the access floor was a framework which mounted the HT filter capacitors and some other equipment.

  The main primary and secondary tank tuning capacitors and inductors were at the back and the RF harmonic filters were on the right side of the transmitter.

  The valves in the modulator and RF units were mounted on a shelf, beneath which ran a duct system.

  The 250 kW Collins short wave transmitter comprised an RF unit, an AF unit and a high voltage power unit. The RF and AF units were fully enclosed without metering. All control and monitoring functions were carried by computer control equipment. Although the high voltage power unit was suitable for mounting outside, it was housed undercover at the station.

* **SOLID STATE EQUIPMENT**

  Modern solid state transmitting equipment is so compact and efficient that equipment is fully enclosed, requiring only a fraction of the volume and floor space required of valve transmitters of equivalent power. Equipment is fully enclosed with sheet metal fixed to an iron frame.

* **UNPACKING AND HANDLING**

  Many transmitters are installed at sites a long distance from the point of manufacture and consequently a great deal of assembly and installation time is taken up in unpacking the various items and assembling or mounting them to form the complete transmitter.

  Packaging methods employed for a particular item depends upon its size, weight, dimensions, site location and any customer special requirements. They usually vary from double wall cardboard cartons and wooden crates to skid mounts with plastic protective covers, and sometimes packed in shipping containers.

  Frequently a fork lift or other suitable mechanical aid may be required to handle bulky and/or heavy items. When the Collins 821A 250 kW transmitters were installed at Radio Australia, Cox Peninsula near Darwin in the 1960s the RF unit alone measured 6.5 m x 3.2 m x 3.0 m in its shipping container and weighed 6400 kg. One oil filled transformer weighed 8400 kg. The transmitters comprised 210 crates with an aggregate weight exceeding 170 tonnes.

  Unpacking material delivered in double wall cartons or wooden crates is straightforward. However, for van packed items such as cabinets and other large items each unit had to be moved close to its ultimate designated position before removing strapping, protective covers and transport supports before clearing the item from the skid.

Maintenance requirements had considerable influence on construction practices over the years. Component failure rate was high, particularly with valves, resistors and contactors and it was important to ensure good access to all components not only for replacement purposes but also for test purposes during fault tracing operations. In recent times, mean time between failure of components has greatly improved but nevertheless good access must still be provided.

The mounting of components on roll-out shelves in the late 1930s was a major step forward in assisting maintenance staff, and with modern solid state equipment the practice has been taken a step further with plug-in modules which allow a faulty or suspected module to be withdrawn and taken to the workshop where test jigs and other facilities are available for rapid testing and fault location.

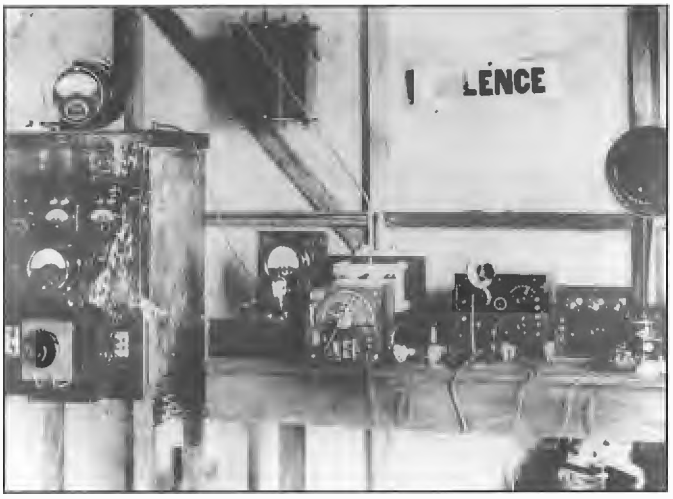
Initially, testing solid state transmitters involved the setting up of a test facility requiring connection of power supplies, switches, LED indicators and other test equipment. More recently manufacturers have developed a range of test jigs which include units for the modulator driver, the modulator module, the monitor module, the rectifier/regulator module, the RF driver module and the low voltage power supply module. Designers are working on other jigs to expand the range available to the transmitter Operator. In most cases, using the test jig only requires the connection of external power supplies and test equipment.

Today, broadcasting construction and installation practices are closely controlled by the implementation of Total Quality Management (TQM) principles. Major broadcasters having facilities provided under contract now call for a Quality Assurance Plan to be submitted in accordance with specific Australian Standards which cover Australian Standard Quality practices. In this way, the customer can be assured of minimum installation costs and a high standard of installation.

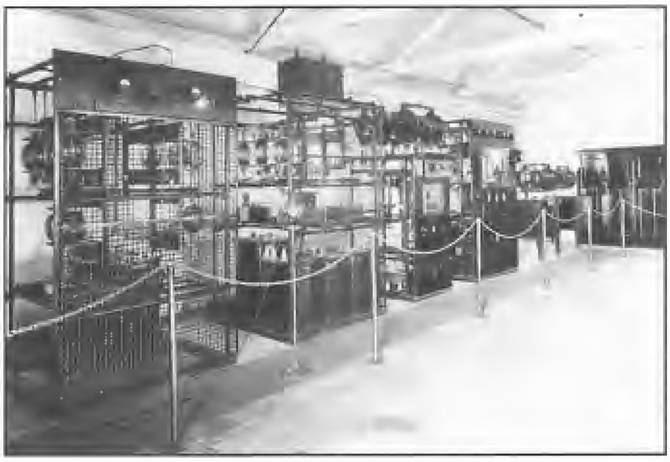
The National Transmission Agency which was responsible for Government funded ABC and SBS transmitting facilities announced in late 1995 that it was planning to introduce an upgraded Information Technology system to enable more efficient management of its Capital Works Program which for 1995–96 had a budgeted value of $55 million.

The new system was intended to improve the overall planning and co-ordination of all stages of the Works Program by pulling together in one computer system all the work plans from the Agency's seven business units. The system was based on a high capacity management package with customised extensions to meet the remainder of the NTA's information management and reporting requirements for the Capital Works Program.

First broadcast transmitter to be commissioned in Australia. The 500 watt 2SB (later 2BL) transmitter constructed by local technical experts for Broadcasters (Sydney) Ltd began full-scale program transmission at 8 pm on 23 November 1923 from the roof top of The Daily Guardian Building, Phillip Street, Sydney. Ray Allsop (left) was Technical Consultant to the company, becoming Chief Engineer in June 1925.

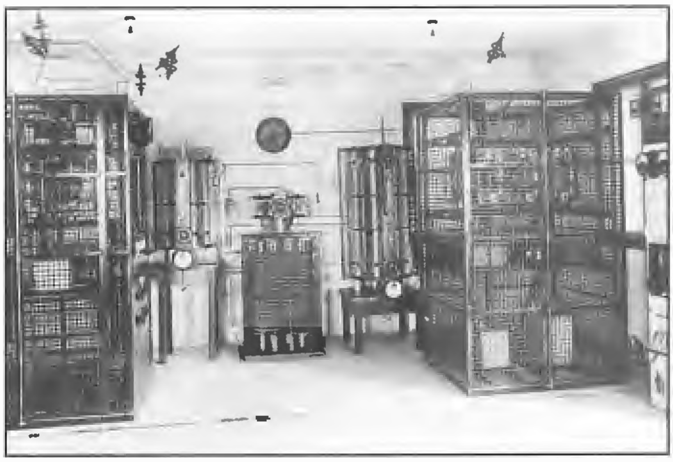


Experimental 10 watt transmitter 2HP owned by William Maclardy, Managing Director, Broadcasters (Sydney) Ltd and installed by Ray Allsop. It was used for test purposes on 350 metres during October 1923 prior to commissioning of 500 watt 2SB (later 2BL) transmitter.

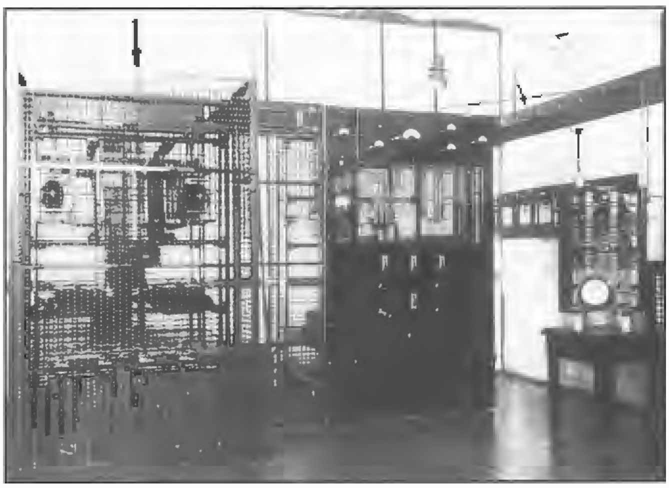


One of the 5000 watt transmitters designed and manufactured by AWA for A Class stations 2FC, 3LO, 5CL and 6WF commissioned during the period 1923 to 1925. Stations 2FC, 3LO and 6WF operated on long wavelengths while the others operated on medium wavelengths. The installation comprised six main units and the transmitter required a power supply of 15 kW. Senior AWA Engineers associated with design and manufacture included Joe Reed and Chief Engineer Arthur McDonald.

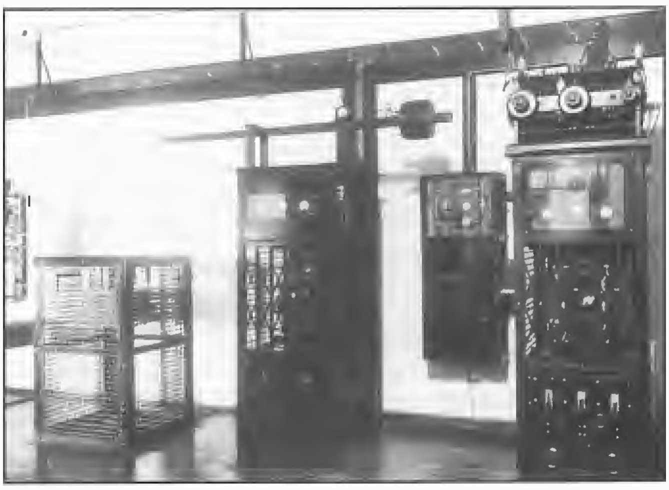
In accordance with CCIR Recommendations of 1929 changing the method of determining transmitter power, these transmitters were rated at 3500 watts.



Part of an AWA 5000 watt transmitter installation at one station illustrating the method of interconnecting HT leads between units. Conductors were suspended from the ceiling with strain type porcelain insulators fitted with corona rings. Units (L to R) Magnifying unit, tuning inductors and capacitor, and HT rectifying unit. The wall lead-through insulators for aerial and counterpoise feeds are in the centre. The counterpoise feed point is partially obscured by components. AWA Construction Engineer D Campbell.

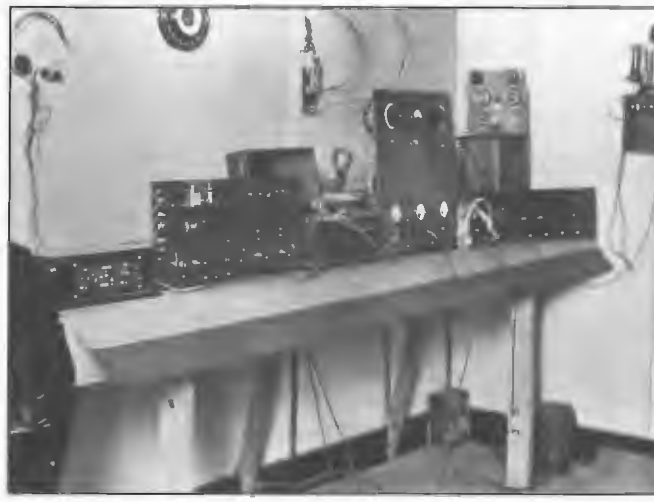


The rectifying panel (L) and magnifying panel of 6WF Perth AWA 5000 watt transmitter commissioned on 4 June 1924. The rectifier employed six MR6 type valves to provide 10 kV DC. Chief Engineer and Manager Walter Coxon.



Other sections of the 6WF transmitter. The total installation comprised three phase HT supply, power amplifier and modulator, submodulator and line amplifier, master oscillator, closed circuit inductor and capacitor and the aerial circuit inductor.

The original A Class station 5CL Adelaide commissioned on 20 November 1924 for Central Broadcasters Ltd on the roof of the Grosvenor Hotel. Input to the final stage was 175 watts. Don Gooding was in charge of operations.



Original 5DN Adelaide transmitter 1924. The transmitter was previously used with an experimental station operated by Lance Jones. The speech input equipment included microphones purchased direct from Western Electric Co. in USA by the station owner Mr E J Hume. Initially, input to the final stage was 35 watts.

The 3AR Melbourne station was established by Associated Radio Company on 26 January 1924 as an A Class station. The original transmitter operated from a site in the city but later a new site was established at Essendon with a transmitter using silica envelope valve in the high power stage and an input to the stage of 1600 watts. The transmitter was later relocated to 7ZL Hobart. The photo shows the master oscillator, power amplifier and aerial tuning unit. Construction Engineer Donald Macdonald.

Original AWA 5 kW transmitter installed at 5CL Adelaide 1925. The transmitter was modified by Chief Engineer Harry Kauper in 1927 and equipped with WE4220B water cooled valves to replace the air cooled types in the high power stage. The transmitter was replaced in 1936.

Original installation under control of Donald Macdonald Consulting Engineer, Associated Radio Company of Australia Ltd.

(a) Final stage.

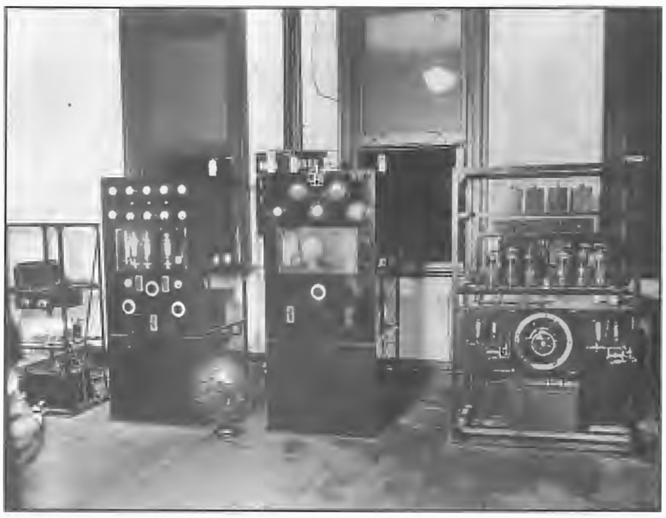
(b) Rectifier unit.

AWA 600 watt transmitter originally installed 4QG Brisbane 1925 pending commissioning of 5000 watt unit. It comprised three units. Main Rectifier and Power Control Unit Type H3402 Serial No 1, Modulator Control Unit Type J3101 Serial No 1, Series Modulated RF Unit Type J3100 Serial No 1. It was upgraded in 1930 and installed at 4BK Brisbane. Later transferred to 4AK Oakey as standby unit. In 1994, housed in Oakey Museum.

Erection of the 7ZL Hobart transmitter building and installation of earth mat at a site known as Radio Hill, December 1926. On 3 March 1926, the station was taken over by Tasmanian Broadcasting Pty Ltd from Associated Radio Company of Melbourne who held the original licence. Station Construction Engineer Donald Macdonald.

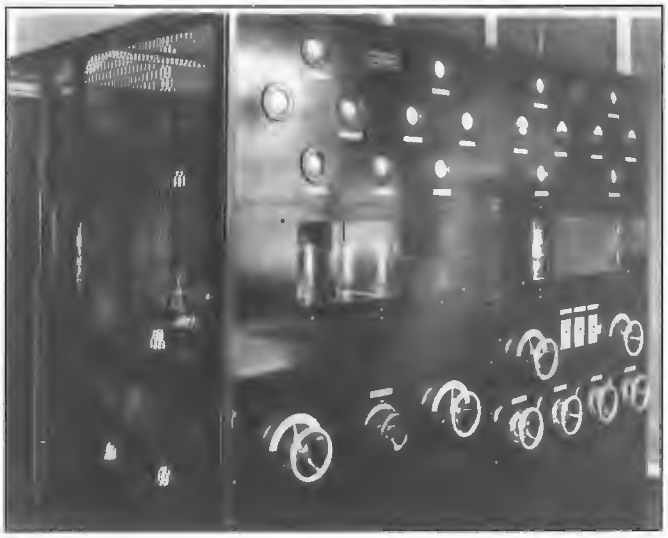
AWA 5 kW transmitter commissioned for 4QG Brisbane in Queensland State Insurance Building 22 April 1926. It was similar to AWA transmitters installed for A Class stations in other States at the time. Chief Engineer-in-Charge of operations was Fred Stevens.

Broadcasting station 3EX designed and built by Amalgamated Wireless (A/Asia) Ltd and on display at the 'Made in Australia' Exhibition, Melbourne 1929. The exhibit was a complete station and was activated each evening to produce and transmit special programs of entertainment. Visitors could see the plant, operators and artists through large glass panels. Transmissions were conducted on 240 metres. The design formed the basis of transmitters being planned for commercial broadcasting during the following year, 1930, during which 12 Commercial stations were commissioned.



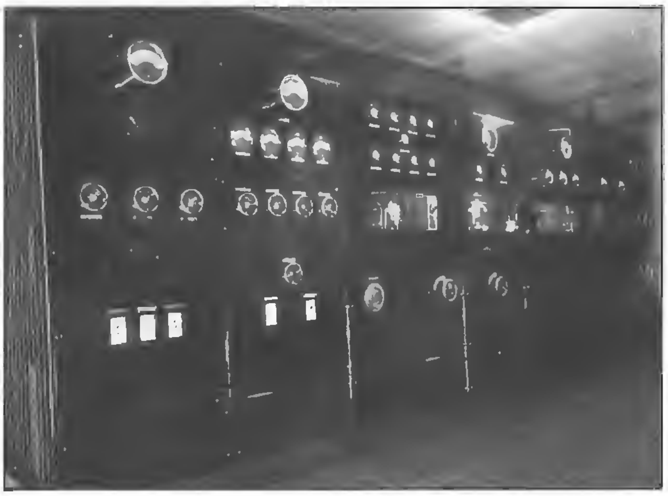
Original 5AD Adelaide transmitter constructed by station staff under Harry Kauper and put to air in 1930. Originally, the final stage employed two air cooled valves in parallel to provide 300 watts to the aerial but were replaced by an STC 4228 water cooled type. Further changes took place over the years until it was replaced by an STC 2.5 kW model in 1954 at Cavan.

Original 50 watt 3BA Ballarat transmitter commissioned 31 July 1930. The station was established by two local radio experimenters Warne Wilson and Alfred Kerr. The locally constructed transmitter was contained in two cubicles and produced 50 watts of carrier power. The power amplifier valve was a Philips QB2/75 type.

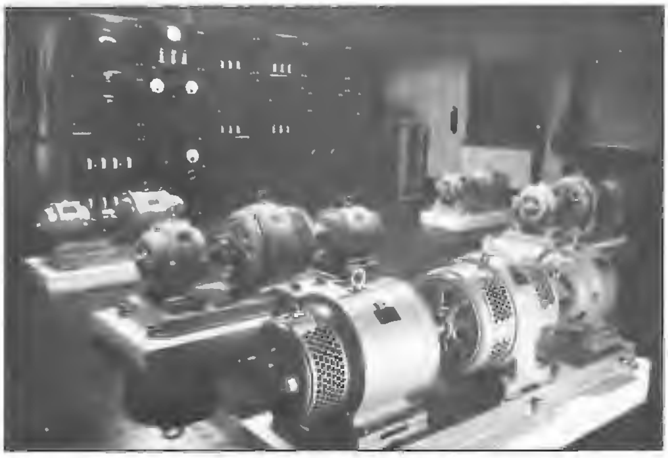


STC 2 kW transmitter commissioned at 2NC Newcastle on 19 December 1930. A similar model was commissioned at 4RK Rockhampton on 29 July 1931. Harry Weir was in charge of the 2NC installation. They were the first two Regional NBS stations installed in Australia. Final stage used a pair of 4228A water cooled triodes. First Officer-in-Charge at 2NC was Bill Robinson.

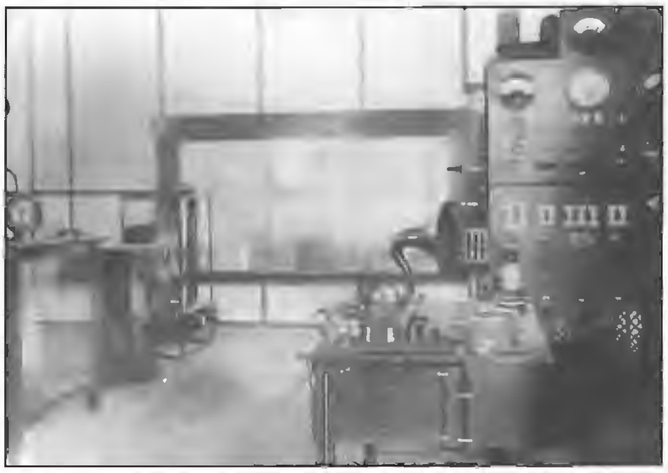
The 4RK Rockhampton machine room 1931. Power requirements for the 2 kW transmitter were provided by duplicated motor generator sets. High tension supplies were generated by two double wound generators driven by a common motor. The filament and bias supplies were provided by separate units. The machine room also contained the water cooling pumps. Station 2NC Newcastle had a similar installation.



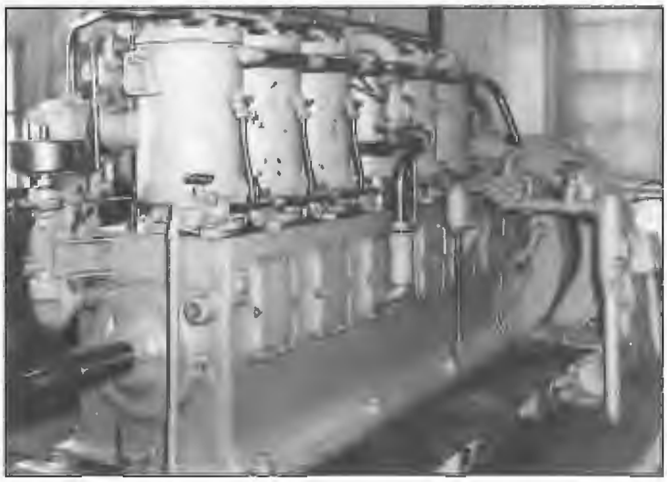
5CK Crystal Brook 6.75 kW STC transmitter commissioned 15 March 1932. An identical unit was installed at 2CO Corowa. Installation engineers were Frank O'Grady and Laurie Billan. The transmitter remained in service for 20 years.



Motor generating plant 5CK Crystal Brook 1932. Generators provided 18 volts at 155 amps and 26 volts at 100 amps for filaments; 750, 1500 and 4000 volts HT and 300 volt bias voltage.

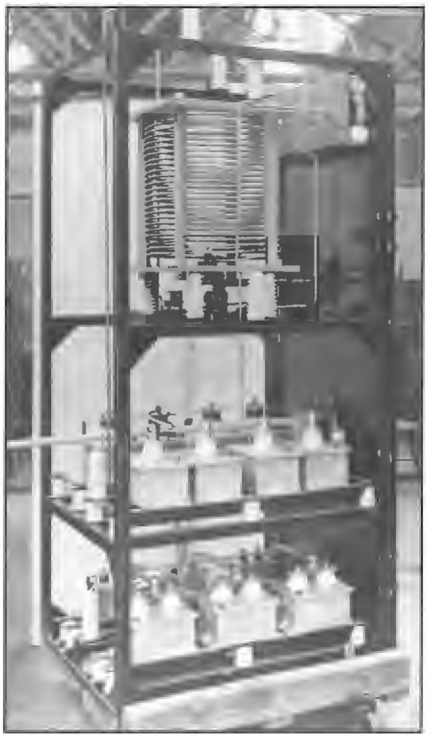


The power board, monitoring equipment and part of the transmitter (L) in the 7ZL transmitter building Hobart 1931. Machinery and power equipment are visible beyond the large window. The transmitter had been earlier installed at 3AR Melbourne in the 1920's. It was replaced in 1939.

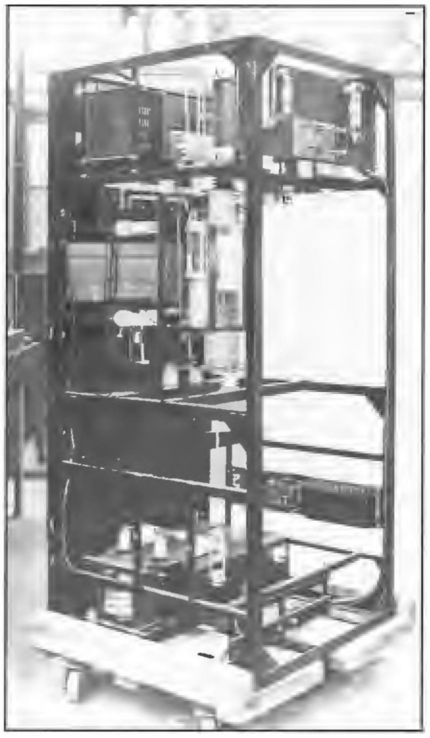


Emergency power plant 5CK Crystal Brook 1932. The unit was a 120 HP Gardner petrol engine direct coupled to an 80 kW 415 volt three phase alternator. Cooling water was contained in twelve galvanised iron tanks mounted outside the building.

Power amplifier unit 2CO Corowa and 5CK Crystal Brook at the installation stage 1931/32. The unit contained two WE4220B water cooled valves, hose coils, water flow and water temperature alarms plus anode and grid meters on the front panel.



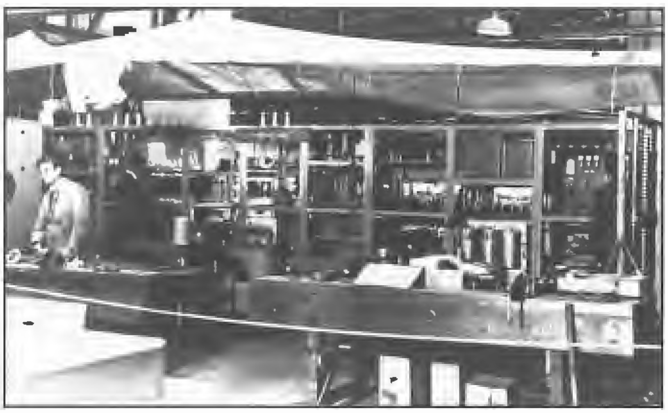
Aerial tuning unit 2CO Corowa and 5CK Crystal Brook at installation stage 1931/32. The unit contained aerial coupling capacitors on the two lower shelves and the aerial tuning coil on the top shelf. Tuning controls and RF meters were located on the front panel.



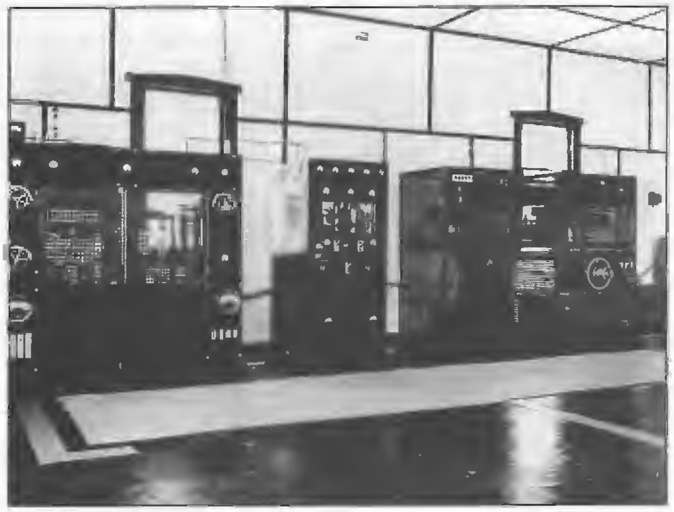
RF amplifier unit 2CO Corowa and 5CK Crystal Brook during installation stage 1931/32. The amplifier consisted of two 4015A 1 kW air cooled valves in parallel working with an anode voltage of 4 kV as a linear Class B amplifier.

Station 3YB, Australia's first successful mobile broadcasting station. Service commenced 13 October 1931 with equipment housed in two motor vehicles with Bert Aldridge as Chief Engineer. On 17 October 1932, facilities were transferred to the luxuriously appointed Melville carriage of the Victorian Railways. The mobile service ceased on 15 November 1935 and the station became a fixed service.

(a) The 6WF Perth NBS transmitter after commissioning on 14 December 1932. Tests showed it produced an unmodulated carrier power into the aerial of 3.6 kW giving an overall efficiency of 15%. This was the first time the PMG's Department had undertaken the entire design, construction and installation of an MF broadcasting station.



(b) The transmitter being assembled in Melbourne prior to testing and shipping to Perth. Foreman Mechanic Stan Hosken is at the bench. Project leader was Roy Badenach.



Station 5PI Port Pirie 2000 watt transmitter 1934. Designed and constructed by 5AD Adelaide staff under Chief Engineer Don Gooding. Final stage employed STC 4228A water cooled valves with filament power being supplied by two DC generators 24 volts at 100 amperes.

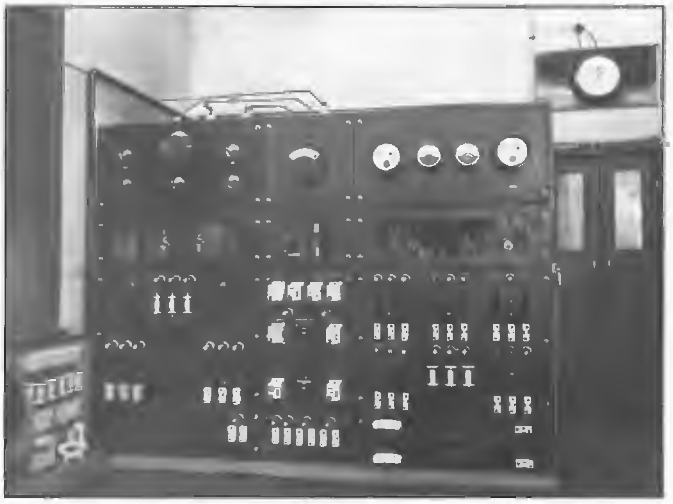
Transmitter constructed by Amalgamated Wireless (A/Asia) Ltd and installed at the AWA Radio Centre Pennant Hills for Commercial station 2SM circa 1935. The transmitter was maintained by AWA technical staff for the owners of 2SM, Catholic Broadcasting Company. The transmitter with 1 kW output employed series modulation in which the modulating valve was connected in series with the anode potential supply of the valves of the high frequency amplifier of the transmitter.

Front view of 3GI Sale transmitter. Similar units were provided for 7NT, 2NR, 4QN and 6GF in the mid 1930s. The final amplifier employed a pair of 4220B water cooled valves. With the exception of the final stage, power for all filament and anodes was provided using copper oxide rectifiers. The EHT was provided by three water cooled 4222A diode valves. Divisional Engineer Harold Robertson.

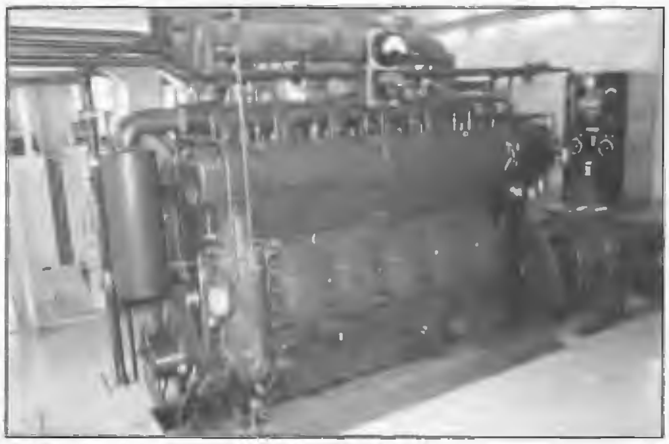
STC 6.25 kW transmitter commissioned at 3GI Sale on 31 October 1935. The first linear amplifier used a pair of 4015A type air cooled triodes to drive a pair of 4220B water cooled triodes in the final stage. The modulator also used a 4015A type valve. The transmitter was replaced in 1954.

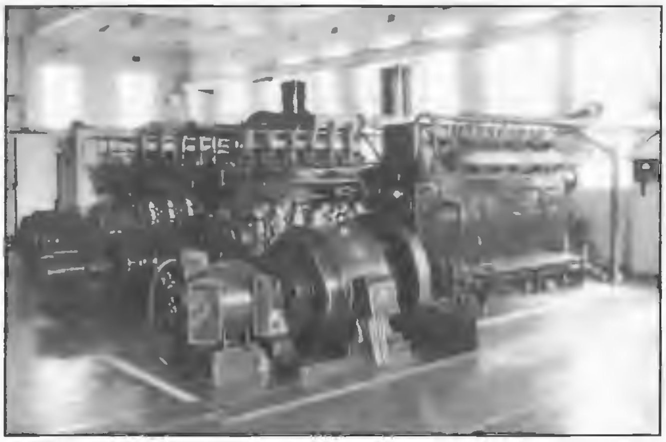
The original 4QN STC 6.25/7 kW transmitter installed at Clevedon November 1936. Installation Foreman was Reg Baker and first station Officer-in-Charge was Les MacDonald. The transmitter was destroyed by fire on 26 May 1951 when Officer-in-Charge was Geoff Beetham.

Transmitter 5CL Adelaide installed at Brooklyn Park in 1936. It replaced the AWA transmitter installed for Central Broadcasters Ltd original operators of the A Class station. The new transmitter provided 5 kW into the aerial. The final stage was a linear Class B amplifier using 4220C water cooled triodes. A motor generator supplied DC for the filaments of the water cooled valves. Ted McGrath was in charge of the installation.



Power and rectifier cubicles 5CL Adelaide 1936. High tension supplies of 1500, 4000 and 12000 volts were provided using three phase HCMV rectifiers. Engineers involved were Frank O'Grady and Laurie Billan.



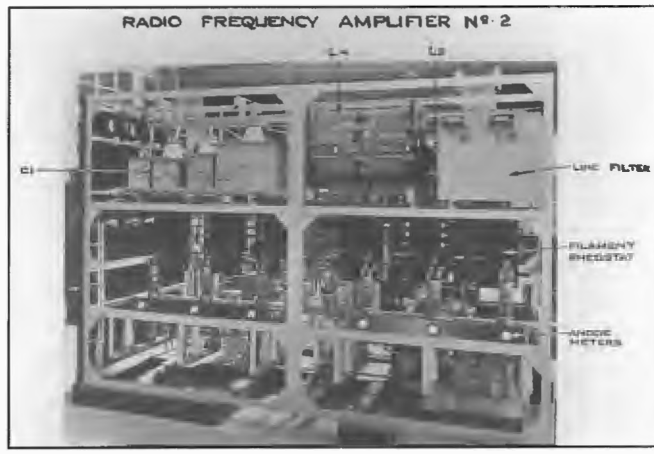


During the 1930s some National stations were located in areas beyond commercial power supplies and so local power generating plant was provided as part of the transmitting plant. Stations so equipped included 2CR Cumnock, 6WA Wagin, 3WV Dooen and 4QN Clevedon. Usually three engine sets were provided for the transmitter and a small unit for supplying residences after hours. Engines were typically Ruston and Hornsby 6 cylinder diesels coupled to 133.5 kVA alternators. All plants were subsequently recovered except for 2CR where one set was still on site in 1992. The 6WA three engine set (R) was removed in 1961.

The 500 watt 3BA Ballarat transmitter manufactured by Transmission Equipment Pty Ltd and installed 1936 at Cardigan. It employed a 1 kW water cooled valve in the final stage and fed a 60 m high radiator. It replaced an old installation at another site. Chief Engineer (Transmitting Station) Warne Wilson.

STC 2 kW water cooled transmitter 4RK Rockhampton and control desk circa 1936. The desk included a General Radio Modulation Monitor type 731A. The floor mounted monitoring loudspeaker replaced a WE 560-AW table model provided in 1931 when the station was commissioned. Officer-in-Charge 1931–36, Harry Conway.

Program input equipment and control centre 5AD Adelaide 1936. Chief Engineer Don Gooding making adjustment. He was Chief Engineer from 1931 to 1961. The station began operation on 2 August 1930 and the control room equipment included a four channel input audio mixer together with turntables for playing discs from the control room.



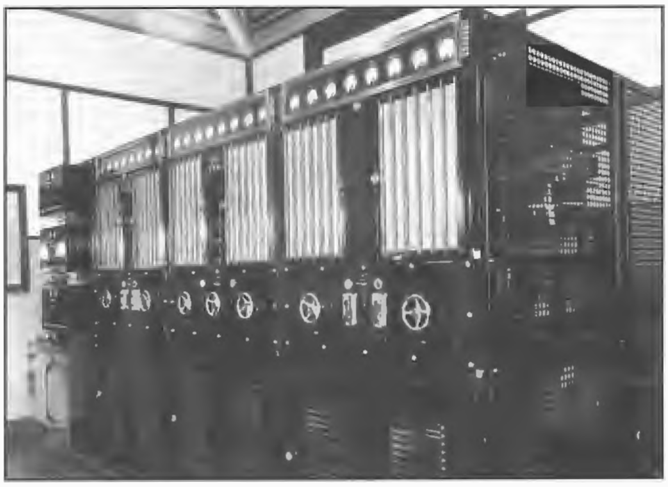
Final RF amplifier of STC 10 kW transmitter installed at 3WV, 6WA and 2CR during 1936–37. It employed four working and two spare water cooled 4220B valves in the final amplifier. This transmitter was an expanded version of a 6.25/7 kW model using two working and two spare 4220B valves and provided at 4QN, 2NR, 3GI and 6GF 1935–36.

On 15 October 1937 the 5AN Adelaide transmitter began operation in an annexe of the Central Telephone Exchange building using a 500 watt STC transmitter. On 4 May 1944, the facilities were transferred to a new building at Brooklyn Park and the transmitter power increased to 2000 watts by providing four 4279Z valves in push-pull parallel in the power amplifier stage. Ted McGrath was involved in the project.

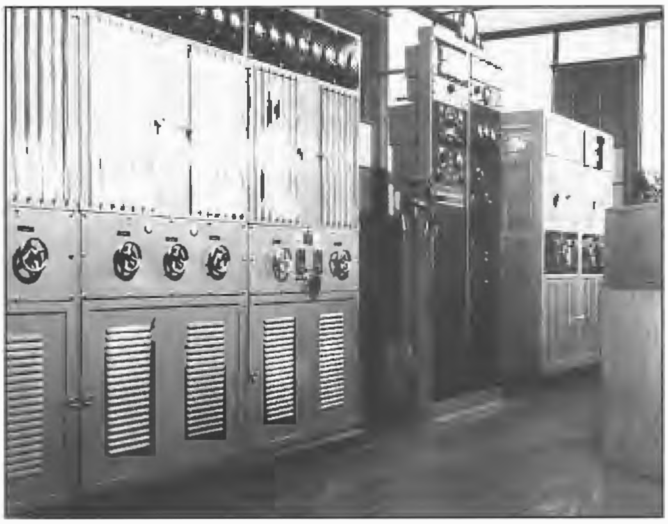
Station 5KA Adelaide 500 watt transmitter made by station staff 1938. Most of the major components including transformers, chokes fixed capacitors and rheostats were manufactured in the workshop. The final amplifier used four 805 type valves in parallel push-pull configuration. The unit was originally installed at Currie Street but in 1943 was transferred to a building in Franklin Street. Chief Engineer during construction of the transmitter was Charlie Tareha.

Original STC transmitter installed on 6th Floor, Perth GPO when 6WN was commissioned on 12 October 1938 on frequency 790 kHz. The final linear amplifier stage comprised a pair of 4279A valves in push-pull and produced 500 watts output. The design by STC was intended to cater for a range of transmitter powers in the range 50 to 2000 watts to meet the needs of Commercial and National broadcasters in the 1930s.

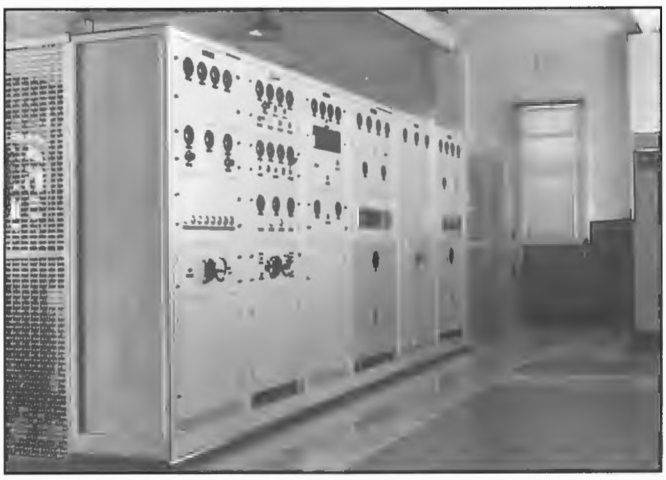
STC 1 kW 6WN transmitter installed at Canning Bridge 6 km south of Perth. The transmitter had operated at 500 watts from the Perth GPO since 1938 but with the outbreak of hostilities with Japan in 1941, the transmitter was moved to a bushland site at Mt Lawley and later relocated to Canning Bridge in 1946.



Original 2 kW VLW short wave transmitter manufactured by Transmission Equipment Pty Ltd, Melbourne and commissioned at NBS station Hamersley near Perth on 1 December 1939 to provide a short wave service to remote areas of Western Australia. Transmission frequencies were 9560 and 11830 kHz. The facility operated in its original configuration through the 1940s but was modified in the mid 1950s. The VLW service was closed down in 1994.

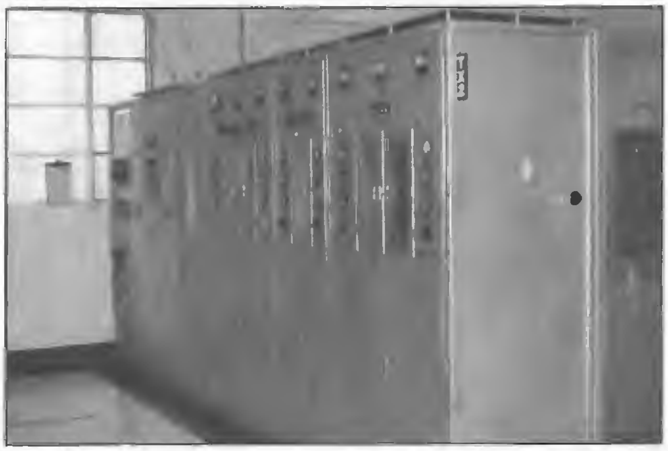


Transmission Equipment Pty Ltd transmitter at 7ZL/7ZR Hobart. The 7ZL 2 kW transmitter (L) was commissioned on 1 July 1939 to replace the original transmitter. The Class C modulated amplifier and modulator stages both employed TA/2000 type valves. The other unit a 500 watt model was provided for 7ZR on 22 June 1938.



STC type A513 10 kW transmitter commissioned at 4QS Dalby on 17 October 1939. The transmitter employed low level modulation with the final amplifier being two parallel 5 kW units using 4220B water cooled valves. Installation Supervising Engineer, Jim Hutchinson and first Officer-in-Charge Harry Conway. The transmitter was replaced in 1968.

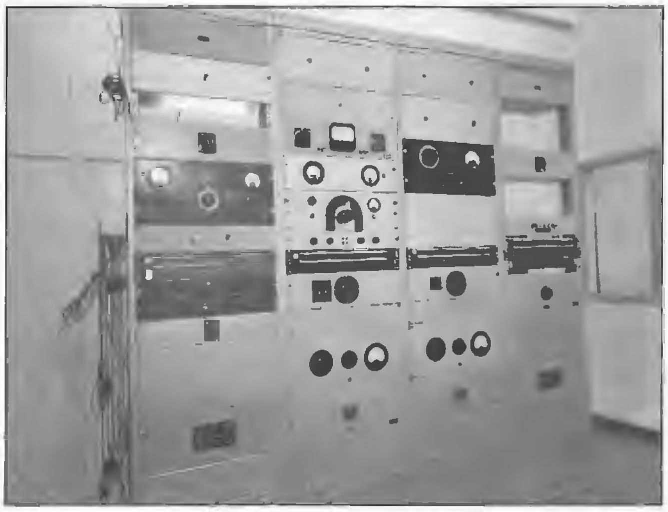
Photo by Eric Nissen who worked on the transmitter for its entire service life of 28 years.



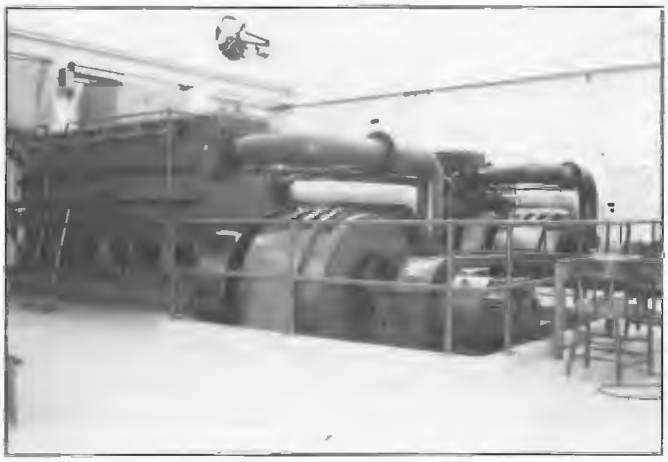
VLQ short wave transmitter Bald Hills STC type A880A provided service to inland Queensland for ABC programs. Commissioned 17 February 1943 with 10 kW output. Transmitter originally employed two double ended water cooled triode valves type SS1971 in final linear amplifier. Arthur Clark was in charge of installation.

VLQ 10 kW transmitter STC type 4-SU-48B installed 1968 to replace A880A model. Final amplifier and modulator employed valve types 3X2500A3. Operational frequency was 9660 kHz. It was closed down during December 1993.

Duplicate water pumping system installed at VLQ Bald Hills 1943 as part of cooling facility for 10 kW STC transmitter type A880A which employed SS1971 type valves and later 3Q213E type. The 2-3/4 HP motor circulated distilled water to the valve anodes at rate of 6 gallons per minute. Divisional Engineer in charge of installation was Vern Kenna.



Program input equipment racks 5CL/5AN Adelaide installed 1944 when 5AN was transferred from a city location to the 5CL site Brooklyn Park. A new building was erected to accommodate the 5AN transmitter and the station program input equipment. Divisional Engineer in charge of installation, Frank O'Grady.



Emergency power plant Radio Australia, Shepparton installed during the 1940s and comprising two Crossley 800 HP diesel engines each coupled to a 400 kW Brush alternator. Equipment operated as a synchronous pair and remained operational until 1993 when it was taken out of service. Staff who worked on the engine generator equipment at various times included Dick Cox, Brian Bingham, Steve Nankivell and Keith Dahlberg.

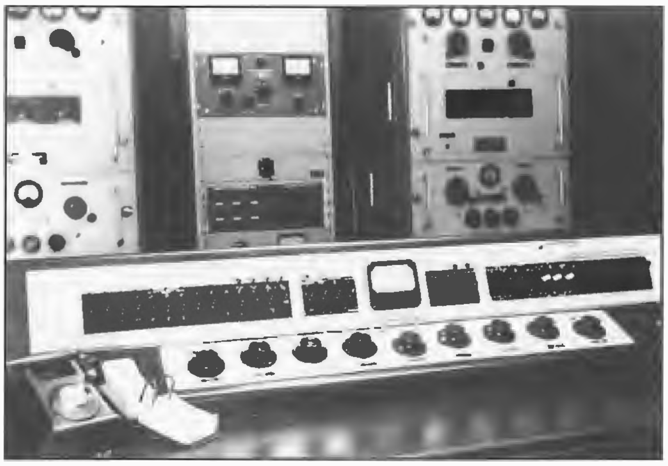
Outdoor water cooling systems for transmitters Radio Australia, Shepparton installed 1946. Water pumps were accommodated in the building while the air cooled radiators were installed outside.

The first transmitter to be commissioned at Radio Australia, Shepparton was an RCA 50 kW ML Series transmitter which went to air on 15 May 1944. The original transmitter consisted of two 50 kW PA stages, and a single modulator and power supply. In 1959, two separate 50 kW transmitters were built with the addition of some new components. The original transmitter operated for some 50 years before being taken out of service. Officer-in-Charge when transmitter commissioned, Jack Hargreaves.

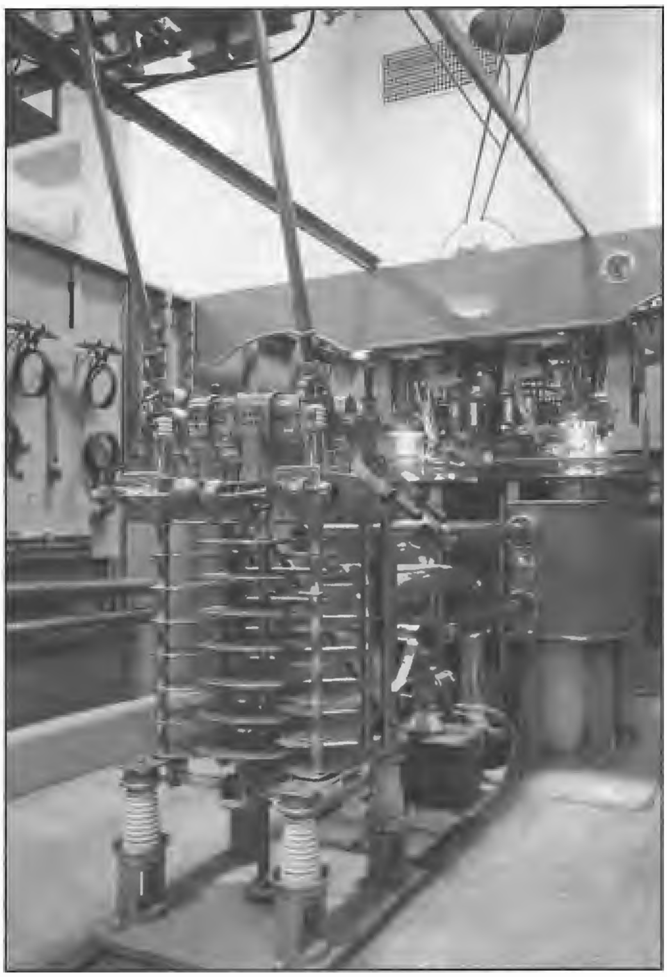
Mr J A (Jack) Hargreaves ISM, first Officer-in-Charge, Radio Australia, Shepparton when the facility then known as International HF Transmitting Station, began operation in 1944. He had previously worked at the Lyndhurst HF Transmitting Station. Jack managed the Shepparton station for 18 years. He was a talented artist having painted some 80 scenes and features mainly in the Portland district.

Water pumps and associated equipment for removal of heat from the anodes of the high power valves Radio Australia, Shepparton. Air cooling ducts are also visible. Part of the original 1946 installation.

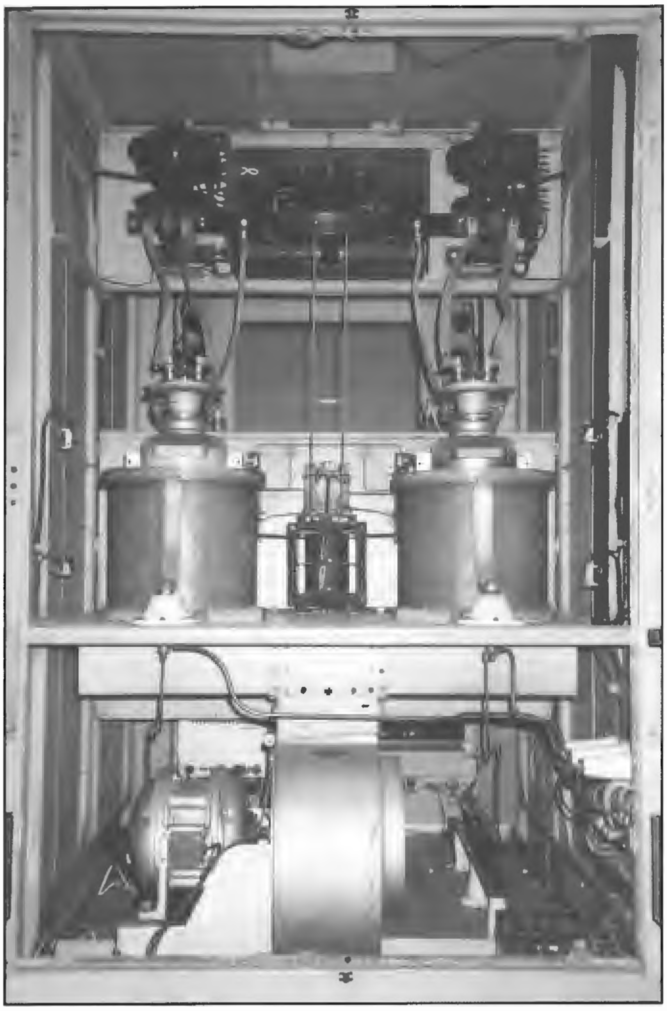
Transmitter Hall, Radio Australia, Shepparton 1946. Left: 10 kW AWA transmitter. Right: STC/AWA 100 kW transmitters high power stages. Centre: Control and aerial switching desks. Alan McIntosh was the first Resident Engineer.



Control desk and 200 watt transmitters 5DR (later 8DR) Darwin, 1947. The BC200 series of transmitters had been made by Thom and Smith Pty Ltd, Sydney for use by the Army Amenities broadcasting service. Ted McGrath was Divisional Engineer in charge of the installation. First Officer-in-Charge was Brian Woodrow.

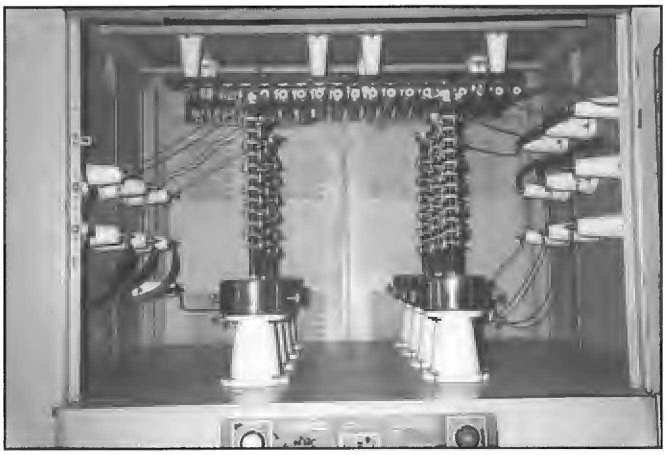


Radio Australia, Shepparton power amplifier of 100 kW transmitter commissioned 1946 showing water cooled F124A valves, insulated jackets, anode inductor rods and tuning capacitor. Supply of the two 100 kW transmitters during the War years was a joint AWA/STC effort.



Rear view of modulator cabinet of STC transmitter 4-SU-11A used for Parliamentary Broadcasting Service 4PB from August 1988 and located at Bald Hills. The modulator originally employed a pair of 3J/221E triodes in push-pull, later changed to TBL 12/25 type because of supply problems.

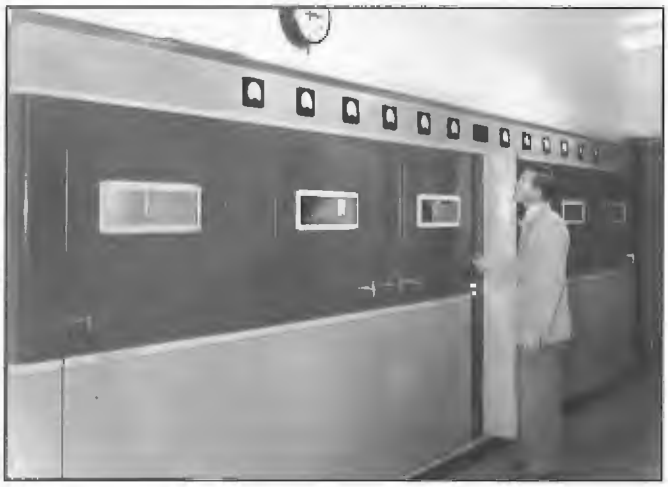
Heavy components associated with modulation circuitry of 10 kW transmitter STC 4-SU-11A operated during 1994 as 4PB Brisbane. Large components were a characteristic of designs employing high level modulation. The transmitter located at NBS station Bald Hills near Brisbane was manufactured in 1948. ·



EHT solid state rectifier stacks with STC 4-SU-11A type transmitter operated with 4PB Bald Hills. The 12 kV EHT supply was originally provided using 4078Z mercury vapour diodes. The transmitter had at various times since installation in 1948, operated with the NBS 4QG and 4QR services. Divisional Engineer in charge of installation, Vern Kenna.

Bob Barrett (left) Broadcasting Operations Manager and Wally Clair examining 4279Z valve of the STC 2 kW HF transmitter VLI at Liverpool. The service was commissioned in December 1948 and transmitted ABC programs to outback New South Wales until it was closed down in October 1983. The centre also housed the 2FC and 2BL transmitters. Wally worked at the centre during the period 1938–71.

AWA 200 watt valve transmitter 5LN Port Lincoln commissioned 14 November 1950. Identical main and standby units were provided. First Officer-in-Charge was Jack Martin. In 1974, the valve transmitters were replaced by a pair of STC 100 watt solid state units operating in parallel mode. In 1998, a new 200 watt transmitter replaced the STC units.



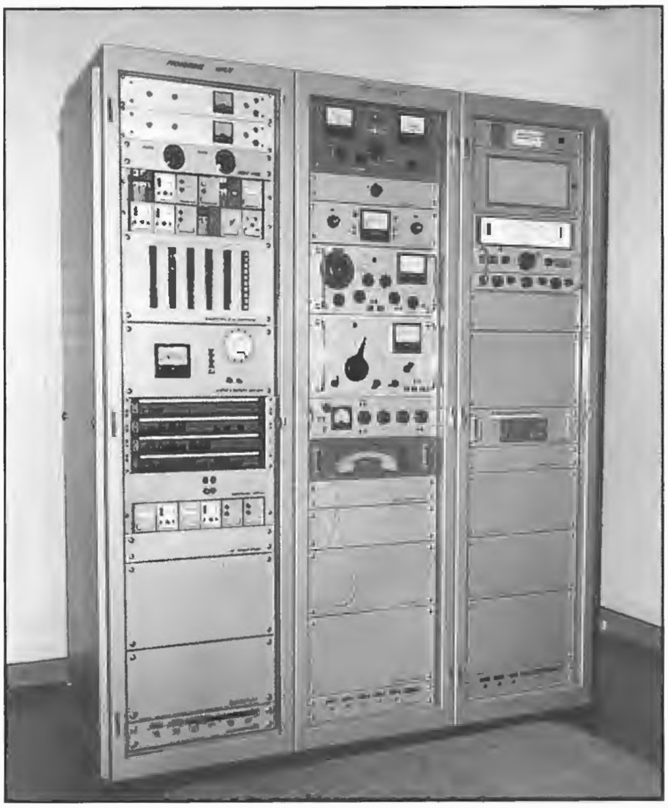
The original 5CK Crystal Brook STC transmitter commissioned in 1932 was replaced by a 10 kW AWA main unit with 2 kW standby unit on 29 March 1949. Ivor Shearer making adjustment. These two units were replaced in 1966 by a pair of STC 5 kW transmitters operating in parallel mode.

VLM 10 kW transmitter type STC type 4-SU-12A installed January 1951 at Bald Hills for HF Inland service and still operational when service closed down during December 1993. Operational frequency was 4929 kHz. Beyond David Sanderson standing near the VLM transmitter, is 2 kW unit used as standby for 4QG (4RN).

STC 10 kW transmitter type 4-SU-11A commissioned at 4RK Rockhampton 15 September 1954. It was painted Corio Sand colour, a colour scheme STC also used with some 2 kW models. The 10 kW transmitter employed high level modulation with the modulator and final power amplifier employing 3J221E triode valves. The EHT supply of 10 kV was provided by six 4078Z HCMV valves. The transmitter remained in service until 1988. Installation staff, Gordon Gilbert, Ian Byrnes and Col Williams.

A pair of Philips 1656 transmitters manufactured in Adelaide and installed at 5DR Darwin 1955. The transmitters were originally installed at Gardens Hill but in 1965 were transferred to a new site at Ludmilla. They remained in service until 1978. Similar transmitters were installed at 5MV and 5PA in South Australia. Officer-in-Charge 5DR (changed to 8DR) was Ken Soar.

A pair of Philips 200 watt valve transmitters operating in main/standby mode at 5MG Mt Gambier. Commissioned on 26 September 1955, a similar installation had been provided at 5WM Woomera and operating on the same frequency. Installation Divisional Engineer was Murray Higgins and first Officer-in-Charge was Bill Legg. In 1974, the 5MG transmitters were replaced by a pair of STC 100 watt solid state transmitters operating in parallel.

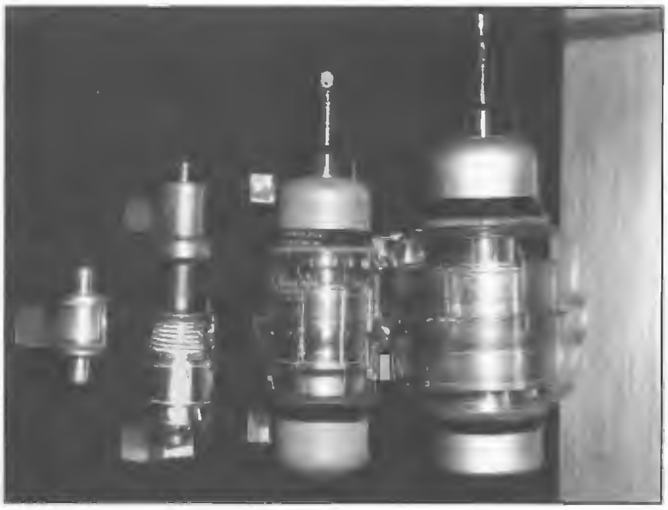


Typical Program Input, Test Equipment and Telemetry racks installed at NBS 2 kW transmitting stations during the 1950–70s. This installation was at 5PA Penola commissioned on 14 December 1956 with a pair of Philips 1656 type transmitters operating in main/standby mode. First Officer-in-Charge was Lew Grubb. The station was closed down in 1960 and a new facility established at Naracoorte with twin 5 kW STC transmitters with the 5PA callsign.

Graeme Wilmot, Officer-in-Charge, 7ZL/7ZR Hobart adjusting the 7ZL AWA BTM10 transmitter which was installed during 1958 sharing a dual frequency radiator with 7ZR. A directional radiator was put into service in 1964.

NBS transmitting centre Newcastle. Left, 2NC 10 kW AWA BTM10 transmitter and on right, 2NA 10 kW Collins 21E/M transmitter. The first 2NC transmitter was commissioned on 19 December 1930 followed by 2NA in 1943. The two 10 kW transmitters were installed in 1959.

AWA BTM10 standby 10 kW transmitter (left) and STC 55 kW transmitter 3WV Dooen. The 10 kW unit was originally installed as the main unit in 1959 and the 55 kW model began operation on 31 August 1960. Over the years, the building had suffered a number of structural problems due to soil movement and in 1988 a new building was erected and a 55 kW solid state transmitter installed.



Typical vacuum capacitors used in modern transmitters and aerial coupling units. Fixed capacitors using vacuum as a dielectric were first manufactured in 1937 but did not find acceptance with Broadcast Engineers until about 1950 when concentric re-entrant flange construction technology was employed. The introduction of high power transmitters resulted in widespread use of this type of capacitor in high voltage circuits.

Oil filled vault equipment fitted with conservator tank and dehumidifier provided with STC 55 kW transmitters installed at NBS stations from 1958. The equipment was designed for either inside or outside mounting. This shows the 5CL Adelaide system installed 1961.

Control desk 5CL Adelaide installed 1961 to control 55 kW/10 kW transmitters. A similar unit was installed for 5AN. Design Engineer was Frank Mullins with installation under control of Bert Steer.

Mr W (Bill) Davidson, BEM, Officer-in-Charge, Radio Australia, Shepparton 1962–80. He began work at the station in 1943 during its construction as a member of the team responsible for the installation of transmission lines, switching and aerial systems. During the major upgrade of the station facilities commencing 1957, Bill was in charge of the Radio Installation team for the five years it took to complete the project.

Modified STC/AWA 100 kW transmitters Radio Australia, Shepparton. Transmitters 3 and 4 in foreground and RCA 50 kW transmitter on right. The two original 100 kW transmitters were converted into four separate 100 kW units by using redundant and extra components during 1960s. Officer-in-Charge was Bill Davidson.

Program control desk Radio Australia, Shepparton 1961. Allen Dobson at the controls.

STC 55 kW transmitter installed at 3LO Melbourne 1962. Officer-in-Charge, Russell Rolls standing near the transmitter. It shared the 214 m radiator with 3AR. The site located at Sydenham was established in 1938 to accommodate 3LO and 3AR on a common site. The STC transmitter was replaced in 1991 by a twin 25 kW Nautel ND25 solid state installation.

The STC 55 kW 3AR Melbourne transmitter was installed at Sydenham in 1962 sharing facilities with 3LO. The transmitter was replaced in 1991 by a Nautel ND25 25 kW solid state transmitter. The station now operates with callsign 3RN.

Transmitter Hall, NBS station Hamersley near Perth circa 1962. Transmitters comprised (left to right): 10 kW STC type 4-SU-64 main, 2 kW Philips type 1956 standby both for 6WN (later 6RN); 55 kW STC type 4-SU-38B main and 10 kW STC type 4-SU-64 standby, both for 6WF.

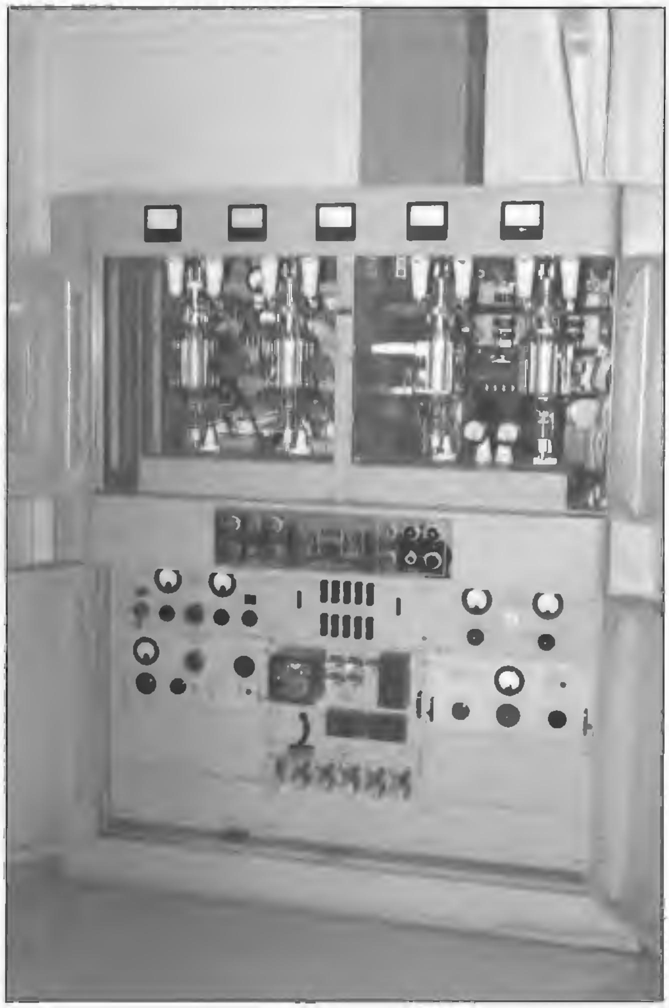
AWA 10 kW BTM10J standby transmitter (left) and 50 kW AWA BTM50 main transmitter at 2CR Cumnock. The station began operation in 1937 with an STC 10 kW transmitter. In 1963, a 50 kW AWA transmitter was installed and was the only such transmitter installed in Australia. When originally installed, it employed English Electric AR63 mercury arc excitrons of a single anode mercury pool type in the main rectifying system. The transmitter was operational until January 1994 when it was replaced by a Nautel solid state model.

STC type 4-SU-61 50 kW HF transmitter at VLW Hamersley, Western Australia for ABC Inland service. It was installed in 1963 and was operational until 1994. It was the only transmitter of this type operational in Australia for broadcasting purposes. Band changing was achieved by using pneumatic rams remotely controlled by frequency selection switches in the driver unit.

Front view of STC 10 kW transmitter type 4-SU-48B installed in 1963 and operational at Hamersley until 1994. Two were in service covering the 6 and 9 MHz bands. The design was employed as the driver unit for the 50 kW transmitter also in service at the station.

Murray Little, Officer-in-Charge adjusting one of the three VLW transmitters associated with the HF Inland service based at Hamersley near Perth. The service operated with two 10 kW and one 50 kW transmitters, broadcasting on three frequencies. The service was closed down during January 1994.

NBS transmitting centre, Canberra. (Left) 2CN 2 kW transmitter. (Far right) 2CY STC 10 kW main transmitter. (Near right) 2CY AWA 2 kW standby transmitter. Station 2CY began operation on 23 December 1938 followed by 2CN in 1953. The 10 kW STC transmitter was installed in 1964. As at 1992, the 2 kW AWA transmitter was being used for Radio for Print Handicapped Service.



STC 2 kW transmitter type 4-SU-14C at 4RK Rockhampton October 1963. It had previously been installed at 4QN. This Corio Sand colour transmitter was very popular with broadcasters being widely employed at National and Commercial stations from about 1949. Some were still operational in 1996. Power amplifier and modulator used 4279Z valves in push-pull configuration.

STC 2 kW transmitter installed at 5DN Adelaide 1964. The station transferred from the CML Building in the city to a site at Dry Creek in 1954 and installed new transmitting facilities and aerial system. Chief Engineer was George Barber.

Twin STC 5 kW transmitters installed 5CK Crystal Brook 17 June 1966 operating in parallel mode. They fed into a sectionalised 190 m radiator via a six wire coaxial line.

One of the 250 kW Collins 821A transmitters at Radio Australia, Cox Peninsula during installation stage 1969. Modulator stage on left. On right is power amplifier stage with cavity tank circuit, balanced to unbalanced transformer and band pass filter. The employment of a cavity for the tank circuit was a radical departure from the usual coil/capacitor arrangement.

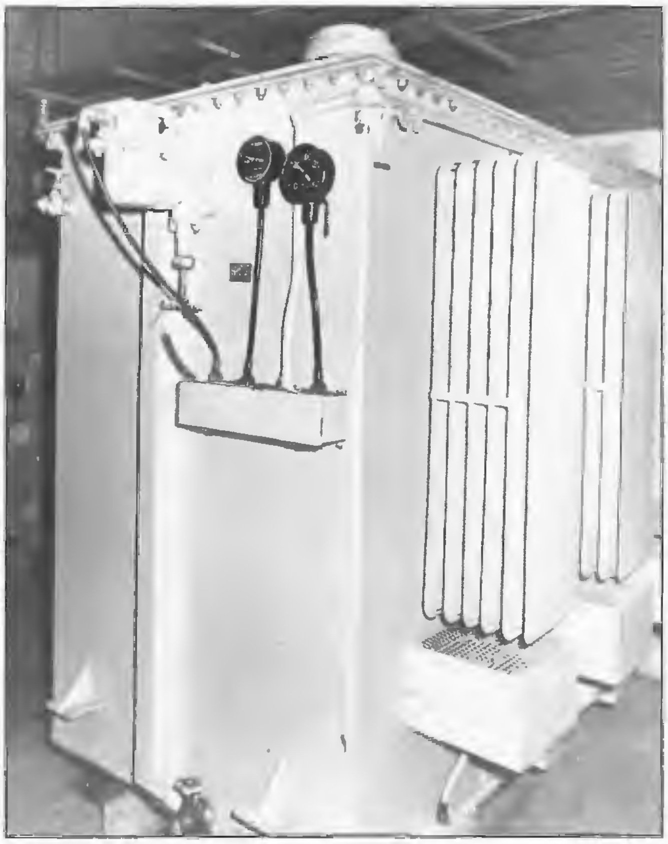
Steam condenser units provided for the vapour phase cooling system of three 250 kW Collins 821A transmitters at Radio Australia, Cox Peninsula. The station began transmissions in 1969 and was the first in Australia to employ vapour phase cooling of the high power stages. Project Engineer, Jack Ross.

Two 250 kW Thomson-CSF transmitters were added in 1993–94 giving a total of five 250 kW outlets at the station.

Control room Radio Australia, Cox Peninsula 1969. Facilities included communications, program input, frequency selection, aerial switching, transmitter digital control, emergency power and gate surveillance equipment. Design Engineer, John Robertson.

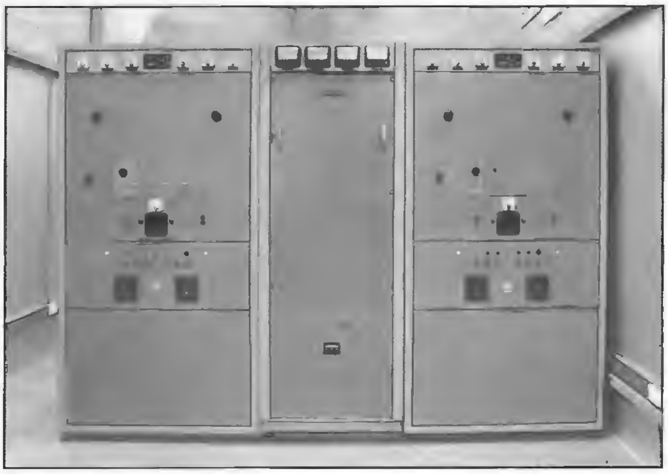
Emergency Broadcasting Station, Berry Springs, Northern Territory established in 1968 to provide broadcasts to the public in Darwin in emergency situations. The station was closed down as a broadcasting facility in June 1991.

Alan Hubbard making adjustment to AWA BTM2 emergency transmitter, Berry Springs. The transmitter provided 2.5 kW into a top loaded radiator and was set up on the same frequency as NBS station 8DR. David Young was installation Engineer.



Main station power switchboard Radio Australia, Cox Peninsula placed in service 1969 to cater for three 250 kW transmitters. Power to the substation was provided at 66 kV from Darwin via 18 km of overhead construction and two parallel submarine cables. In 1992, the switchboard was extended to cater for two additional 250 kW transmitters. Initially, electrical services on the station were maintained by a team of Electrical Fitter and Mechanical Trades staff.

EHT transformer provided with 250 kW Collins 821A transmitters Radio Australia, Cox Peninsula 1969. Fans and projecting fins were provided to keep oil temperature to a safe level. Solid state 12 phase bridge rectifier system for the 15 kV DC supply was immersed in oil in the top of the tank. Installation Engineer, Bill Shapley and first Officer-in-Charge, Ken Bytheway.



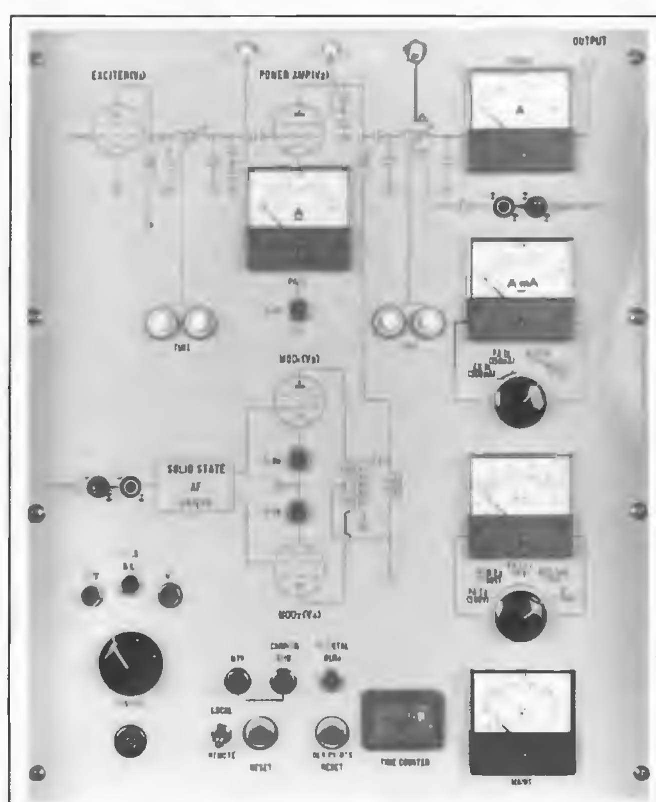
Parallel 1 kW STC transmitters with combiner installed at 3MT Omeo on 18 April 1976. The transmitter employed power amplifier valve types 5/500A with HT being supplied by a silicon rectifier system. Aerial system was a 108 m directional type with two masts.

Station control desk Radio Australia, Carnarvon. The station was established in 1976 with a 100 kW Harris transmitter and a 250 kW Brown Boveri transmitter feeding four curtain aerials. Project Engineer, Terry Sellner.

Brown Boveri 250 kW HF transmitter type SK53F3 installed at Radio Australia, Carnarvon 1976. Officer-in-Charge, Jack Clugston.

100 kW Harris/Gates transmitter installed Radio Australia, Carnarvon 1976. It employed pulse duration system of modulation.

NEC type MBN-7237B 5 kW medium frequency broadcast transmitter installed at Commercial stations late 1970s. It employed four high gain tetrode valves, one in exciter stage, two in modulator and one in PA. Other stages employed solid state circuits.



Right: Mimic Board as provided on NEC type MBN-7237B transmitter. In addition to providing facilities for measuring various currents and voltages an appropriate OLR operated and provided a lamp display should the transmitter undergo an overload due to fault in the output circuit, valves or high voltage power supply.

Water cooled 500 kW dummy load installed at Radio Australia, Carnarvon 1976 for testing 100, 250, and 300 kW transmitters. The station ceased operation in 1996. Officer-in-Charge when station closed, Les Fancote.

Last day of operation of STC/AWA 100 kW HF transmitters Radio Australia, Shepparton 1983. The transmitters were originally installed during 1946 and upgraded during the 1960s. Retired staff were invited to perform tuning operations of the old transmitters. (Left to right) Jack Nicholas adjusting PA tuning, Bill Davidson adjusting output tuning and Fred Barker adjusting input tuning.

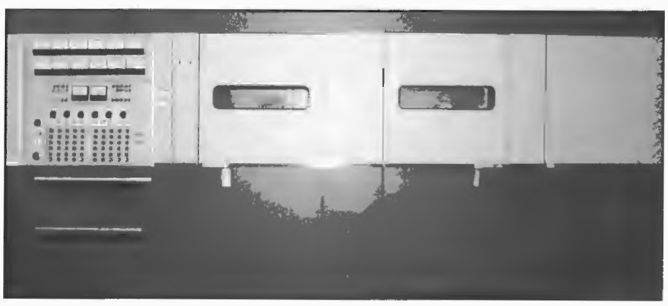
The 5 kW Harris transmitters commissioned for 3EA Melbourne on 26 January 1980. They were located at Craigieburn and fed a 61 m high directional aerial system. Neil McCrae was in charge of the project.

NEC 10 kW FM transmitter installed at Mt Gambier 1981. The output valve employed is displayed in front of the transmitter. This is typical of many FM transmitters installed throughout Australia for the ABC FM Stereo service which began in 1986. Officer-in-Charge, Rawdon (Ron) Mitchell.

Control room, Radio Australia, Cox Peninsula after recommissioning in 1984 following extensive damage by Cyclone Tracy in 1974. Program input equipment racks in background, aerial and power control desk to the left and main control desk to the right. Officer-in-Charge was Ross Kearney.

Transmitter Hall, Lyndhurst transmitting station 1986. Control room is on left. The station was established in 1928. In the late 1960s eight new STC 10 kW transmitters were installed to cater for the many commitments provided from the station. Its functions gradually declined and the station was closed down on 12 June 1987. Officer-in-Charge at closedown was Max Fowler.

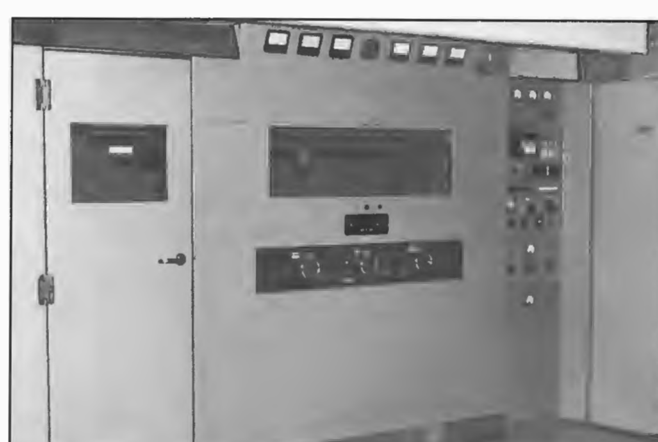
Max Fowler, last Officer-in-Charge at Lyndhurst before closure 1987 adjusting one of the STC 10 kW transmitters. In the 1960s, eight new 10 kW transmitters were installed.



Continental Electronics transmitter type 418D-2 installed at Katherine, Tennant Creek and Alice Springs to provide service to Northern Territory using vertical incidence transmission. The 100 kW transmitters were cut back to provide 50 kW to the aerials. They were commissioned during 1986 and operate in the 60 metre band during the day and in the 120 metre band during night and morning. Senior Engineer, Bruce McGowan and Project Engineer, Wayne Croft.

3WV Dooen 50 kW AMPFET50 Nautel solid state transmitter installed in 1988. It was the first solid state 50 kW transmitter to be commissioned in Australia. The power is obtained by using 48 identical 1.25 kW power systems combined into 5 kW groups. Twelve 5 kW blocks provide up to 60 kW output capability. Nautel transmitters are manufactured in Canada by Nautel Electronic Laboratories and distributed in Australia by JNS Electronic Industries.

Nautel 10 kW AMPFET10 solid state transmitter commissioned at 4RK Rockhampton during 1988. Jeff Cirson, Officer-in-Charge at the unit. The transmitter was installed in a small building adjacent to the original building which had been erected in 1931.



STC 10 kW transmitter type 4-SU-36C operating on 585 kHz at NBS station Hamersley, Western Australia for the Parliamentary Broadcast Network station 6PB. The service in Western Australia commenced on 11 October 1988 using a STC 5 kW transmitter later transferring to a Nautel ND5 unit and in May 1990 to the STC 10 kW transmitter. The transmitter had previously served as a standby unit for 6WF.

Three STC type 4-SU-48B 10 kW short wave transmitters at Radio Australia, Brandon. The transmitters had previously been installed at Lyndhurst in the late 1960s but on closure of that station were transferred to Brandon in 1989. Engineers associated with establishment of the station HF facilities included Janis Ozolins, Richard Womack and Doug Sanderson.

Typical dual 10 kW NEC FM transmitters undergoing tests in the manufacturers screened room 1990. NEC was the largest supplier of FM transmitters in Australia and assembled 10 kW and 20 kW transmitters at its Mulgrave Broadcast Engineering Centre near Melbourne from imported sub-assemblies and locally sourced items. Roger Greenwood was Manager NEC Broadcast Systems.

One of a pair of 10 kW Harris MW10 transmitters used from September 1990 for 4RPH Tingalpa near Brisbane and operating on 1296 kHz. The transmitters derated to 5 kW each were originally part of 4BK facility until that station transferred to the FM band. Harris transmitters are manufactured in USA by Harris Corpn and distributed in Australia by Comsyst Pty Ltd.

Two 5 kW ND5 AMPFET Nautel solid state transmitters operating in parallel at 5CK Crystal Brook March 1991. Each transmitter used four identical power sub-systems containing 3 FET power amplifier modules and its associated pulse duration modulator giving an output up to 5.6 kW per transmitter.

Main water cooled tuning capacitors used with Collins 250 kW transmitters Radio Australia, Cox Peninsula. Jennings CVT 1600-70X types (left) were employed in the transmitters from 1969 but in 1992, Comet CV4W 1000E types were fitted. Both types had similar electrical characteristics. Capacity range was 100-1600 pF, peak working voltage 36 kV and maximum RMS current 1000 A.

The Comet capacitor modified to fit into the Collins transmitter. It enabled tuning of the transmitter over the designed range 6-26 MHz without any component change.

CTE FM transmitter installed at Gladstone in 1993 by Telecom Broadcasting for TAB as part of its Racing Radio Network. Programs are sourced from 4TAB, the TAB's station in Brisbane and relayed to other stations throughout Queensland via satellite. The Gladstone station was one of 16 installed during 1993.

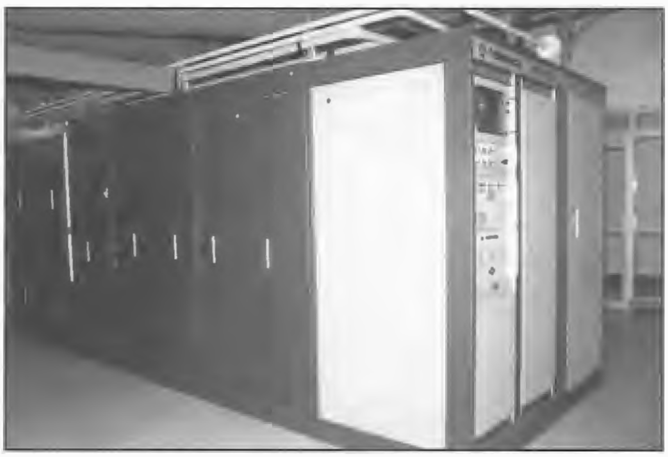
One of two Nautel 10 kW AMPFET 10 solid state transmitters installed at Viewbank, site of former Commercial station 3DB Melbourne. Callsign was later changed to 3TT and upon the owners of 3TT obtaining a licence to transmit on FM at another location, the AM facilities were transferred to the Commonwealth's National Transmission Agency. The two transmitters were used to provide an outlet for Parliamentary Broadcast Network station 3PB on 1026 kHz the former 3TT frequency and for an alternative standby transmitter for National station 3LO on 774 kHz for the Sydenham facility as from April 1993. The two transmitters had access to the aerial via a remotely controlled switching system.

New control desk installed Radio Australia, Cox Peninsula 1993 as part of upgraded facilities to enable the station to operate with five 250 kW HF transmitters. Computer terminals for three Collins transmitters are at far end of room.

New program input equipment, monitoring and test racks installed at Radio Australia, Cox Peninsula 1993 as part of upgrading the station to accommodate two additional 250 kW transmitters. Aerial control panel and power supply mimic diagram in cubicle near end of racks.

Nautel ND5 solid state transmitters installed at NBS station Dalwallinu during late 1994. Two ND5 units are combined to produce 10 kW to line for each service. The front unit caters for a new Radio National service 6RN while the rear unit is associated with Regional service 6DL. Station 6DL has been operational since 22 November 1963.

Filtered air ventilation systems with 250 kW Thomson—CSF TRE 2326 transmitter installed Radio Australia, Cox Peninsula 1993-94. A high pressure system provided air to the RF stage while a low pressure system catered for the Modulator stage. Equipment mounted to the right comprised 11 kV switchgear and 11 kV/400 V step-down transformer. Contractor's installation and commissioning staff comprised Marc Moreau, Guy Pellett and Didier Thomas.



Thomson-CSF TRE 2326 HF 250 kW transmitter commissioned Radio Australia, Cox Peninsula 1994. Two identical transmitters were placed in operation bringing the total 250 kW transmitters at the station to five. A video colour display module incorporated in the transmitter control panel indicated the transmitter status. In the event of a fault, plain language messages were displayed in conjunction with faults to assist in fault resolution. Project Engineer, Graham Baker.

Transmission from the station ceased on 30 June 1997 and facilities placed in a caretaker mode by maintenance staff.

Radio Australia, Shepparton transmitter hall 1994. (Centre) Program Control Room; (Left) Transmitters 5 and 6, Harris SW100, 100 kW transmitters installed 1978; (Right) Transmitters 1, 2, 3 and 4 Harris SW100A, 100 kW transmitters installed 1983. Officer-in-Charge, Bruce Wilson.

Chapter Three

Studio Equipment and Facilities

The Early Days

The First Steps

At some of the early Commercial stations, the Announcer, performing Artists, musical instruments and even office facilities shared a common room with the technical facilities, including the transmitter. The area was often a room in the home of the station owner. Some of the more well-to-do owners like Mr E J Hume who owned 5DN in Adelaide, were able to allocate a separate room in the home for the studio and locate the transmitting equipment elsewhere.

Very little was known of the acoustic requirements of a broadcast studio but it soon became evident that some experimental work was essential to minimise reverberation and other effects. Walls and ceilings were draped with thick material such as blankets or hessian to provide insulation against sounds generated outside, and to minimise reflections from internal walls. Frequently, only one microphone was available and artists were often placed at a considerable distance from it, so adding to reverberation and other problems. Windows were extremely difficult to treat and bed mattresses were widely used where street noise was a problem. Even at the 3LO studio in Melbourne's Cambridge Building at 139 Collins Street, heavily padded mattresses had to be employed to attenuate the traffic noise. However, they were concealed by tasteful decorations in tune with the royal blue floor carpets.

Typical of small country studios in mid 1920s was 2MK Bathurst where the main studio was draped with dyed hessian with a final overlayer in maroon colour. One Artist commented, 'the effect was pleasing to the eye and there was an absence of echoes'.

One well-known female broadcaster from England who visited Australia in 1926 to make a series of broadcasts, in commenting about broadcasting in Australia told a London audience that in Sydney the broadcast studio, like those in London, was heavily draped to deaden echoes whereas in Melbourne, there was very little use of draperies. There, the studio was a beautifully furnished room with fine paintings mounted on the walls.

In the early 1920s, a large part of classical programs originated in the studio as live performances. There were frequently long periods of silence between items while the Studio Manager ushered one lot of performers out of the studio and prepared for the next. Where a performance was given by a band or choir, the studio was often too small to allow the group to be seated, so they had to stand.

With some of the early stations where studio and transmitter were located on the roof of a city building, it was not unusual for a choir to be assembled outside the studio on the roof and the studio microphone wheeled out with a long extension cable. Station 2BL Sydney was typical, and city shoppers in the street below were often surprised to hear music and voices coming 'down from heaven'.

Some studio operations were carried out under appalling conditions. For example, one Queensland country studio was damaged by fire and while waiting for the erection of a new studio complex, an ironmonger's store was used temporarily. The building was no more than a shed with a dirt floor and when the building next door was demolished, the studio was left without one wall for some weeks.

In the case of 6WF Perth, built in 1924, control of outside noise was effected by suitable design of the studio walls. There was a 75 mm air space and a further 75 mm space filled with sawdust between sheets of felt. The walls and ceiling of the main studio were draped with pleated hessian covered by a heavy cloth material, also pleated. Artistic hangings and curtains improved the overall decor. The studio air circulation system comprised a blower motor and fan located at the back of the building with the air being blown into the studio via a long duct. In this way, motor vibration and fan blade noise were highly attenuated. The air was exhausted via two ventilators mounted on the building roof.

Two 6WF studios were provided, and comprised a large room which was the main studio and a small room which was used for continuity purposes while bands and choirs were being assembled in the main studio prior to a performance. The main studio which was the only one provided when the station commenced operation measured 8 m by 5 m.

The studio facilities included a Western Electric carbon microphone on a moveable pedestal, a Stek Duo-art player piano and a Sonora gramophone.

No intercom system was provided between Control Room and Announcer's Desk. Announcer and Technician communicated by using hand signals via the window. Switching of the microphone was under the control of the Technician.

In addition to being treated to minimise outside noise and to improve acoustics, the main studio was completely surrounded by sheet iron electrically bonded and earthed to prevent interference to the microphone circuit from the high level RF field produced by the overhead aerial system.

Shortly after the PMG's Department took control in 1928, new studios were installed at premises in Milligan Street, Perth. An electrically powered pianola was provided and gave 10 minutes of music program. With other facilities, this gave great improvement on program presentation compared with a single Victrola gramophone at the original studios in Westralian Farmers Building.

From the 1930s, studios took on a new look. They were very spacious and furnished with simplicity which characterised the then modern approach to interior decoration. With the beautiful perforated veneered wood panelling, the thick carpet, the system of soft electric lighting, new types of microphones and the very quiet air conditioning which gave fifteen or more complete changes of air per hour, Artists and Commentators felt more at ease when broadcasting.

When new ABC studios associated with 2NC/2NA Newcastle were commissioned in August 1944, specially designed acoustic walls in V shaped panels were provided to disperse high frequency reflections. Portions of the wall were perforated and the space behind the front sheet filled with mineral sound absorbent material. The glass window to allow viewing between studio and the control room was constructed of three sections of plate glass each of different thickness and in a separate frame. Consulting Architect for building work was Vivian Taylor and PMG's

Department Studio Engineer responsible for the broadcast technical facilities was Eric Watt.

Vivian Taylor, a Melbourne Architectural Acoustic Consultant had been involved in design and conversion of cinemas with the introduction of 'talkies' to replace silent films. An Architect, he began working in the field of acoustics from about 1928 and during his lifetime had been associated with the design of new and modification of existing auditoria throughout Australia at hundreds of centres. He also undertook acoustic work with broadcast studios and recording studios and in 1931 for the first time employed convex and other diffusing panels. The aim was to avoid absorptive materials and produce as much diffusion as possible to maintain reverberation considered appropriate to the particular use of the room.

Because of the difficulty of obtaining materials during the War years, Architects and Engineers used a range of materials where additions or new studio rooms were required, to fill the space between walls. Materials included saw dust, sea weed, confetti, papier mache, ti tree bark, granulated cork and others.

In more recent times, the broadcasting industry has been well served by many Acoustic Consultants. In the 1980s, there were more than 20 organisations in operation providing a range of services including studio, control room, monitoring room and auditorium acoustics and sound isolation; ventilation and noise control; design of acoustic finishes; design of vibration and noise control systems in buildings housing studio facilities; preparation of architecturally detailed tender documents; administration and supervision of contract construction and automated acoustic rating test of studio performance.

Some Consultants possessed laboratories equipped with an anechoic room for measuring microphone characteristics and loudspeaker Thiele-Small parameters. They were able to provide total design of studio monitoring sound reinforcement and high fidelity loudspeaker systems, including closed box, vented box and horn loaded systems.

During July 1981, 3KZ commissioned new studios at 24 Victoria Street, Carlton at a cost of about $1 million. With two complete production areas and two new booths, the studio layout allowed the Announcers, Production and Library staff easy access to all studio facilities. Production studio acoustics allowed considerably greater microphone distances than those allowed with conventional designs. Chief Engineer-in-Charge of the facilities was Brian Perry.

All studios were completely floating, had double walls between the studios and were lined with lead sheet. In the recording booths associated with both studios, the largest wall used polythene to achieve a resonance absorption panel at low frequencies. The wall consisted of 100 mm of rockwool and a chequered pattern of thin polythene. All opposite panels provided different absorption response, with end walls absorbing low and mid frequencies and the damper ceiling absorbing high frequencies.

Technical Facilities

Studio technical facilities were primitive compared with modern equipment. There was no electric pick-ups for playing records and no long playing transcription records for half hour plays or concerts. Microphones were carbon types using modified telephone transmitters or Reisz types made by station staff, or a Western Electric commercial type made specially for broadcasting for those stations which could afford such luxury. Also, there were no portable recorders and definitely no offensive 'four letter words' broadcast. Transmission took place for only a few hours a day, usually spread over morning, mid-day and evening sessions.

At some stations, and certainly at 4QG in Brisbane, the Announcer stood up when he read the news. There was no sitting down. News was too important. The microphone was mounted on a tall, non-adjustable stand somewhat like a hall pot stand and the Announcer stood in front of the microphone with loose sheets of paper in one hand. When he finished reading a sheet, he moved it to one side and allowed it to flutter to the floor. If the next item was a gramophone recording, he would read the title from the disc and signal the Technician to fade out the microphone. He would then gently pick up the microphone, place it in front of the flare of the gramophone horn, change the needle, wind up the spring motor, start the turntable, place the acoustic reproducer on the disc and give a nod to the Control Operator who would then fade in the microphone. At some studios, the microphone would remain fixed and the gramophone wheeled over to the microphone.

Many of the broadcasting stations employed Edison Diamond Discs for recorded music. One such station was 2HD Newcastle, which when it began operations on 27 January 1925, was the first broadcasting station established outside the capital cities. The station owner, Harry Douglas, used two Edison phonographs and a collection of Edison Diamond Discs.

When station 3UZ Melbourne commenced transmission on an experimental basis in 1923 before being granted a B Class licence, it also employed an Edison Diamond Disc machine, with a Magnavox microphone.

These discs were vertical-cut (hill and dale) with 150 grooves per inch and were 10 inches (250 mm) in diameter, and 3/16 inch (4.7 mm) thick. They were played at 80 RPM and gave a playing time of about four minutes.

When first introduced, the discs were a celluloid-sandwich construction, but later, a thermosetting plastic was used.

One of the earliest Edison phonographs used in studios was the Model A250 with a brown enamelled bedplate, a gilt reproducer and fittings, and with a Bowden cable-controlled volume control operating into the throat of the horn which was behind a fabric-backed fret. The instrument was in a mahogany floor standing cabinet finished in maroon enamel and oxidised copper mandrel etc. Two drawers provided storage for the diamond disc records. It was originally manufactured about 1914 but by 1926, an improved version Model N19 became available. The tone arm with its heavy diamond reproducer was fed across the disc by a lead screw.

Program Problems

Obtaining Artists for vocal numbers was not easy. The Program Director would go to a card index of names of Artists who had recently passed audition tests. He may decide that none on the list would suit his purpose and so select one of the contract Artists. He would then telephone the person in question, only to find that he or she had a prior booking, was out of town, or did not know the type of song required. Many singers had a limited repertoire of the most ordinary ballad type. There was also another problem. Microphones and transmitters were easily overloaded and the Director had to place a ban on some songs or Artists.

Many programs, particularly at the Commercial stations, introduced a fair measure of acts by Comedians into the programs. Unfortunately, many well-known stage Comedians were a flop on radio. On the stage, if a Comedian sat on a pin or broke a saucer, he was sure of a guffaw from all over the house. Similarly, if he mentioned a drink, sausages or mothers-in-law, he was quite safe.

However, on the radio the listeners did not see, nor could they always visualise the red nose and baggy trousers of the recognised stage comic and his gags on the air were consequently somewhat vapid or flat.

When 3LO was established in Melbourne by the Broadcasting Company of Australia Pty Ltd following receipt of licence on 22 July 1924, its principal shareholders included Farmer and Co., Ltd who held the 2FC Sydney licence; J C Williamson Ltd, Messrs J and N Tait; Herald and Weekly Times Ltd, and Buckley and Nunn Ltd. With Sir George Tallis as Chairman of Directors, the program policy was considerably influenced by theatrical interests. No doubt this contributed to the success of the station. In the late 1920s, it was the only A Class station in Australia operating at a profit.

High quality programs began from the very start. The opening program when the station went to air on 13 October 1924, included Dame Nellie Melba's farewell performance from the stage of His Majesty's Theatre. The costs of putting on these high quality programs was kept low because of the resources which were available through the good offices of some of the major shareholders. Allan's Music Warehouse, an associate company of J and N Tait, supplied music, records and musical instruments while the Buckley and Nunn Studio Orchestra made frequent broadcasts.

An unusual situation existed at the time, in that some magazines paid considerable sums for the privilege of publishing programs in advance of the broadcasting date. Stations which prepared programs on a day-to-day basis because of financial considerations, therefore missed out on a valuable source of income.

The 3LO management employed only highly talented and respected people as Announcers, and coupled with its popular programs, easily maintained its position as the top station in the State for many years.

The Announcer was well paid for his work compared with Technical staff. When the PMG's Department took over the operation of 5CL in 1929, Announcers wages paid by Central Broadcasters Ltd, were £12 ($24) per week, while the technically qualified Control Booth Operator received only £3 ($6) per week. Even at £10 ($20) the station Chief Engineer was worse off financially than an Announcer.

When the Australian Broadcasting Commission began providing programs for the National Broadcasting Service from July 1932, each State organisation ran its own programs using local resources. However, before the end of that year a degree of program centralisation was introduced with Melbourne and Sydney broadcasting on alternate evenings, a national program to transmitters in eastern States. By the end of 1933, with the availability of program lines between all Capital cities except Hobart, regular programs were relayed between Brisbane, Sydney, Melbourne, Adelaide and Perth. Hobart was not linked into the network until 1936.

With the appearance of television services on the scene, there were predictions that radio broadcasting had run its course and was finished. The long running serials, quiz shows and Sunday night plays of the 1930s through to the 1960s were no longer viable as advertisers deserted radio broadcasting to put their money into television.

To meet the challenge, Commercial broadcasters developed new identities not only to compete for a share of the declining numbers of listeners but to entice back to radio those who had left to follow 'the box'. A considerable amount of money was invested in audience research programs to assist station owners in determining suitable program formats to recover lost ground.

In 1990, although the television share of overall media advertising revenue was 35.5% compared with 8.7% by radio, the radio revenue had shown a slight increase of 0.8%. However, many station profits fell sharply, and some networks began selling off stations and writing down the value of licences.

According to the Australian Broadcasting Authority, by mid 1994, the financial situation of radio broadcasting had improved with revenue being up by 6.5% on the previous year. The nine capital city stations which had transferred from AM to FM bands during the period July 1993 to June 1994, had a much larger increase, with the figure being about 31%. However, over the same period, revenue of the nine original capital city FM stations had fallen by 3.5%.

The national trend towards an Adult Contemporary/Gold Music format continued with some 117 of the 146 Commercial stations then in operation adopting this format or one closely allied to it. Music was the major component of the Public radio formats, although a much wider variety of styles were featured when compared with their Commercial counterparts.

One of the signature tunes associated with early Australian broadcast programming was the sound of the Laughing Kookaburra also known as Laughing Jackass and Bushman's Clock. According to an Aboriginal legend, the Kookaburra's chorus of laughter during early morning 'is a signal for sky people to light the great fire that illuminates and warms the earth by day'.

During the 1930s, it was played each morning by a number of stations to indicate commencement of transmission for the day. In 1931, when the Australian short wave service 'The Voice of Australia' was operated by AWA, transmissions were opened and closed with a recording of the Laughing Kookaburra, a tradition later carried on by Radio Australia but in more recent times only used on occasional programs.

One bird which became famous was Jacko from Watts River in Victoria as the 'Broadcasting Kookaburra'. A recording arranged and produced by Mrs Harold Clapp of the Australian Travel Association was in the library of many broadcasting stations and frequently used. The owner took Jacko on a tour of Victoria, New South Wales and Queensland and during the tour entertained many groups and made a number of live broadcasts from broadcast stations. The story of Jacko is told and illustrated in the book 'Jacko — The Broadcasting Kookaburra' by Brooke Nicholls, published in 1933 by Angus and Robertson Ltd, Sydney.

From the 1930s for a period of more than 20 years, radio enjoyed a dominating role in Australian public entertainment with its musical, variety, quiz, and comedy programs, serials and sport broadcasts.

At the outbreak of the Second World War in 1939, there were at least 24 recording organisations, transcription producers and agencies providing talent and program services for the broadcasting industry. Many Engineers, Technicians and Apprentices were employed in this field on recording and control booth technical duties. Some companies such as George Edwards and Co., and James Raglan and Co., were releasing hundreds of transcription titles over a 12 month period.

During the War years, the importation of overseas scripts and recorded material almost ceased, opening the way for Australian organisations to increase their output even though resources and technical plant were difficult to obtain.

After the War, there was a rapid increase in custom built radio features, particularly in recorded commercial announcements and serials, with new technology being introduced to meet the demand.

However, during the 1960s, with the introduction of television, the dominance of radio as an entertainment media, especially with transcription serial programs began to diminish, and by the mid 1970s, production had almost ceased.

THE PROGRAM CRITICS

Even after more than 75 years of experience, broadcasters are still not able to operate without criticism from listeners, although the ratio of number of listeners to number of complaints has improved considerably over the years.

In the early days of broadcasting, dealing with complaints from listeners occupied an exceedingly large amount of time of administrators. Irate listeners' groups and Radio Clubs maintained pressure on management and the Postmaster General's Department which was responsible for administering the Regulations under which the stations operated.

The term 'listener-in' was commonly used to describe a person who listened to a wireless broadcast program, but in later years, it became shortened to 'listener'.

Some listeners accused the stations of being beyond doubt a hotbed of incompetence and drivel, a home of lost illusions inhabited by dreary people of suicidal tendencies and broadcasters of 'piffle'. One well-known broadcaster commented in 1925, that 'We broadcasters scarcely dare lay our heads to rest for fear that the pillow may contain a dagger, murderously placed there by a disgruntled listener-in. I am severely apprehensive that an indignation meeting is being organised to deal with me when I step out from the studio one of these nights.'

The broadcasters had to cater for such a diversity of tastes of listeners that it was utterly hopeless for any one station to attempt to provide an evening's program that would satisfy and gratify everybody. Sometimes programs were amazing mixtures of incongruities skipping from Grand Opera to red hot jazz, and 'bitzanpieces' to Gladys Moncrieff, without a tremor. No wonder the critics were active.

The appeal of broadcasting to the emotional side of individuals naturally rendered the subject of program criticism so diffuse as to be difficult of analysis.

In 1926, station 3LO Melbourne in conjunction with the 'Melbourne Sun Pictorial' ran a competition in order to find the perfect broadcast program. Well over 1500 entries were received from all over Australia but tastes varied so widely that the only conclusion reached by the judges was that 'there was no such thing as a program that would suit every listener'.

In 1928, 3LO again took up the issue of programs. Listeners were invited to write their frank opinions of 3LO programs and prizes of half a guinea ($1.05) were offered for the best letters of criticism and appreciation. The response was enormous, with letters of criticism far outnumbering those of appreciation.

The half guinea for best criticism was awarded to the listener who wrote as follows:

> 'Holder of Licence 81088, ventures a few comments. He has never written to a newspaper on the subject, but sympathises with those who have done so. 3LO's program is like the curate's egg — good in part, possibly wholesome, but not appetising.
>
> Very often the entertainment is delightful, but not very often. When the listener has been uplifted by some entrancing bit of music, crash comes some banal joke or ditty!
>
> The quality of the program varies too much. Why not improve the transmission of 3AR? Give it all the jazz, sport and frivolous music, markets, steamer arrivals and river gaugings. Keep 3LO for high class entertainment — good music with good artists; and talks by well educated speakers. 3LO should aim at giving listeners better than what is asked for. That is the way to educate and uplift the public taste. Never, never "give 'em muck", even though they ask for it.'

An analysis of many of the other letters complaining about the services included a number of complaints of a technical nature. They included improper level control at the studio, blasting of microphone by singers and bands, bad control of transmitter modulation, low transmitter power output, high record scratch level, high distortion during violin programs, inefficient aerial systems, improper use of microphones during Church broadcasts, rustling of papers by Announcers, excessive delays between end of speech and playing of gramophone, frying noise from microphones, cheap needles employed for playing records, low signal during rainy days, hum level too high, and others.

Strangely, the half guinea for the best letter of appreciation did not go to a local listener. It went to a listener at Ceduna, some 1200 km from Melbourne on the road to Perth. He wrote:

> 'I have listened to 3LO's programs almost solely for two and a half years. Here am I more than 500 miles west of Adelaide, nightly enjoying first class programs week after week, year in and year out. What a wonderful thing wireless is!
>
> Every Saturday evening my home is the rendezvous of several friends who, being less fortunate in not possessing a receiver, come to enjoy a little of what the city folk enjoy in reality.
>
> The educational talks, orchestral music, the "Old Time Nights" and the wrestling descriptions probably appeal to me more than any other items of the programs and I consider them wholly enjoyable. The Program Director of 3LO must possess an organising ability and versatility that are uncalled for in any other vocation.
>
> My best wishes are with 3LO who, receiving no share of my licence fee, supply me with programs that are always full of enjoyment and value.'

During the 1920s and 1930s, children were entertained by their radio 'Aunts' and 'Uncles' and other colourfully named identities such as Bobby Bluegum, Little Miss Kookaburra, Jackoo, Professor No-all, Nicky and Tuppy and many others. These children's sessions in the main comprised stories, recitals of poetry, jokes, riddles, singing, plays and birthday calls. Management was somewhat loathe to put on programs which had an air of education about them. Children often wrote letters saying they 'listened to the teacher all day and wanted only amusement from the radio'.

With the establishment of the Australian Broadcasting Commission in 1932, listeners to the A Class stations at least were given a wider choice for their licence money. By the use of national relays the Commission was able to provide economically, a wide range of programs. Alternative programs were available for those of varying tastes. During the first six months of its control, the Commission provided studio presentations of nine grand operas, five light operas, three musical comedies, three comic operas, nine musical plays, thirteen reviews, twenty five dramas, sixteen comedies, two pantomimes, nineteen symphony concerts, eleven classical concerts in addition to many special features such as cricket Test Matches between England and Australia and the short wave relay of the King's Christmas message.

Very little of the program time was devoted to talks. The Commission saw no merit in talks and also they were concerned that many topics could raise the eyebrows of politicians. It was tactful to play music. Plays were heavily censored. Such words as 'hell', 'bum', 'damn', 'cripes' etc. were taboo. The Commission considered itself the watchdog to ensure that no offence was given to listeners. It did not intend to insult 'decent Christian people', least of all in their own homes.

However, this apparently had little effect on the critics. They still made known their opinions at every opportunity. Some wrote direct to the Commission, some wrote to newspapers or various radio magazines such as 'Listener-in' and 'Wireless Weekly' while others took the matter up with the Radio Inspector or visited the Commission offices to make known their opinions. In the Commission's first year of operation, nearly 190000 letters were received from listeners — an average of 100 per day per State. The letters dealt with various aspects of program compilation, administration, subject matters, bias, poor presentation, and technical matters. The Commercial or B Class stations also received a lot of mail, particularly in relation to advertisements.

More than 50 years after the commencement of broadcasting, listeners were still complaining but the number of letters had dropped considerably compared with earlier years. In 1977, only 26 letters were received by the Australian Broadcasting Tribunal from listeners throughout Australia. The main themes were poor taste, excessive sport, unsuitable recordings, bias in news and current affairs and objections to specific programs.

Today, the ABC is guided by the ABC National Advisory Council in relation to program matters. Council's advice on programs and feedback from the community is considered regularly by the Board. During 1992–93 the Council held forums on broadcast standards in Sydney and Canberra and Council provided a report to the Board on community responses to the ABC's handling of sensitive issues. Some of the radio broadcasting issues concerned Children's Programs, Journalism Education, Program Standards, Contact Lists for Opinions, Triple J, Radio National, Regional Radio, Parliamentary Broadcasts, Cricket Broadcasts and Extension of the Transmitting Station Network.

Within its organisation, the ABC has an Independent Complaints Review Panel to review written complaints of serious bias, lack of balance or unfair treatment arising from ABC broadcasts.

The Australian Broadcasting Authority is the Government watchdog to deal with complaints relating to actions under licences and class licences and also relating to National broadcasting services which includes the ABC and the SBS.

Over the 1994–95 financial year, the Authority handled about 30% more complaints than in the previous year. Complaints related to radio broadcasting included 441 concerning Commercial radio, 231 ABC radio, 126 Community radio, 12 SBS radio and 21 Open Narrowcasting radio.

With regard to complaints handled by Commercial radio stations where the complaints are made directly to the stations, the Commercial Radio Code of Practice and Guidelines requires each Commercial station to provide the Federation of Australian Radio Broadcasters (FARB) with an extract of the record of complaints. FARB provides a consolidated report to the ABA.

During the final quarter of 1996, 305 complaints were lodged in relation to Commercial radio. Of the total, 105 concerned offensive matters with 77 of the complaints being associated with talk-back and discussion type programs.

For more than 20 years from about the mid 1930s until the mid 1950s, radio drama was by far the most listened to program on radio, drawing enormous and appreciative audiences. Programs such as Lux Radio Theatre, Macquarie Radio Theatre, Caltex Theatre, George Edward Players and others had wide family appeal.

The Sunday night Lux Radio Theatre went to air in Australia on 19 March 1939 over 2GB and the Macquarie Network. Len Schultz Chief Engineer 2GB was responsible for technical facilities associated with the broadcast. Initially, 2GB had no auditorium at its studios at 29 Bligh Street, Sydney so the program was presented in the 2GZ Sydney auditorium before large audiences.

In 1941, the program was broadcast by 2UW and the Commonwealth Network.

Dad and Dave recorded by Columbia Graphophone (Aust.) Pty Ltd with George Edwards as the star, rated very highly from 1937 when it started until 1953 when it ended, when Edwards died.

In 1939, Columbia where Reg Southey was Recording Engineer, had the largest recording studio in the Southern Hemisphere. The area contained three recording studios, two control rooms, reception rooms, offices, Engineers quarters, and technical process rooms. The huge factory contained 26 high speed presses. Technical equipment employed had been developed in the Columbia Research Laboratories in England.

Unfortunately the introduction of television had a major impact of broadcast of radio drama programs. Production of radio drama programs for Commercial stations ceased in 1964, but the ABC kept production going until early 1980 when it too ceased making these programs. However, in 1993, an attempt was made by the ABC to reintroduce radio drama to the listening audience when it recorded a series of twenty 10 minute episodes.

Technical Improvements

By 1929, considerable improvements had been made in the technical facilities. New types of microphones were available, electric pick-ups were in widespread use for playing records and good quality amplifiers were available for studio and outside broadcast work. Most studios had permanent links to churches, town halls, sporting grounds and other places for outside broadcast purposes.

On the formation of the National Broadcasting Service with the technical facilities being provided and maintained by the PMG's Department, the Department made considerable use of its Research Laboratories in improving and developing new facilities. When it took over the A Class stations, most of the equipment was in a run down condition. It was very dissimilar between stations and was far from standard. The question of standardisation and ease of operation and maintenance were early priorities.

Control Booth Operators are seldom employed now, except at large studio complexes, but in earlier days they played an important role before the advent of limiters and other level control amplifiers. It was not unusual for the transmitter to be over modulated if the Operator was not closely monitoring the program. At one transmitter the Heising choke flashed over and set fire to cotton covered insulation on adjacent cables when the sound of a loud clap of thunder produced by the sounds effect man during a play, hit the transmitter at high level.

Although level indicators were provided to assist the Operator in his work, he had to exercise considerable care and judgment if a loss in quality of the program was to be avoided.

Advancements in technology played a major part in assisting the programmers to produce programs of improved quality. For example, with the availability of portable tape recorders in the 1950s the character of radio documentary was changed from being a structured studio feature to on-the-spot reporting complete with sound effects. Portable radio transceiver equipment played a similar role by enabling direct broadcasts from aeroplanes, ships and roving OB points. Improvements in international communication circuits enabled new programs to be introduced by including overseas sources. Up until about the early 1960s, reports from overseas correspondents were transmitted over international short wave radiocommunication circuits and even at the best of times were of inferior quality because of fading, atmospherics etc. With the commissioning of new submarine cable circuits particularly Compac and Seacom, the producer had available high quality circuits free from fading and with low noise levels. Just as the submarine cable replaced the short wave radio circuits for overseas program material, so the cable in turn was superseded by an improved radio circuit with the introduction of the satellite system giving the producer a facility of even better quality.

Radio Frequency Interference

A major problem which early studio designers had to face was interference from radio frequency radiation. In many cases the studio, transmitter and aerial were located together, usually on top of a building. The unscreened transmitter and overhead aerial system produced high level voltages which caused problems with low level speech input equipment. The RF radiation also caused other problems. At 4QG Brisbane on at least one known occasion during a large social gathering in the studio, the elaborate room decorations fell to the floor when the steel support wire was burnt through as a result of excessive heating from a high circulating RF current.

At some stations, the studio equipment was separated from the transmitter and installed in a screened room. Typical screening comprised galvanised wire netting with adjoining sheets being soldered together at short intervals. The netting covered all walls, the floor and the ceiling as well as windows and doors. The netting on the door opened with the door, but when the door was closed, the netting formed a complete circuit with the remainder of the wall screen. Except for the windows, the netting material was usually covered with wallboard or other suitable material. In the floor, it was either laid under the carpet or imbedded in concrete. The screen was tied to the station earth system by a lead of low inductance, frequently a flat metal strap. Loudspeakers located outside the screened area were frequently difficult to cut off entirely when the monitoring amplifier was left switched on. The input circuit of the amplifier often acted as a detector of the high level RF carrier and produced an audio program in the speaker, even though the monitor feed was switched off at the studio control point.

When 6WF was commissioned on 4 June 1924 with studio and transmitter being located together on the fourth floor of Westralian Farmers Building in Perth, the main studio dimensions were 6.7 m by 9.1 m and the room was completely surrounded by sheet iron with all sheets being electrically bonded together. At a suitable point the metal surround was connected to the station earth by a low impedance copper strap.

Such was the closeness of the studio facilities to the transmitter at some installations, that the Radio Inspector in his Report following an inspection of 4GR Toowoomba in 1932, recorded in the column 'Distance of Studio to Transmitter', that the distance was six inches (15 cm).

Emergency studios at transmitting stations were also shielded but because they were seldom used and not used by the public, a more economical installation was provided. For example, the galvanised wire netting covering walls and ceiling was left exposed and not covered as for a normal studio.

Studio Equipment

Initial Facilities

Initially, the studio and control facilities were few and generally comprised a microphone, a switchboard much like a telephone switchboard for outside broadcast lines, a level indicator, amplifiers, equalisers, and a horn type loudspeaker or headphones for monitoring purposes.

Many Engineers built their own microphones and speech amplifiers to various circuit arrangements described in technical magazines. A typical amplifier for a carbon microphone employed two triodes in a choke or transformer coupled arrangement. All power supplies were provided from batteries.

The level indicator connected after the speech amplifier, employed a sensitive galvanometer in the anode circuit of a valve amplifier. A level measuring key for large steps and a level measuring switch for small steps, connected in the grid circuit were calibrated directly in Transmission Units (TU) from zero level of volume.

Some of the early A Class stations which commenced transmissions during 1924–25, for example, 4QG and 6WF operated with the studio and transmitter located on a common floor. This simplified the arrangement for amplification of the studio signals and supply of these to the transmitter input equipment. In the case of 4QG, the speech amplifier was located on the studio control panel and comprised a three stage choke capacity coupled amplifier type Western Electric 8A, employing valve types WE102D in the first stage, WE102D in the second stage and WE205D in the third stage. Filament supply was provided by a 12 volt battery and anode supply from a 150 volt battery.

Meters were provided for reading anode and filament currents, this being done by patching into appropriate jacks with a flexible cord.

Keys were fitted to the amplifier panel for the purpose of selecting the points from which the input to the amplifier was obtained. By throwing the keys to the appropriate positions, the input could be obtained from the following pick-up points:

- Studio microphone No. 1.
- Studio microphone No. 2.
- Reception Hall microphone.
- Switchboard pick-up point.
- Time signals.
- City Hall chimes.
- Gramophone pick-up (not provided initially).

Controls were provided as follows:

- Main gain potentiometer, used when transmitting from the studios or the reception hall.
- Potentiometer controlling input from outside pick-up point.
- Volume control for gramophone pick-up.

A Volume Indicator was provided for indicating the output level of the amplifier. Operating instructions to the Operator, stated that 'the output of the amplifier should be kept as high as possible without overloading the transmitter modulator'. The overload point was indicated by a red mark on the meter.

Facilities also included an EMMCO monitoring amplifier using E415 and 171A type valves in push-pull circuits. It was fed from the studio amplifier and had switches which allowed feeds to be supplied to the studio Operator, the studios, the reception hall and the office. It was powered by the 240 volt AC mains with high tension DC being provided by a full wave rectifier employing a UX280 valve.

The proper control of signal level to the transmitter or to line where the transmitter was located remote from the studio was an important function of the studio Engineer. At the time, the Announcer had no means of monitoring or controlling the level. The following procedure recommended by Standard Telephones and Cables for studio equipment they designed and manufactured about 1927 is typical:

'Adjustment of the volume will be necessary not only between the items but also during the actual performances. The latter may be occasioned by a sudden change of the Artiste's position or by inexperience on the part of the Artiste of the conditions peculiar to broadcasting. It is found in these circumstances that unduly large fluctuations of intensity occur resulting sometimes in insufficient modulation and sometimes in excessive peaks. The necessary adjustment is made by means of the Gain Control Potentiometers. The two potentiometers are operated jointly to obtain the coarse adjustment and either one of them independently to obtain the fine adjustment. They should be set so that during the normal maxima of intensity, the galvanometer needle gives a kick of 30 divisions (up to the red zero position on the scale) on the average once every 10 seconds. Smaller fluctuations occurring more frequently and occasional larger deflections may be ignored.

The object of making the adjustments described above is merely to avoid objectionable extremes and the greatest care is necessary in monitoring a piece of music not to destroy the Artiste's interpretative rendering, by eliminating contrast. Considerable discretion must therefore be exercised by the Control Operator who should certainly understand music and might with advantage follow the musical score.'

An equaliser was provided to correct the poor frequency response of the OB lines. It comprised a variable resistance connected in series with a parallel circuit of inductance and capacitance. The whole network was bridged across the line and adjusted to improve the line frequency response characteristics. The network was also sometimes employed at some stations to accentuate the frequency characteristics of the studio speech input equipment over the range 40 to 1000 Hz because of the poor performance of typical home loudspeakers in use at the time.

A variable attenuator or line pad was provided for OB work to reduce the incoming line level, if necessary, to correct level before passing it through other studio facilities to the transmitter. For a typical studio microphone such as in use at 6WF in 1924 with a Western Electric double button type, a microphone switch was fitted near the observation window between the studio and the control room where the Western Electric Control Panel was located. Operation of the switch activated the microphone and also two small lamps. The studio lamp indicated to the Artist or Announcer that the studio was on air, and the one in the control room alerted the Operator to monitor the level. The 6WF studio facilities also included a relay and gong associated with the broadcast of the time signals from the Perth Observatory. The studio relay was operated remotely by the Observatory time gun. Initially, the time signal was broadcast at 1 pm and at 8 pm.

Although facilities were available at most studios for monitoring the program by taking a bridge from the output of the line amplifier, Technical staff preferred off-air monitoring as it enabled them to check the transmitter performance at the same time.

At 3LO in 1925, where the studio was located on the second floor of Cambridge Building in Collins Street, Melbourne, an aerial supported by two white painted wooden poles was erected on the roof of the building and fed a two valve receiver tuned to the transmitter operating frequency.

Control Engineer-in-Charge of the 3LO studio technical facilities was Frederick S Stevens. Fred began his career in radio as a Marine Operator in the Naval Transport Service during the First World War. He served for about a year at the Fanning Island Submarine Cable Station in the Pacific Ocean. He left his ship 'Levuka' in 1924, and took up appointment as Studio Control Engineer at 3LO. During 1934, he made an overseas visit on behalf of his employer, Amalgamated Wireless (A/Asia) Ltd to study latest developments in Broadcasting Technology. In 1937, Fred was appointed Engineer-in-Charge responsible for studio equipment of Commercial station 2CH Sydney in York Street. The station was operated by AWA and studio facilities included three studios, with most of the equipment being of AWA manufacture. He subsequently became station Chief Engineer.

At 5DN Adelaide during the mid 1920s, the transmitter and studio were located on adjacent blocks, and Ern Hume, in charge of technical operations for his father's station used a locally constructed receiver and a short wire aerial to monitor the program off air. The receiver was built in the workshops of the Adelaide Radio Company whose Manager Lance Jones supplied the transmitting equipment.

THE LATE 1920S

Facilities in service at 7ZL Hobart in 1927 were typical of those at the smaller A Class metropolitan establishments at the time. The equipment included a control board comprising three panels.

Each of the two studios was allocated one full panel for access to facilities and the third was used for outside broadcast work. A five valve Udisco receiver with horn type loudspeaker was provided for off-air monitoring of the transmitted signal.

Included in the panel equipment was a three point fader system used for balancing purposes during live broadcasts of an orchestra or a band. There were two three stage amplifiers for amplification of studio signals before transmission to line. A portable three stage amplifier was available for outside broadcast work and a further amplifier was installed in the studio for use when long distance OB lines were being used. In all, there were 26 lines connecting the Post Office trunk room at the GPO to the studio with 14 circuits being permanently connected to various places such as churches, dance halls, sports ovals etc.

The studio was linked to the transmitter by three circuits accommodated in an eight pair cable via the local telephone exchange main distribution frame.

Faders provided in the control room to enable smooth change-over to be made involving microphones, gramophone pick-ups, outside broadcasts etc., were double arm constant impedance types. This arrangement was employed to minimise changes in the frequency response of the whole system with different positions of the faders.

Most studio control rooms had a patch panel on which was mounted several sets of jack strips. In a well designed installation the entire wiring arrangement was subdivided at break jacks in such a way that every portion of equipment could be quickly tested separately and spare units patched-in, should a fault occur during transmission.

About August 1927, Western Electric 8B Speech Input Equipment was installed at the 3AR studios at Leonard House, 44 Elizabeth Street as part of a station upgrade project.

Basically, the equipment consisted of three racks of equipment located in the control room, a control cabinet and condenser microphones in the studio, and a battery system with charging facilities. The panels on the racks mounted amplifiers; volume indicator for visual monitoring; a meter panel for the testing and adjustment of the equipment; condenser microphone control and mixing circuits; relays for switching and outside line signalling; control panel for the studio control system; jacks for patching and testing equipment; fuse panel for battery circuits and a high voltage rectifier with associated resistances for supplying DC to the anode circuits of valves of amplifiers and the volume indicator valve, and polarising voltage for the condenser microphone. The arrangement catered for the use of three microphones in the studio and one in the control room, but facilities could be easily changed to cater for other combinations.

The No. 1 rack, or Amplifier Panel, included the line amplifier, monitoring amplifier, the volume indicator and the meter panel. The rack also catered for a power amplifier and a volume control panel for operating several loudspeakers in studios and reception rooms.

The No. 2 rack, or Miscellaneous Equipment Panel, included relays of studio control equipment, apparatus units, order wire lamps, low level jacks, high level jacks, remote line jacks, mounting plates and potentiometers associated with the condenser microphone amplifiers.

The No. 3 rack, or Power Panel, included battery fuses; rectifier for supplying high voltage DC to the anode circuit of valves in the amplifiers, the volume indicator, and for the microphone polarising voltage; mounting plate on which was mounted Ward-Leonard resistances for adjustment of various DC voltage requirements; capacitors used in filter and order wire drop circuits; and retardation coils used to supply battery and ground, and to interphone circuits, and part of the filter system of high voltage supply to the condenser microphone and associated amplifiers.

Storage batteries were installed to supply power to relays, signal lamps and valve filaments.

The main or line amplifier used to amplify the program from microphone or OB circuit to the program line to the transmitter, was a three stage amplifier using 102E type valve in the first stage and 205D type in the other two stages. A 22 step potentiometer mounted on the front of the amplifier and connected in the grid circuit of the first stage valve was the main gain control of the speech input equipment.

The monitoring amplifier was a single stage unit with a 205D valve with capability of operating two WE 540AW double cone loudspeakers. Station Chief Engineer at the time was David Cameron.

When new studios were provided for 2FC Sydney and officially opened by the Governor of New South Wales on 30 April 1928, the contractor, AWA, provided state-of-the-art technical equipment. The studios had previously been on the roof of Farmer's Departmental Store with the new facilities being established in Market Street, in premises adjoining Her Majesty's Theatre. The Architect designed the accommodation along Old English lines employing domed roofs and walls of cellotex finished throughout with beams and panels of burnt wood. The system of wall drapings used in early studio designs were not part of the new design. Three studios were commissioned. Number 1 was 6.7 m by 7.4 m, Number 2 was 15.2 m by 6.4 m and Number 3 was 7.6 m by 6.4 m.

The technical control room was located between main studios and occupied an area of 4.5 m by 4.4 m. The 200 line Private Branch Exchange was also located in this room.

When 2FC began operation in December 1923 it had six lines available for outside broadcast work but with the new studios, there were 97 OB circuits available.

Noteworthy programs provided over OB lines up to the time of occupying the new studios included, first broadcast of Parliamentary proceedings; arrival of American fleet which was met by a steamer equipped with a radio link to the studios; Great Public Schools regattas 1925, 1926, 1927 and 1928 broadcast from the Parramatta River; broadcast from first train to run underground; Prime Minister's policy speech trunked from Dandenong in Victoria; first broadcast of a church service, April 1924; first broadcast of a complete Gilbert and Sullivan Opera, and others.

John Holland of AWA was one of the Technical staff who participated in many broadcasts from OB points, with Eric Burbury AWA Engineer carrying out functions at the studio end of the circuits.

By 1929, following telephone transmission practice, studio technical facilities, except that fitted to a console or desk, were at some studios accommodated on standard steel channel racks and generally designated as Speech Input Equipment. A typical installation comprised three racks and contained the necessary amplifiers, level indicators, meter panel for testing and adjusting the equipment, relays for switching and outside line signalling, the control panel for the studio control system, jacks for switching and test purposes, fuse panel for battery circuits and the high voltage rectifier for valve anode circuits and condenser microphone polarising voltage.

At the time, all steel channel equipment racks as used in the National Broadcasting Service were assembled using rivets or nuts and bolts. Welding was not employed in the manufacture of the racks. When program input and emergency studio racks were being installed at 5CK Crystal Brook during 1931–32, there was no AC power available on site at the start and all drilling work associated with racks, transmitter installation and aerial work was carried out using hand operated drills.

Until about 1935, studio equipment was mostly powered by battery installations due to the unavailability of suitable valves with low AC hum level characteristics.

Prior to conversion to AC operation on 10 July 1935, the Adelaide studios of the ABC employed a system of A, B and C batteries. All equipment except gramophone motors was operated from the system. In the event of AC mains failure, a spring-drive turntable was accessible in the control room. This turntable had been provided to enable the control Operator to reproduce test records before the beginning of each session.

Details of the battery installation are as follows:

- A Batteries.
  The filament supply for valves of the amplifier units was obtained from two 12 volt accumulators. The capacity of the main unit was 290 ampere hours at the 10 hour discharge rate, while the capacity of the second unit was 120 ampere hours at the 10 hour rate. The schedule of charging and discharging of the two units was arranged to maintain the maximum possible capacity available for emergencies.
  The cells were in glass containers mounted on standard battery racks. Separate 6 volt accumulators of 120 ampere hour capacity were provided for the condenser microphone amplifier valve filament.
- B Batteries.
  The anode supply for the valve of the main amplifiers was provided by two 350 volt accumulator system of 5 ampere hours capacity.
  They were in ebonite cells and were normally operated in parallel on a full floating basis. Provision was made for operating either group separately or on a charge/discharge basis should the necessity arise.
  A single 130 volt accumulator system was provided for the anode supply of the condenser microphone amplifier valve and for test equipment.
- C Batteries.
  A grid bias supply was provided by dry cells mounted in each case on the equipment racks close to the amplifier units.

A battery charge/discharge panel catered for all battery requirements. Rectifiers were Westinghouse copper oxide types for 12 volt A batteries and 350 volt B batteries.

The microphone A battery was charged by a Westinghouse Rectox thermionic valve rectifier while the B battery was charged by a Philips 1002 type rectifier.

THE 1930S

Facilities installed at 3BA Ballarat when the studio was commissioned in 1930 are typical of those installed at Commercial stations at the beginning of the decade. The facilities included locally made Reisz microphones, automatic warning lights, double turntables for standard records, 18 inch (45 cm) turntable for transcription discs, Westminster chimes clock and a radio receiver. Telephone lines from outside points, the mixing panel for the studio microphones, gramophone turntables, studio amplifier and splitting amplifier were arranged along a control table immediately under the Operator's window at the studio. The power supply for the amplifiers comprised accumulators for valve filaments and DC mains for high tension.

Another station commissioned during 1930 was 4BK Brisbane. The studio equipment was designed and built by Chief Engineer Arthur Dixon assisted by Bob Browne. The Announcer's desk was a hinge type desk fitted with two turntables, pick-ups, microphone, amplifier cabinet and control switches. Outputs from amplifiers were fed to line via a double pole switch under Announcer control to provide selection of Announcer's microphone, guest microphone, left or right pick-up and outside broadcast line. The switch contacts also controlled 'silence' and 'audition' lights on microphones, monitoring panel and studio entrance door.

The main speech amplifier was designed to ensure maximum flexibility. Input was via a Ferranti AF transformer with the speech amplifier employing three valves, comprising Mullard PM6 coupled by an AF transformer to a Mullard AC4 valve which in turn was coupled to a Mullard DO/60 submodulator. The amplifier panel incorporated a mixing panel catering for four outside broadcast circuits as well as the studio facilities. The panel accommodated three Ferranti meters, line switches, monitoring jacks, controls and feeder knobs. The cabinet was enclosed by an oxidised copper shield to provide RF shielding from the high field from the nearby transmitter and overhead aerial. All of the components required to construct the unit were obtained from Edgar V Hudson Ltd, one of the owners of the station.

The A, B and C power supplies for the studio and speech amplifier were derived from Clyde 200 ampere hour A battery and Exide B and C batteries. Battery charging equipment was provided adjacent to the battery benches.

When local studios were provided for the 4RK Rockhampton transmitter in 1931, facilities were provided in a room of the Rockhampton Post Office. STC, who supplied the transmitter, also provided the studio equipment. It was similar to emergency equipment provided at the transmitter with all amplifiers being battery powered and using STC valve types 4102D and 4205D. The microphone was the standard Western Electric condenser type with the amplifying valve and condenser unit being housed in a polished wooden box. Record playing facilities in the form of two turntables were provided with Western Electric oil damped pick-ups. These pick-ups were operated by the control room Technician on signal from the Announcer.

During the mid 1930s, steps were taken to convert some studio amplifiers to full AC operation. One of the first studios to be converted was 5CL Adelaide in July 1935. Prototype amplifiers employed valve types 77 and 89, both designed for low AC hum level, but in the final installation, type 6C6 valves were used.

Station 3GI Sale, the first regional station of the National Broadcasting Service in Victoria was provided with a small studio in Sale when the station went to air on 31 October 1935. The greater part of the station program was normally provided from the Melbourne ABC studios, but the local studio provided regular programs of local interest. The studio was of size sufficient only for short program segments but had suitable acoustic treatment for the purpose. The whole of the technical equipment was installed in the same room as the Announcer's facilities and operated from the local AC mains. The facilities included an Announcer's desk and one rack of equipment.

The Announcer's desk included a key switching panel with four-point fader and mixer unit for controlling microphones, gramophones and program circuits; two moving coil microphones; two self-starting synchronous turntable units for 78 RPM and 33⅓ RPM records; two WE type 4A gramophone reproducers and equalisers, loudspeaker and headphone monitoring units and a telephone.

The rack accommodated a single stage preamplifier, a four stage resistance/capacitance coupled control amplifier for amplifying the output of the fader mixer unit, a single stage high impedance channel amplifier and a two stage high impedance monitoring amplifier. The overall maximum gain from control amplifier input to channel amplifier output was about 87 dB.

By 1937, studio equipment had been fairly well standardised, even among the many Commercial stations, and a number of manufacturers were producing complete studio facilities and systems. One such manufacturer was Lekmek Radio Laboratories, Sydney, and the equipment the firm provided for 2MW Murwillumbah is representative of facilities employed by a relatively small broadcasting station at the time.

Facilities included an Announcer's desk fitted with a control panel, two turntables, pick-ups, microphones and an amplifier rack. The studio building layout provided for combined talks studio and control booth and a larger studio for program presentation. The amplifier rack was located in the talks studio. Incoming and outgoing outside broadcast lines were terminated on the amplifier rack so that a complete program of any type could be equalised, amplified, monitored and fed to the transmitter program line.

The Announcer's control panel provided for mixing of five audio input channels, two microphones, two pick-ups and one OB line. In addition, provision was made for switching and controlling the monitor speaker. A master gain control and a volume indicator were also provided. The latter was fitted with a level amplifier so that the program going to the transmitter line could be monitored around any desired level.

Microphones were Western Electric non-directional moving coil types fitted with indicator lamps built into the stands. The outputs from the microphones were taken direct to independent 30 dB preamplifiers through 50 ohm cables. The preamplifiers used two 6C6 type valves as triodes, in a transformer coupled push-pull arrangement. After amplification, the signals were taken to the control panel through 300 ohm cables for fading and mixing.

The record playing equipment consisted of dual speed turntables and RCA transcription lateral pick-ups fitted to bent arms for reduction of tracking error. Outputs of the pick-ups were fed to equaliser networks to ensure electrical output from any recording was substantially linear from about 50 Hz up to the top limit of the recording. After equalisation, the pick-up outputs were fed to fader controls on the panel. The OB line was also provided with fader control.

The amplifier rack equipment included low level amplifiers, line amplifiers, monitor amplifiers, splitting amplifiers, splitting amplifier control and power supply equipment for the entire audio and signalling equipment. All amplifying equipment was operated from alternating current power supply.

Other companies which equipped Commercial stations with full studio technical facilities included Amalgamated Wireless (A/Asia) Ltd, Sydney; Colville Wireless Equipment Co., Pty Ltd, Sydney; Transmission Equipment Pty Ltd, Melbourne; Philips Lamps (A/Asia) Ltd, Sydney and others. Many distributors provided specific equipment items only, and included A M Clubb and Co., Sydney; ETC Industries Ltd, Sydney; Internationoal Radio Co., Pty Ltd, Sydney; Wm J McLellan and Co., Sydney; Raycophone Pty Ltd, Sydney and others.

During the mid 1930s, considerable effort was put into the development of equipment which would provide increased service area coverage of the station without increasing the transmitter rated carrier power or changing the aerial system. This work led to the introduction of 'peak limiter amplifiers', which was one way of achieving the objective.

One of the early manufacturers to commercially produce a suitable amplifier was Colville Wireless Equipment Co., Pty Ltd, Sydney which announced in early 1938, the availability of The Colvillco Peak Limiting Amplifier which would provide the following advantages:

- A practical increase in power output.
- A service to present poor and dead areas.
- Improved reception in secondary areas.
- Improved quality and volume generally.
- Eliminates the need for constant supervision of monitoring.
- Prevents transmitter overmodulation.

Not all Commercial station entrepreneurs could afford to start off with a professionally manufactured and commissioned turn-key facility. Some went to air with minimum equipment, and with plans to improve as the business became profitable.

In 1937, when Metropolitan Broadcasters Pty Ltd decided to establish studios in Clebourne House, Murray Street, Hobart for their station 7HT, Chief Engineer Gil Miles formerly of 3AW Melbourne, and Technician Norm Stone who was on his first job following graduation from the Melbourne Technical College set about building the technical facilities from purchased items.

The main studio was in a rented portion of the photographic room of Beatties Studios with the separating wall being inadequate for sound isolation purposes. The dark room operator had to work silently every time the Announcer opened his microphone to broadcast. It was four months before the situation was corrected.

A studio control room was not provided initially due to a shortage of funds so for the first year of operation, program level control had to be handled by the transmitter staff located out of town on Rosny Hill.

The Announcer's main desk housed twin Garrard 78 RPM turntables and Garrard pick-ups using steel needles which had to be replaced after playing each record, an RCA ribbon microphone, a control panel and a set of gongs. On a side table in an L shaped layout, twin turntables known as the 'Green Flyers' were mounted for playing recorded serials on 33⅓ RPM records. A GR microphone on a stand was provided for interview purposes. More microphones, including hand held types were later provided when funds became available.

When the Tamworth Radio Development Co., Ltd commissioned 2TM Tamworth on 27 February 1935 with transmitter, control room and one studio in Manilla Road Tamworth, it broadcast 7–9 am, 11–2 pm and 3.30–10.30 pm, using a 50 watt transmitter on 201 metres.

The licensee was originally allocated callsign 2WO but this was changed to 2TM prior to the station going on air.

Technical staff comprised Tom Whitcomb Chief Engineer and F Potter. Tom was also a Director of the company. However, within about two years of beginning transmission, additional facilities were installed at new studios in 312 Peel Street and a new 2000 watt transmitter Type KVF2/4 manufactured in Australia by Colville Wireless Equipment Co., under licence from Philips, Holland and installed at Duri. Technical staff then numbered four, and the total station staff, 25 people.

The studio technical facilities were constructed by station staff with program production facilities including a four turntable console unit and a portable control turret with provision for three microphone channels, with capability for setting up three additional channels if required. Studio 'A' was equipped with two turntables and a turret providing control of a remote microphone and one incoming OB or relay circuit. Equipment in the control room allowed for 15 incoming lines for telephone, local OB circuits or relay program lines. A number of facilities were provided to allow for auditioning purposes.

By that stage, transmission hours had been increased to cover the period 6 am to 11 pm.

In 1956, the business became a Proprietary Company.

In 1975, 40 years after establishment of 2TM, transmission hours were 5 am to 1 pm, studios were at Radio Centre, Calala, Tamworth and a 2 kW transmitter was in service at a site in Goonoo Goonoo Road.

Station Chief Engineer Tom Whitcomb had been involved in the commercial side of the radio industry since 1925 when he worked in the Radio Department of the Australian Branch of the British General Electric Company marketing Gecophone brand receivers and components. While working with the company, he toured New Zealand as a Radio Consultant, training staff in BGE offices in New Zealand.

In 1928, he left BGE to join the Australian General Electric Company as Country Representative but later transferred to the Technical Department where he worked for about four years before resigning to be a Director of Tamworth Radio Development Co., Ltd and to construct the technical facilities for the station. In 1941, Tom became a Member of The Institution of Radio Engineers (Australia).

Up until 1937, only Sydney and Melbourne had two transmitters to enable the ABC to provide alternative programs to local metropolitan listeners. However, during 1937–38 additional transmitters were provided in Brisbane, Adelaide, Perth and

Hobart. This enabled the ABC programmers the ability to provide two sets of programs for all State capital cities.

As the content of program material from Sydney and Melbourne increased, it caused some concern for Adelaide and Perth ABC Managers mainly because of time differences. Perth also had a program line problem. Although a standard radio program line, the ABC considered it not up to their standard for classical music.

Mainly because of these concerns, the ABC Manager in Western Australia was allowed more initiative than Managers in the other smaller States. For this reason, 6WF and 6WN needed more capacious studios compared with others, so in 1937, a new Broadcast House in St Georges Terrace, Perth was opened to replace the old Westralian Farmers Building studios at Cnr Hay and Milligan Streets which had been used to provide 6WF programs since 1924.

The new Broadcast House was the only ABC building in the country designed specifically for broadcasting purposes. The ABC followed this by acquiring land to build new studios in Forbes Street, Sydney; William and Lonsdale Streets, Melbourne; and Hindmarsh Square, Adelaide.

By the time the two ABC outlets had been provided for all States, Engineers of the Postmaster General's Department who were responsible for design and provision of the technical facilities, had standardised on studio technology. Hec Adams, Engineer in the Department's Head Office, played a leading role in the work.

Facilities provided in operating areas included:

- Announcer's Console.
  Keys for selection of two microphones (Announcer and Speaker) and two turntables; outlet switching; loudspeaker and headphone monitoring; keys for switching OB lines and time signals into the program; telephone answering key; talk back to control room; lamp display showing outlets in operation.
- Control Booth Console.
  Talk back to studio, switchroom and other selected points; telephone answering key; keys for selecting and mixing multi sources; signal level control fader; overmodulation indicator; keys for switching studio outlets; monitoring loudspeaker and headphones; switching OB to studio and feeding program back along line; lighting 'ON AIR' display when studio on air; lamp signals to Announcer to show which outlets were ready to accept broadcast.
- Switchroom.
  Presetting all circuits for switching outlets from one source to another; preparing OB circuits for broadcasting; talkback to studio booth Operators recording rooms, OB lines and carrier trunk room; routine performance tests on studios and OB circuits; monitoring of incoming and outgoing programs; switching automatic signals such as time signals.

Switchroom facilities were mounted on standard telephone channel iron racks and included line terminating rack, switching relay rack, amplifier rack including volume control and level meter, branching amplifier racks, test equipment rack and power distribution rack.

Test equipment in the switchroom comprised noise and distortion measuring equipment, beat frequency oscillator and line testing equipment.

Each studio had amplifier racks which housed four pre-amplifiers having a gain of 25–30 dB, an A amplifier of gain 45 dB, a B amplifier of gain 45 dB and power capability of 250 milliwatts, and a C amplifier with gain of 30 dB and power 3 watts for monitoring purposes. The design of the amplifiers allowed for transformer input and transformer output with intermediate resistance-capacitance coupling between stages. All input transformers were astatically wound and provided with electrostatic screen between primary and secondary windings.

Loudspeakers were cabinet types with folded horn construction loading the rear of the loudspeaker. Dual loudspeakers were fitted to cover the desired frequency range.

Maintenance Routines

Special routines were laid down for regular testing of studio amplifiers, batteries, valves, microphones, pick-ups, turntables and cables to ensure they were maintained to certain performance standards. In addition to the routine studio tests, overall frequency tests were made each morning to check performance of the program line to the transmitter.

The following duty statement for a control room Operator at one of the Sydney metropolitan Commercial stations is typical of the role of a studio Technician in the late 1930s:

- The control Operator is required to arrive at the control room half an hour preceding the broadcast day.
- Each studio channel and associated power equipment is to be tested, inspected, and repairs and replacements made if necessary.
- Continuity tests are to be made on each studio and Announcer's microphone circuit, transcription equipment, remote pick-up and network positions.
- A frequency run is to be made on the program line from the control room to the transmitter and characteristics of the line checked and equalisation provided where required.
- When the program begins, the Operator is to operate the control, gain and mixing panels, make the necessary switching to Announcers, studios, pick-ups and chain networks, operate transcription machines and handle program orders by telegraph.
- The Operator is to keep a program log showing the nature of the program, the time each station callsign announcement is made and the time the program commences and stops.
- At the end of the day, the Operator must close down all the equipment, place storage batteries on charge and inspect and clean the equipment.

From the start, some stations operated with the studio in close proximity to the transmitter, while others had the transmitter located at a site remote from the studio. By the late 1940s, there were very few establishments operating in the MF band where the main transmitter and studio were together.

The result of separating the transmitter and studio, was to introduce a degree of specialisation among the Technical staff. In many cases, staff with a preference for high power Radio Engineering were allocated to the transmitter, while those with preference for a program environment were allocated to the studios. Some Chief Engineers rotated the staff, as it was easier to handle staff absence situations and to meet short notice program commitments. In the National Broadcasting Service, at the time when PMG's Department staff manned both studios and transmitters, some staff were accomplished musicians, so they were allocated to studio work on an almost permanent basis. They were particularly useful for orchestral broadcasts from ABC studios or Town Hall studios.

The situation today, is that National transmitter and ABC studio Technical staff are completely separate and there is no interchange of duties. In the case of Commercial and Public Broadcasters with unattended stations, staff must be competent in both transmitter and studio activities.

The Post War Era

By this stage of broadcasting, the patch-up arrangements which many operators had to introduce during the War years 1939 to 1945 were now behind them. The approach of designers in setting the pattern for major studio replacements was to ensure that the performance and quality of workmanship, as well as the genuine appearance of studio technical facilities were of the highest possible standard.

Gone were the days when the studio equipment — loosely referred to as speech input equipment — was an appendage of the transmitting station, and acoustics was a black art, little understood by Broadcast Engineers. The old type studio with its heavy curtains and overuse of sound absorbent materials was depressing psychologically, and an acoustic disaster, as far as broadcasting was concerned. Some studios had walls and sandwich floors filled with sawdust which leaked out through cracks and holes caused by rats and mice, resulting in a cleaner's nightmare.

Engineers and Architects got together, and soon established technical criteria which today form the basis of modern sound broadcasting studio design. During the 1950s, many studios were erected and old ones modified to produce the beauty and symmetry in studios of the period with randomly spaced, curved surfaces, hinged acoustic panels and accurately calculated reverberation characteristics.

Some designers even employed nonabsorbent surfaces throughout, using a variety of curved and sharp irregular surfaces to ensure minimum attenuation of high frequency sounds and at the same time preventing standing wave build up. The studio was irregular in shape with no two walls being parallel.

The designers had come to the conclusion that it was not enough to just concentrate on reducing signal-to-noise ratio of the amplifiers, improving frequency response, reducing harmonic distortion, increasing dynamic range etc., of the technical facilities. The sound insulation characteristics and reduction in unwanted internal and external sounds were also part of the overall problem in designing the ideal studio. It led to the widespread use of new construction techniques such as building the studio floor on rubber pads or blocks, and separating walls and ceilings from the building in which the studio was housed. This also included the isolation of air conditioning ducts using canvas joints and the employment of sound absorbing material inside the sheet metal duct. Windows, observation windows and entry doors also received special treatment with the aim being to achieve attenuation from plant to the studio of 90 dB and from studio to studio of 120 dB. Power and lighting currents were provided by flexible shielded cables.

As well as dealing with these technical aspects, the Architect had to take into account that people worked in the studio, often a single person, on duty for long periods. The studio had to be a pleasant place in which to work and encourage good performance.

These building construction techniques are still being followed today. In the design of the new Sydney studios of the ABC opened in June 1991, all of the studios are isolated from the noise and vibration from nearby streets and railway lines. The entire building is constructed on massive piles socketed into the site's bedrock to render the building as insensitive as possible to the vibration. Each studio is a separate box-like construction within the building. The floor of each studio is a floating slab resting on a bearing pad of neoprene rubber to isolate the studio from the structure base vibrations. The pads constitute the only point of contact between the studio and the building. Most studios have stud frame walls but the major rehearsal hall and two major studios have masonry walls and concrete roof slabs.

The building comprises seven floors and two ground levels. About half of the total building space is used to house studios and associated acoustic booths. The Centre also includes the Eugene Goosens Hall, the first permanent home for the Sydney Symphony Orchestra. The Hall is the largest recording studio in Australia.

The total cost of the project was $150 million.

Microphone and pick-up equipment development had been at a standstill during the War period, and studios were still making use of microphones produced during the 1930s, and even earlier. These included various velocity, condenser, crystal, dynamic, pressure operated and cardioid directional types. There were still some carbon granule types being pressed into service, particularly with outside broadcast work. Most of the microphones suffered from low fidelity and it was almost impossible to find one which combined high fidelity with high output. Pick-ups had the same problems of low output, high distortion and poor frequency response characteristics. Diamond and sapphire point pick-ups were becoming available, but Engineers were hesitant in installing them in studios as there was a feeling that Announcers would damage them.

Studio equipment had for many years been built with standard 19 inch racks, probably influenced by PMG's Department practices which were carried over to the National Broadcasting Service studios from 1929 when the Department took over the A Class stations. With these channel iron racks, the wiring forms ran up the channel with a standard copper earth strap 1 inch x ⅛ inch (25 mm x 3 mm). The equipment mounted in the rack was covered with sheet metal dust covers of the push-on type.

Another type employed at some Commercial stations studios was a cabinet type. The front panels were the same as for the channel iron frames but the rack was totally enclosed with a hinged back door. This type of construction did not require sheet metal dust covers, but nevertheless in some dusty country areas they were fitted as an additional precaution against dust entry.

The number of racks or cabinets employed depended on the size of the studio installation and facilities. For a large installation, it was usual practice to use separate racks for different groups of similar equipment. For example, at one installation with five racks of facilities the distribution centred on preamplifiers and A amplifiers on rack 1; B amplifiers, bridging amplifiers, splitting amplifiers on rack 2; high level equipment such as monitoring amplifiers, off-air receivers etc., on rack 3; power supplies and distribution on rack 4 and test equipment on rack 5. Great care was necessary in wiring and layout of forms etc., to avoid crosstalk, noise and hum pick-up. It was customary to run low level circuits in one channel and high level circuits in the other.

A typical audio frequency chain of designs being developed at the time, catered for the use of a preamplifier, mixer network, an A amplifier, a B amplifier and a monitoring amplifier. Output to line was set at +8 dBm. The design of the preamplifier which accepted a microphone level of about -60 dBm required careful selection of components, particularly valves as any unwanted noise introduced at this stage was amplified throughout the whole amplifying chain. The input transformer was usually astatically wound and well shielded with two high permeability cases, one within the other. Valve types most commonly used included 1603, 6J7, 6SJ7 and 6AU6 types. The gain of the preamplifier varied from 25 to 45 dB depending on its application and preference of the designer when fixing the mixer insertion loss.

Although rotary faders had proven satisfactory over many years of service, the use of vertical types was under consideration following successful trials at overseas studios. Today, they are very common. Designers pressing for greater use of the vertical or straight line slider types claimed they gave a more easily seen picture of the gain settings of the various faders and also they allowed the simultaneous operation of up to three faders with one hand.

Those in favour of retaining the rotary type came up with improved designs including translucent plastic knobs which glowed over the whole surface when a pilot light mounted under the knob was illuminated. Another design copied from BBC practice, had a scale with a black mask which progressively uncovered a white scale which showed how far the control had been 'faded up'. However, the straight line fader with its deposited-film resistance strip has today replaced all forms of rotary type studio faders.

One project of interest completed just after the end of the War, was the establishment of studio facilities in Parliament House, Canberra to enable broadcast of Parliamentary debates.

During the War years, some members of Parliament had been considering the matter of the broadcast of Commonwealth Parliamentary debates, and within one month of the surrender of Japan on 14 August 1945, the Parliamentary Standing Committee on Broadcasting raised the issue of the broadcasting of Parliamentary debates, claiming that such broadcasts would 'raise the standard of debates, enhance the prestige of Parliament and contribute to a better informed judgment throughout the community on matters affecting the common good and the public interest, nationally and internationally'.

On 19 June 1946, a Parliamentary Proceedings Broadcasting Bill was introduced. Following passing of the Act, the first broadcast was made on 10 July, after a hurried installation of facilities.

The Act provided that the Australian Broadcasting Commission should broadcast the proceedings from:

- A medium wave National Broadcasting Service station in the capital city of each State and in the city of Newcastle.
- Such other NBS stations — including the short wave transmitters — as are prescribed upon such days and during such periods as the Joint Committee on Broadcasting of Parliamentary Proceedings determines.

Immediately Parliament gave its approval, there was great pressure to go to air as quickly as possible.

The Postmaster General's Department which was responsible for the provision and operation of technical facilities for the ABC had to fast-track design, equipment procurement, installation and commissioning to enable early broadcasting to begin. At the same time, the Department of Interior had to erect the control and equipment rooms.

The design and installations of the technical facilities was under the control of Eric Watt, Broadcast Engineer of the Department's New South Wales Engineering Branch. The installation team included Supervising Technician Ken Taylor, Senor Technician Vic Le Pla and Technicians Len Linder, George Hobbs and Maurie Morris.

Because of the poor acoustic qualities of the Chambers, dynamic type microphones purchased for the project proved entirely unsatisfactory for broadcasting due to excessive reverberations. RCA ribbon types with their figure of eight pattern characteristics gave much superior performance, but as they were manufactured in USA it was evident that there would be considerable delay in supply. There were a number in use at ABC studios throughout Australia, so decision was made to have all these microphones removed from the studios and despatched to Canberra. It was 12 months before the replacements arrived from overseas.

The facilities installed included 49 microphones in the House of Representatives and the Senate plus 110 amplifiers. In 1949, when the numerical size of both Houses was increased, the number of microphones had to be doubled even though members were required to sit closer together than previously.

The microphones were arranged in two rows, and there were four on the table of the House of Representatives for sound reinforcement within the Chamber itself. In this House, the equipment room containing the amplifiers and other technical equipment was in the basement.

Because of the need for rapid access to any one of the many floor mounted microphones installed in both Chambers, the microphone switching panels were laid out according to the floor plan of each area. This was a horse shoe shape, colour coded for ease of operation. The Operator could therefore switch on the microphone nearest the Senator or Representative whom he saw rising to speak.

In the House of Representatives the Operator and Announcer originally shared the control booth but in the Senate there were separate booths for control and announcing.

Operation of the facilities was under the control of Stan Bancroft who later retired as Supervisor of Radio Operations. In 1938, Stan was with 2CY Canberra installation team and remained at the station for six years before transferring to the Sydney studios of the ABC.

For many years, the Parliamentary broadcasts were transmitted by 2BL Sydney, 3LO Melbourne, 4QR Brisbane, 5AN Adelaide, 6WF Perth, 7ZR Hobart, 2CN Canberra and 2NC Newcastle but in more recent times a special network has been set up to cater for the broadcasts using callsign PB prefixed by appropriate State identification.

With the construction of the new Parliament House, the ABC was given the task in 1984 to design a broadcasting complex to be operated by the Department of the Parliamentary Reporting Staff's Sound and Vision Office (SAVO) to cover television, radio and other communications support facilities.

Four years later, and at a cost of $50 million, the English company Vinten in conjunction with several other companies had devised and implemented a highly sophisticated broadcasting infrastructure based around a revolutionary remote controlled broadcasting system.

In 1993, of 2000 hours of chamber and committee proceedings and press conferences handled over a period of 12 months, about 630 hours were broadcast via the Parliamentary Broadcast Network. The service is co-ordinated from SAVO's radio studio complex which in 1993 was equipped with a 24 track audio mixing console, AMS audiofile digital editing system, DAT editing system, broadcast cart facilities, professional ¼ inch record/replay facility, CD replay units and various audio processing units.

One of the many Commercial station studios constructed in the immediate Post War period was 5KA Adelaide. The station had been closed down on 8 January 1941 when National Security Regulations were acted upon and remained off air until a licence was granted to new owners on 25 June 1943. Transmission recommenced on 6 December 1943 from the Central Mission building Franklin Street, Adelaide, using some recovered material from the earlier station in Currie Street and some loaned or donated by other local Commercial stations. Staunton McNamara was a member of the rebuilding team.

Plans were prepared for construction of new studios in the building employing a straight line system whereby the control and presentation rooms were centred between two studios permitting simultaneous visual control of programs being produced for local transmitter 5KA and relay station 5AU at Port Augusta. Large windows dividing the rooms were triple glassed with each pane at a different angle in order to reduce reflection problems as much as possible. The walls of each room were treated with rockwool tiling to meet specific acoustic requirements. The same treatment was provided in the auditorium which at the time was the largest in Adelaide providing seating accommodation for some 450 people. Included in the many up to date facilities were Presto disc recorders and a Pyrox wire recorder.

Chief Engineers who had been associated with 5KA to the period when it celebrated its Golden Jubilee in 1977 included Roy Buckerfield, Ern Gunner, Charlie Tareha, Colin Howie, Bob Paech, George Matthews, Col Crowe and Bruce Martin.

THE 1960S

By about 1960, many advances had been made in studio equipment technology, particularly in the areas of recording, microphone performance and amplifier design, and most broadcasters took advantage of improvements to build new studios. A typical example was the construction of new ABC studios in Perth to provide programs for 6WF, 6WA, 6WN, 6AL, 6NM, 6GF, 6GN, VLW and VLX transmitters.

In designing the studio facilities, opportunity was taken to employ equipment incorporating the latest technology and the best of past designs together with new features that would reduce fault liability and reduce routine maintenance work. The housing of equipment, including control and Announcers desks, record and tape replay cabinets etc., were designed to harmonise with the studio interior treatments and the use of small plug-in amplifier equipment meant less jacking facilities and the elimination of large equipment racks in control rooms and tape booths.

The technical installation was designed using the continuity suite system of operation. This involved the use of a number of key presentation studios each with its associated control booth from which all programs leaving the studio were controlled. The Announcer's desk included, in addition to the control panel, three 30 cm disc replay machines with long playing and standard pick-ups.

The studio tape and disc recording and replay equipment included ten console tape recording machines arranged in five pairs with each pair being installed in a recording booth with a control console being used to channel and control programs to and from each machine, two disc recording machines and a portable type booth containing four Byer 77 machines housed in two transportable cabinets. Tape editing and dubbing equipment was also provided. This comprised a pair of portable tape recording and replay machines, a pair of portable tape replay machines and one transportable disc replay machine.

An event of significant importance in the mid 1960s was the transfer of studio technical facilities to the Australian Broadcasting Commission from the Postmaster General's Department. When the National Broadcasting Service was established in 1929, staff of the Postmaster General's Department took over responsibility for the technical facilities but the Australian Broadcasting Company and later the Australian Broadcasting Commission were far from happy with the arrangement, particularly with operation of the studio equipment being carried out by people over whom they had no administrative or disciplinary control.

The ABC raised the issue with the Postmaster General at every opportunity to seek control of the technical facilities, but it was not until 1964 that approval was finally granted. Staff of the Postmaster General's Department were given the option of transferring to the Commission and as most accepted, it enabled smooth transfer of the facilities to take place.

The first State to transfer the facilities to the ABC was Western Australia. Jack Mead was Divisional Engineer of the Department and Jack Zelling was Supervising Technician-in-Charge of the studios. Other staff working at the studios at the time included Ted Leppard, Don Hope, Ray Stevenson, Sam Wainwright and others. Engineer Alec Cohen transferred to the ABC Sydney office where Vern Kenna was in charge.

In South Australia, the ABC took control on 4 October 1964. Jack Grivell Officer-in-Charge of Studios transferred to the ABC together with many other PMG's Department staff. Divisional Engineer was Brian Perkins and other Engineers included Frank Mullins, Tom Harrison and Noel Murphy. At the time of transfer, the Adelaide studios comprised six network studios and four production studios each with individual control booths with facilities comprising some 20 amplifiers in each, a switchroom containing 105 amplifiers and 8000 transistors and diodes used for program switching, tape recording facilities comprising 12 high quality console recorders and 115 portable recorders and replay machines.

In April 1965, senior ABC technical staff from all States and Head Office participated in a Radio Service Conference in Sydney to discuss a number of issues resulting from the transfer. By that stage, the ABC had already been responsible for TV studio equipment.

The transfer of the sound studio technical services brought the ABC about 600 new officers on its staff and some $4 million worth of equipment. All branch office Superintending Engineers and all Senior Engineers (Radio) attended the three day Conference with acting Director Operations (Radio) Frank Shepherd being Chairman of the meeting. Vern Kenna, Controller Technical Services opened the Conference. Specialist officers from ABC Head Office who attended included Sectional Engineer (Planning and Installation) John Poll, Sectional Engineer (Design and Development) Carl Wilhelm and Acting Sectional Engineer (Plant Performance) Don Anderson. Other staff included D Wark (HO), Bill Smitheram (HO), Bryan Madeley (HO), Colin Stockbridge (Vic), Staunton McNamara (SA), John Starr (SA), John Guttman (WA), Alec Cohen (WA), Neville Brown (Tas), Peter Holt (Tas), Ed Powe (Qld), Kevin Bourke (Qld) and Barry Carlson (NSW). Other ABC staff who also had a radio responsibility about the same period included Bill Pike, Jim Toogood, Dennis Andrew, Len Blackett, Peter Gonda, Don Woolford, Alan Hullett, Ranald McKilligan and Neville Thiele.

Neville Thiele who became Director of Engineering Research and Development in 1980, joined the ABC in 1968 and was employed on the design and assessment of equipment and systems for sound and television broadcasting. Before joining the ABC, he had worked with EMI (Australia) for nine years on the development of radio and TV receivers, test equipment and telemetry. He was President of the IREE (Aust.) during 1986–88.

Neville retired from the ABC in 1985 but continued working as Consultant in the fields of audio, radio and television. Up to 1993, he had published more than 30 Engineering papers on loudspeakers, filters, equalisers, and testing methods for sound and television broadcasting.

In the late 1960s consideration was being given by the ABC to the concept of The Solo-Dual system of studio utilisation.

The traditional method of broadcasting, involved a studio and an associated control room. The Announcer operated a microphone key and two or three gramophone faders, while the Technician in the control room, was responsible for all level control, switching of incoming lines, taking groups of preselected transmitters etc. In the 'solo' mode, studio and control room were dissociated. A complete program could be transmitted to air from the control room by an Operator provided with reel-to-reel and the then new multiple desk cartridge machines and with access to program source selectors giving access to interstate trunk circuits etc. All announcements, including time calls were stored on cartridges. This became known as the One Person Operator system. The studio when in the 'solo' mode could be employed by an Announcer for producing tapes and cartridges for subsequent transmission. In the 'dual' mode the studio reverted to the traditional system of booth control.

Staunton McNamara Senior Engineer Radio with the South Australian ABC staff played a major role in the development of the concept and associated technical arrangements.

In 1971, 2NB Broken Hill ABC studios incorporating The Solo-Dual principles was commissioned and in 1972, one of the ABC Hindmarsh Square studios was converted to One Person Announcer operation transferring the task of level control to the Announcer. During the design of the FM studios and switching system at Collinswood during 1975–76 by Staunton McNamara, the facilities incorporated Solo-Dual principles together with other innovations.

THE 1980–90S

From the start of the 1980s, the broadcasting industry invested considerable funds in the upgrade of facilities and the establishment of new centres to take advantage of advances in technology which enabled reduction in technical personnel levels and improved equipment reliability and efficiency.

In the early 1990s, state-of-the-art technology was such that with the aid of computers, touch-screens and digital audio equipment, the studio technical control booth which had been an integral part of broadcasting studios from the early days, disappeared from the scene and the Announcer's console, surrounded by disc replay machines and pick-ups, tape recorders, cassettes, rotary faders etc., was also heading for retirement.

Station 3WM Horsham, operated by Cameron Broadcasting Services Pty Ltd was typical of Commercial stations at which considerable capital funds were invested in the provision of modern facilities at the time.

In 1979, the aerial facilities were upgraded at a cost of $145000 by the provision of a two mast directional system employing two 55 m high structures on a 2 ha site east of Lubeck and the transmitter power raised to 5 kW. A new 5 kW transmitter was added in 1981, with the models then comprising AWA BTM-5B and Continental 315-1 transmitters. The audio was processed using CRL preparation, spectral and modulation devices.

On 26 March 1982, a modern studio complex costing $450000 located at 2 Stawell Road beside the Wimmera River bridge was opened by the Chairman of the Australian Broadcasting Tribunal, David Jones and the Minister of Communications, Ian Sinclair.

Design emphasis gave the building an open atmosphere with natural lighting and a pleasant working atmosphere. The front foyer provided, as did much of the building, a clear view of the Wimmera River, an indoor garden and also a view of the main studio and the control room.

The control room was sufficiently large to provide area for the technical workshop and office. Several racks faced the foyer including SME Carousel automation equipment which was being considered for future use.

The operational racks made use of RME splitter and monitor amplifiers a TFT status and control system for remote transmitter operation, and an AWA limiter and receiver. A Dbx 20/20 computerised equaliser was fitted in the rack and used for production purposes.

There were four studios, with three in operation, and a fourth reserved for future FM broadcasts.

The main on-air studio employed a Broadcast Electronics 10S350 ten channel stereo console fitted with an extension panel for indicators, clocks, digital thermometer, intercom equipment and display. Tape equipment consisted of three Consolidated Electronic cartridge machines and Consolidated Electronics 77 MK5 reel-to-reel machine.

The Technics SP10 MK2 turntables used Broadcast Electronics Micropoise tone arms and Sedco BA-2A pre-amplifiers. Microphones employed in this studio were Sennheiser MD421 types.

The second studio, used predominantly for production purposes, employed an Eela Audio Mixing Console. Tape equipment consisted of Otari MX5050 two track and eight track machines and a Consolidated Electronics recording cartridge machine. Turntables were Technics SP10 MK2 with SME 3009 MK2 tone arms and Sedco BA-3A pre-amplifiers. Sennheiser MD421 microphones were installed.

Auratone loudspeakers were used for monitoring in this studio but use could be made of wall mounted Technics SB-2 honeycomb disc loudspeakers if a 'music quality' monitor reproduction was required. The third studio, referred to as a 'talks studio' was smaller in size and more suitable for recording interviews or for basic production work.

A Paul Kirk Electronics six channel console, Technics two track 1500 reel-to-reel tape machine, Technics SP 10 MK2 turntable with SME 3009 MK2 tone arms and Sedco BA-3A pre-amplifier were used in this studio.

Sennheiser MD21 microphones were used because they were less directional than those in the other two studios and therefore, more suitable for the studio's purpose.

With the exception of the third studio, the operational equipment had been wired for stereo to enable total stereo operation with relatively little additional equipment and wiring. At the time, the stereo output of the main on-air studio was channelled to the Manager's Office and the Conference Room.

Options were being investigated for a program radio link to the transmitter site 40 km away near Lubeck.

In 1983, the station had a staff of 12 including a resident Technician. Senior Technician was Bruce Lees and Managing Director of the owners, Cameron Broadcasting Services, was Colin McL Cameron.

An example of the 1980s technology employed in ABC studios, is the Broadcasting Centre in Hobart commissioned in October 1987 and officially opened on 27 November. It provided programs for the Metropolitan station, Radio National, Regionals and FM. The FM service was normally taken off line with the local studio providing a live broadcast one day each month. The Centre replaced studios and administration offices on an old railway site which had been in use for many years.

There were six on-air studios, with three operational simultaneously while the others were in use for interviews, recordings or replays. Two production booths were equipped with 16/8 Soundcraft desks, three two-track machines, CD, cassettes, carts and other facilities.

An interesting feature of the major production studio was a variable acoustic arrangement accomplished by using roller blinds. The blinds were manufactured using two sets of fabric allowing a variation from 0.5 second to 1.2 second.

Typical of facilities in service at Commercial and Public AM and FM studios in the mid 1980s included:

- 2BE, Bega, RMS Consoles; Revox and Teac 4 track machines; Batemans Bay, Paul Kirk console; Revox full and 2 track recorders.
- 2CH, Sydney, Teac 16 track, 2xTeac 4 track and 2xStuder 2 track machines.
- 2GO Gosford, RME Consoles; Technics turntables; ¼ inch Otari reel-to-reel machines; CEI cart machines; Teac/Taxcam 4 track production facilities; Urei limiters; Marshall time modulator; Cetec 7000 Automation facility; mobile studio.
- 2GZ Orange, Studer 2 track, Ampex 2 track machines; MTE, RME and AWA consoles.
- 2LM Lismore, Teac 4 track, Revox 2 track machines; Teac and Sedco consoles.
- 2MC Kempsey, 3 McIntosh Series 85 stereo 12 channel on-air consoles; CEI cartridge equipment; Technics SP10 MK2 turntables; Ampex reel-to-reel tape machines.
- 2UW Sydney, Ampex 4 track, Studer 8 track, Revox 2 track Teac 4 track machines; Sound Workshop 30 channel unit.
- 4WK Warwick, MTE console; Otari tape recorders; Cuemaster cartridge machines; Thomson-CSF audio processing equipment.
- 2DAY FM Sydney, Soundcraft Series II mixer; MCI and Teac 8 track with Dbx, recorders; BMX stereo consoles plus two CEI Cueacs computer controlled and random access,
- 2MMM FM Sydney, Lyrec 16 track and Otari 2 track tape recorders; McCurdy and Soundcraft consoles; Yamaha monitors.
- 2MBS Sydney, Studer and MTE audio consoles; Ampex tape recorders; B & W studio monitors.
- 8TOP FM Darwin, MTE consoles; Otari recorders; Technics turntables.
- 5MMM FM Adelaide, Otari and Revox tape decks; Technics turntables; Nakamichi cassette deck.

During the 1980s, Broadcast Engineers had a wide range of commercially designed and manufactured consoles from which to select when upgrading existing or providing new studios. While some were of Australian design and manufacture, the majority were of overseas origin with USA and Canada manufacturers supplying many brands and models.

Models available included Amek, Audiotronics, Audix, AWA, BMX, Broadcast Electronics, Calrec, Harris, Hitachi Denshi, LPB, MBI, MTE, McMartin, Neve, Paul Kirk, RCA, RME, Sedco, Soundcraft, Studer, Teac, Trident, Ward Beck and others. Paul Kirk and RME models were of Australian manufacture.

Included in the Paul Kirk range were BC-E12, a stereo on-air mixer with 12 channels; BC-ED, a stereo on-air mixer with 10 channels; BC-N6, a stereo 'News' mixer with 6 channels; BC-N4, a stereo 'News' mixer; SBS-MBC Series, stereo or mono broadcast console of modular construction with up to 16 input channels, slide faders and LED or VU/PPM meters; AM12, a production mixer of modular design with 8/12 inputs, slide faders, two main sub group, one main output fader, foldback and monitor features, talkback; GEM-2, a compact production/on-air console, 8 channels, rotary faders, interchangeable input modules, built-in monitor amplifier, split cue switching, silent program/cue switching, talkback, and many broadcast options; RMM-1, a rack mounted mixer of 6 channels, and BC-P1, a stereo cartridge preparation console with digital timer, automatic monitor switching and cartridge evaluation facilities.

The RME modules included Type 300C1, with features comprising modular construction, low profile, dual stereo channels, colour identified inputs, in-line faders, push button selection of output channel, fader cueing on all inputs, phantom power, connection for telephone broadcast unit, stop watch panel, temperature gauge and space for custom additions. The Type

300C2-5 features included modular design, 5 stereo inputs expandable to 8, in-line conductive plastic faders, balanced +8 dBm stereo outputs, fader cueing on all inputs, 5 station intercom, loudspeaker dim button, monitoring of 6 stereo programs on dual 50 W amplifiers, telephone talkback unit and space for customer additions.

Typical of facilities provided in the late 1980s period at a Commercial country station were those installed at 3UL (later 3GG) Warrigul.

Following major upgrading work in 1987, in which facilities included conversion to AM stereo transmissions and replacement of the operational RCA BTA 5LZ Ampliphase transmitter by a Nautel 5 AMPFET solid state unit, new studio equipment was installed.

At the transmitting site, a TFT 840 AM stereo exciter was provided together with two control racks using CRL processing equipment with a stereo matrix processor (SMP 900) and special energy processor (SEP 800). A stereo preparation processor (SPP 800) was installed at the studio.

The studio operated on a seven second digital delay with a pair of Audio Digital TC-4s and the SPP 800, custom JNS line amp, twin bantam jack fields and a Krone termination system. Main metering was via an RME 541 M1-42 stereo level indicator coupled to the station mode monitor switcher.

The main on-air studio employed a PKE CSC1 18 channel console with four stereo cart machines, two Otari MX 5050 units and a Studer telephone hybrid system. Chief Engineer Lance Milne was responsible for installation and commissioning the facilities.

With the 3EA studios of the Special Broadcasting Service commissioned at the Australian Ballet Centre in South Melbourne during November 1989, and officially opened on 9 February 1990, comprehensive facilities using modern design techniques were installed for on-air studios, production suites, recording rooms and the central control room.

The two on-air studios were equipped with facilities to enable programs to be provided by voice, compact disc, long playing record, cartridge tape, reel-to-reel tape, outside broadcasts and talk-back sources. An associated news booth was provided with each studio to allow for insertion of news bulletins into the programs.

The distribution and monitoring of all program material was carried out in the central control room. Program feeds were provided to the local 3EA transmitter and to the SBS satellite program reticulation system via Milson's Point, Sydney. In order to minimise operational labour costs, particularly in early morning programming, a tape automation system was installed as part of the facilities to allow the unattended presentation of tape recordings to air.

When two new ABC Radio Far North Studios were commissioned in Cairns in May 1991, each was equipped with a 24 channel Paul Kirk Electronic Stereo Broadcast Mixer Console on which 19 modules were operational. Other facilities included compact disc players, turntables, cuemasters, cartridge machines, Otari reel-to-reel recorders and an ABC designed Auto Disc Loader CDK300PII which had capability for 60 compact discs.

During 1992–93 new ABC studio complexes were brought into operation at Newcastle, Bendigo, Dubbo, Wollongong and the Sunshine Coast.

The largest new radio studio project for many years in Australia was undertaken by the ABC when it established the Ultimo Centre in Sydney in 1991. The Centre replaced 11 buildings occupied by ABC Radio throughout Sydney and was designed around the latest studio control and production technology. The building accommodates a workforce of some 1200 people from the five radio networks, administrative and executive offices, and a symphony orchestra. The five radio networks are the Metropolitan network, a news and information service; Radio National, predominantly intellectual discussions and specialty programs; the Regional Network servicing country studios; ABC Classic FM, a national performing arts network, and Triple J, a youth network.

The Centre also includes the Eugene Goosens Hall, primarily a rehearsal and recording space. It is the first permanent home of the Sydney Symphony Orchestra. The Hall effectively consists of two giant concrete boxes one located within the other and resting on rubber mats. The inner cube weighs some 4800 tonnes while the outer cube is about 5600 tonnes in weight.

The technical nerve centre of the building is Master Control which is responsible for network integrity, audio quality control, studio links for long distance interviews and program switching.

Master Control design incorporates a number of facilities and practices not previously employed in studios. It is divided into an operational area and an equipment area. The operational area houses ten equipment racks which contain line interface units for 500 program circuits which pass via a dedicated Telecom room where the lines are equalised and amplified, emergency broadcast equipment containing audio cassette machines and reel-to-reel recorders for recording incoming material as required.

There are seven pods in the centre of the operations area. Facilities provide for monitoring and control by providing access to any input or output on the computer switcher, off-air receivers as well as pre and post satellite companders; manual control by direct access to the switcher allowing manual connection of inputs and outputs should there be a break in the events scheduled in the Master Events Scheduling Computer; manual program source selector controllers for dialling up satellite circuits and interstate studios; an alarm panel activated by program or carrier failure; an auxiliary control panel with satellite production orderwire controllers; continuous status display monitors indicating what each satellite circuit is carrying and what they are next scheduled to carry; and an intercom panel which services the entire facility including outside broadcast links.

A unique feature of the technical facilities is the touch-screen visual display terminals which have mostly replaced conventional mixing panels. It is known as the Ouija System developed in Western Australia by PKE Ltd. To fade up, the presenter touches the screen's on-air coloured box. It changes colour showing that source is on-air. The presenter then places a finger on the corresponding fader zone on the screen, moving to the right to increase volume level. A second screen is the preview and programming option screen.

Another innovation at the Centre introduced during 1991 is the D-Cart sound management system, a digital multi-user, multi-channel audio mixing and editing system run by a PC. The D-Cart takes inputs from analog or digital sources, digitises the material and transfers it into a hard disk store for simultaneous access by up to 34 different users. In studio operations, it replaces cassette and cart machines. During 1993, the system was extended to Brisbane, Perth and Adelaide ABC newsrooms, improving the quality and speed of news production.

The D-Cart enables considerable cost saving in studio facilities. It reduces the number of cart machines required in a conventional studio set up and because of its central storage facility, information transfer is not necessary. Also, it enables programs of different quality to be stored on disk. The facility was developed by the ABC Radio's Technology, Research and Development Group headed by Spencer Lieng.

In the 1992 Institution of Engineers, Australia, Sydney Division Excellence Awards, the ABC's computerised radio editing system D-Cart, shared the Bradfield Award Prize with a BHP project involving reconstruction of a blast furnace.

D-Cart which also received Excellence Awards in both the engineering products and exports categories, has been purchased by the American Broadcasting Corporation, the Canadian National Broadcaster, Radio Netherlands, Europe One in Paris, Radio Limburg in Netherlands, the British Broadcasting Corporation and other leading broadcasters.

Sales of the revolutionary D-Cart digital editing and retrieval system has generated consideration export earnings for the Corporation and has resulted in significant prestige in that the ABC is now recognised as one of the world's leading research centres for digital audio technology.

In April 1993, the ABC's Managing Director David Hill signed an agreement with AWA Managing Director John Dougall for AWA to manufacture the D-Cart digital radio on-air system for export.

The ABC's Technology Research and Development Department added another important facility to studio operations during 1994 with the D-Radio system. It is an integrated digital on-air system which combines a scheduling, messaging and networked information system with a fully digital signal path.

On 5 November 1994, Prime Minister Paul Keating officially opened the most recent addition to the ABC broadcasting facilities. The building is located at corner Southbank Boulevard and Sturt Streets, South Melbourne. It includes 50 on-air studios and booths, 12 production rooms and other support facilities. These cater for ABC Melbourne staff associated with 3LO; Radio National; ABC Classic FM; JJJ; Regional Radio; Radio Australia; Melbourne Symphony Orchestra and technical support services including a range of satellite transmission and reception facilities with dish diameters up to 7 m and ABC's first all-digital broadcast chain.

A BTS Venus digital switcher is the main program switching controller. In conjunction with the Radio Operations Scheduling System (ROSS), it caters for all program transmission feeds into and out of the building. The central intake point for Radio Australia is provided with a Chiltern 14 channel console. The control booth for the Melbourne Symphony Orchestra Rehearsal Hall includes a 40 channel Amek Mozart computer assisted console and Studer analogue 24 track machine.

The eight main on-air radio studios, dubbed A studios, were designed for digital operation based around a development on the D-Cart concept called D-Radio on-air consoles. The D-Radio operates as a virtual console which is a fully assignable controller for the D-Radio studio computer which in turn controls the digital mixer.

The on-air broadcast and recording studios are isolated from the main building structure. The 26 studios employ a combination of either two of three wall isolation systems with sound absorbent materials being used in the interiors of all rooms. The studios are isolated from noise and vibration by having floating floors mounted on rubber elements or semi rigid fibreglass. Studios have been provided with angled walls and ceilings.

An uninterruptable power supply comprising a gas fuelled reciprocating engine and alternator set, ensures continuity of power for all radio technical facilities and half the building remaining electrical operation.

The building is characterised by a glass enclosed atrium circled by studios and offices on each floor.

The building Project Manager and construction contractor was John Holland Construction and Engineering. The on-air broadcast and recording studios were built by APM Construction Pty Ltd.

Consultants responsible for broadcast studio design and upgrading work today have a wide range of acoustic measuring equipment at their disposal. Typical items employed include Sound Level Meter, Octave Filters, Noise Event Meter, Vibration Meter, Dump Recorder, Flutter Analyser, Spectrum Analyser, Reverberation Analyser, Tracking Filter, Sensitivity Comparator and others.

In 1996, the ABC was one of seven National Engineering Excellence Award winners chosen from 47 entries by The Institution of Engineers, Australia for the D-Radio Integrated Digital On-Air System, the centre piece of the Southbank broadcasting complex.

In mid 1998, Heads of the various Technical areas in the Southbank complex included:

- Des Madden, acting Alphatec Manager responsible for supervision of maintenance and installation of Radio (Victoria) broadcast technical facilities.
- Tim Hughes, Transmission Supervisor responsible for supervision of Master Control (Radio, Victoria), liaison with National Broadcasting Agency and their contractors for domestic ABC Radio in Victoria.
- Nigel Holmes, Transmission Manager Radio Australia, responsible for management of HF transmitting, satellite and relay facilities for Radio Australia, liaison with National Transmission Agency and contractors on Radio Australia works, IFRB/ITU and DOCA.
- Stan Mozel, Building Manager responsible for supervision of technical infrastructure such as power, air conditioning etc.
- Ross Smith, Digital Systems Manager responsible for major digital broadcast systems in Southbank, such as D-Cart and D-Radio.
- John Mann, Information Technology representative responsible for some 500 PCs throughout the Southbank complex.

Because the relatively high cost of its D-Cart installations could not be justified at many of the ABC regional centres, Mini Disc technology was introduced in 1997 to replace existing cart machines and to meet requirements of ENG staff in the field. The technology had been trialed for at least 12 months before decision was made for full-scale introduction. One of its major advantages is that, being an opto-magnetic system, the media has a long life span. Included among equipment purchased by the Corporation were 48 Sony MZ-B3 MD recorder/playback portable units, 21 Denon DN990R desktop MD recorder/playback units, 21 Denon DN1100R rackmounted MD units, 14 DN981F desktop MD player units and 85 Tascam MD801R Mini Disc recorder/playback units.

A digital storage system developed in Australia and which has been marketed overseas is the Digital Audio Mass Storage (DAMS) system. It is finding wide application with Australian broadcasters. Like the Ouija system, the DAMS interfaces with touch-screen technology. The touch-screen acts as a central controller for all the studio's equipment, DAMS being one of the slaves. Other units that can be interfaced include DAT machines, multiplay CD machines and specialised computers.

Specialist organisations catering for the broadcasting industry, such as Southern Broadcasting Systems of Perth have packaged complete DAMS systems aimed at making digital storage economically attractive for any Commercial broadcaster. A typical package meets the operational needs of a two on-air, one production/dubbing studio operation. The system controllers simulate the basic functions of four replay cart machines. Events can be played individually or sequentially.

Included among country Commercial station studios which recently introduced new technology is 4BU Bundaberg when equipment was commissioned in a new building on 25 February 1992. Traditional carts were abandoned in favour of computer technology.

Facilities installed for studio operations and functions included a 16 input PKE CSC-1 audio console, 8 and 12 input PKE MC-200 consoles, Soundtracs Megas series consoles for production and dubbing studios, Otari 8 track and 2 track recorders and other equipment. A Store-Max digital storage system allows 4 hours of program to be stored on hard disc drives with access being available from on-air, news and dubbing studios. Announcers are free to trigger commercials as required.

The installation is the first stage of an expansion plan which will eventually lead to upgrading to the Ouija system combining Store-Max with digital mixer and touch-screen interface to replace audio consoles.

High fidelity in the broadcasting chain is mandatory with modern Broadcast Engineering designs and practices. The aim is to provide the listener with as good a simulation of the original sound as is practicable. Today, most broadcasting stations have some form of signal processing technology to enhance the quality of the signal being broadcast. This is particularly the case with AM transmission where Engineers are always conscious of the competition from FM services with certain superior technical characteristics.

Technical facilities incorporated in the chain are influenced by the station program format. For example, a station with an emphasis on a rock music format will require a different arrangement of technical processing equipment compared with one with a classical music format or even a talkback format. Basically, components in the chain may include limiter, compressor, automatic gain control, equaliser, enhancer, ducker or others.

One of the important instruments in the broadcasting chain is the level meter. Many improvements have been made over the years to assist staff in the proper and effective monitoring of the program going to the transmitter as well as for recording purposes. A recent development is an audio level meter which simultaneously shows three dimensions of program content. Peak, average power and compression are displayed on a colour-coded 40 segment LED scale. It provides high precision indications of program energy content.

Following the successful introduction about 1991 of a USA Computer Concept DCS hard disc system at HOT100 Darwin, Austereo Ltd later installed its first metropolitan system at SAFM Adelaide. By early 1996, the system was being employed at 2DAYFM and Triple M, Sydney; FOXFM and Triple M, Melbourne; and SAFM and Triple M Adelaide, all based on dual station operations. Plans were well advanced to introduce the system in Brisbane upon transfer of Triple M into common premises with B104FM. With completion of the Brisbane project, the company would have potential for national networking capability.

Each facility has about 36Gb hard disc storage with over 200 hours of music and 100 hours of commercial and other material. Each two station configuration of the DCS audio network comprises eight studios with four having CartRack Touch Screen operator interface, four production work stations, a carting work station, two music director work stations, audio server and log server. There are at least 400 DCS systems installed by broadcasters throughout the world.

Austereo Ltd Group General Manager Engineering and Computers in 1996 was Des DeCean.

In early 1998, 2GB Sydney purchased 12 locally developed NewsBoss work stations for program production purposes. The equipment was supplied by Innes Corporation Pty Ltd and all the work stations were linked to two Plentium II 266 servers via a Windows NT network. The system replaced a Basys system which had been operational for some 15 years and used mainly for the Macquarie news room before its closure. Group Chief Engineer responsible for 2GB and sister station 2CH which is accommodated in the same building was Martin Quiggin who oversighted commissioning of the system.

It is not unusual these days for an AM and an FM station to be both controlled by the same General Manager but operated as separate businesses, particularly in country areas. Typical is 2HD licensed to 2HD Broadcasters Pty Ltd and 2NEW (NEWFM) licensed to Newcastle FM Pty Ltd with General Manager being Glen Thornton in 1998. Studio facilities are located in the same building at Sandgate out from Newcastle with the technical facilities including:

- One control room containing equipment for 2HD and NEWFM.
- Technical workshop for servicing both stations.
- Three on-air studios equipped with two Ward Beck and one Paul Kirk desks.
- Newsroom incorporating three prep studios, computerised news system and news on-air studio.
- Two production studios, both featuring Tascam 16 track recorders, and Tascam 24 track mixing desks DAT mastering.
- Computer based digital editing and mixing system.
- Satellite receiving dish feeding four receivers in the control room.
- Sonifex and Cei cartridge machines.
- Otari and Revox ¼ inch tape machines.
- Denon and Revox CD machines.
- Tascam DAT machines.
- A 90 kVA Detroit diesel generator to cater for mains power failure and for use during periods of intense lightning activity in the area.

All music played by both stations is CD format and commercials are played from cart.

Almost everything in the daily operation of the stations is carried out by or with the aid of computers. All scheduling of commercials is done by a computer system. Both stations utilise computers in the record libraries for play list compiling, record data bases and APRA reply.

It is planned that eventually, both stations will access all music and commercials from a central computer in the control room and will be capable of running unattended for selected overnight sessions.

Station Chief Engineer is Ian Porteous.

AMPLIFIER STANDARDISATION

In the early 1930s, studio amplifiers carried company type designations and were manufactured to company design specifications. For example, in 1933 when metropolitan station 5CL and regional station 5CK Crystal Brook were the only National stations in South Australia, programs for the two stations were provided from the ABC Hindmarsh Square studios in Adelaide, using STC manufactured amplifiers. Two studios were in operation with program being produced in one studio for 5CL while another program was produced in the other studio for 5CK. On some occasions, a common program went to the two transmitters simultaneously.

STC condenser microphones were used exclusively at the time, and were each provided with an amplifier using a single 102D valve giving an output of about 40 dB below the standard reference level of 5.9 milliwatts.

An amplifier referred to as the Main amplifier, was an STC ES1096 type comprising four valves providing a maximum gain of 100 dB but normally set at a working level of 70 dB. It provided four split outputs to 600 ohm line transformers. One feed went to 5CL transmitter, another to 5CK and the other two catered for feeds to two Interstate program lines as necessary.

A so called Second amplifier, an STC 8B type with a gain of 80 dB was used to provide a second program when 5CL and 5CK were being fed different programs.

A Monitoring amplifier comprising a two stage push-pull circuit with 102D and 205D valves was used to check program quality. It had high impedance input and could be switched across any of the program lines and certain other circuits.

By the end of the 1930s, the backbone of studio amplifying equipment comprising pre-amplifiers, line amplifiers and branching amplifiers became known as A amplifiers, B amplifiers and C amplifiers respectively.

The alphabetical identification was later extended to include D, F, G, M, W amplifiers and others.

The W amplifier, also called a limiting amplifier, compensated for the loss introduced by the equalised permanent program line from studio to the transmitter. It had certain characteristics which suppressed voltage peaks above a predetermined level to prevent overloading of the transmitter. It also permitted the use of a high level into the transmitter, depending on the degree of limiting used. This was important for short wave transmitter operation where it was desirable to keep the average modulation depth as high as possible.

Considerable advancement has taken place in recent years in improving the quality of the broadcast signal by the employment of signal processing technology. The facilities inserted in the studio processing chain depends upon the demands of the station format. For example, a station with a talkback format will require a different set-up compared with one providing a classical music format. Facilities or components used in the processing chain may include equipment to effect compression, automatic gain control, limiting, equalisation and enhancement. A compressor narrows the dynamic range, an automatic gain controller maintains constant level, a limiter prevents loudness exceeding a preset level, an equaliser allows variation of the levels of selected frequencies and an enhancer adds brightness to the sound quality.

This application of technology to fashion the sound of a station is more important with an AM station than an FM station. An FM signal is less subject to environmental noise and interference and because of its wider bandwidth, requires less enhancement of the sound quality.

AUTOMATIC PROGRAMMING

Automatic programming whereby an electronic system co-ordinates pre-recorded announcements, time pips and recorded music into a normal program format without the presence of an Announcer during the time of the broadcast had been under investigation by Commercial station Engineers since the 1960s. Some attempts were made to use locally developed and constructed equipment but not a great deal of success was achieved. The technology was seen as a possible means of rationalising program production and operations.

However, considerable progress had been made in the USA in developing economically priced systems and some units were imported into Australia in the mid 1970s. One country station which put one of these systems into service was 3UL Warragul. From 9 am to close down daily, programs went to air fully automated from a CDC automatic system. The major units employed included five SMC carousels and one CDC carousel with four Revox reel-to-reel units, a BE time announce two cart machine and a triple deck random access cart machine.

The technology was not accepted to the extent that was envisaged by the system designers, mainly because of the apparent awkwardness in sequencing items. It was evident to listeners that 'a machine was operating the program'. However, it was used to some degree during midnight to dawn programs at some stations but its main use was in sequencing advertisements and station publicity.

One facility installed at 4HI Emerald in 1990 known as DCS System was imported from the USA and had the ability to store the station's entire inventory of commercials and promos on a computer disc with instant access for on-air playing. Operation was straight forward. All commercials and other audio elements were displayed on a screen. The operation had random access to all audio elements by using a trackball and operating a button. Chief Engineer, Ray Rumble, oversighted commissioning of the system.

By mid 1992, considerable progress had been made in providing facilities for automatic programming in Commercial station networks and individual stations. Sydney station 2SM installed one of the largest digital storage systems during a major upgrading of its equipment. The system allowed for the storage of music, commercials and spot announcements on a Computer Concepts DCS system. Storage capacity provided 140 hours of digital audio in two on-air studios.

Brisbane station 4BC also installed a DCS system to provide complete unattended operation of the station.

Many small stations have opted to take programs from an external source such as Arnsat programming service which originate from 2UW Sydney. The stations operated an unstaffed mode taking the satellite program feed supplemented with various local systems for spot storage.

Modern computer technology has had such an impact on broadcasting, that systems with specialised software and equipment are now readily available to assist all the various groups associated with the station operational and management functions catering for Engineers, Producers, Announcers/Presenters, Reporters, Sales Staff, Audience Researchers, Librarians, and Managers.

Although systems are available to cover the complete audio and management fields, there is a tendency for some companies to specialise in systems catering for the audio function, while others specialise in purely management type functions such as administration, sales, traffic, reports, finance etc.

One system designed for control of all functions associated with the audio side of the station operation in the Dalet system developed by Dalet Digital Media Systems of USA in 1996 and marketed in Australia by QASAR Communications Pty Ltd.

The system is centred on digital technology as it enables the entire station's operations to be run using any number of standard computers linked together as a local area network. Features of the system include:

- Windows Operating System.
  Many people these days are computer literate to some degree and even those with no experience will soon become proficient in its use of graphics with a short course training program. Transitions between applications are simply a matter of moving the on-screen pointer to the desired window and clicking. Rapid movement from production to scheduling, from recording to broadcasting, from live-assist to automatic can be effected without having to exit any application.
- Standard Network Configurations.
  Each work station using a standard PC based computer configuration can have its own choice of screen, layout and other user-specific settings and have access via a network to all audio at any moment.
- On-line Database for Instant Access.
  Any musical item, news story or spot can be retrieved in a matter of seconds. Titles are referenced in a database so that audio or text can be isolated by typing in a few designated details. The material can then be loaded into an application for editing, scheduling or broadcast.
- Pre-emptive Multi Tasking.
  The operator is not restricted to completing one task before moving on to another. Audio broadcasting always takes precedence, ensuring a broadcast is never sacrificed at the expense of another operation.
- Automatic Recording.
  The AUTOREC facility automatically records satellite feeds onto the service; CALL and RECORD facility allows journalists in the field to record stories into the system from an outside telephone. The recordings are then available immediately for playback at any work-station.
- Control Panels.
  Modular panels can be used for greater control of the software. Four panels can be grouped in any configuration for different uses such as production, on-air etc. The software icons are reproduced on the panels' keys, allowing users to point select, insert, play and scrub without using the mouse.
- Software. The software is in modular format. The broadcaster can choose among several packages, the one that corresponds the most to the broadcasters' needs — from simple cart replacement to 24 hour local programming. Options can be easily added to the system to meet new challenges.
- The Central Storage Server.
  The Server holds all audio program logs and texts. Audio is compressed using MPEG Layer 2 algorithm. The required storage capacity depends on the compression rate selected by the broadcaster. One gigabyte stores over 7.5 stereo hours.

A wide range of fault tolerance solutions is available to ensure total security.

The same company produces the Team Radio Traffic System for Windows. This is a software package that equips sales representatives, administrators and data operators with the means to work productively as a team. Five task oriented principles help to discern the grouping of users' needs.

MODULAR STUDIOS

Studio construction using conventional materials and methods can be very expensive, as every studio has to be individually designed, with little room being available to the designer in the way of standardisation. This is a major problem for small community broadcasting stations with very limited financial resources.

Modular studio construction is one way of reducing overall costs of establishing the station. The designs have been based on facilities provided for non radio locations where external noise reduction is a requirement, such as for small teaching rooms; test rooms for hearing impairment in hospitals; telephone and communication areas in power houses etc. Basically, they comprise sheet metal panels separated by sound absorbing fibre with the inside panel sheet being a perforated type. The panels are put together using resilient joints and the range of panels include doors, windows, ceilings and floors.

The advantage of employment of modular studios include:

- Materials can be prefabricated in a factory where close quality control can be exercised.
- Standard designs can result in predictable performance when the studio is assembled on the site.
- Installation can be carried out with minimum disturbance to activities in nearby areas.
- Transport costs are minimal because component parts can be broken down into manageable sections and are lightweight.
- Because the overall weight of the structure is low, there would seldom be a floor loading problem.
- The studio can be easily dismantled or rearranged should this be necessary in the future.

Some of the limitations of the technique include:

- Skilled labour is required to ensure a first class installation.
- Decorative treatment of inside panels may be necessary to ensure a satisfactory working environment for Announcers and other staff.
- Parallel walls do not make for good acoustics and some sloping panel sections may have to be added, if it is found that the room is too 'lively'.
- Special support may be necessary in some situations to provide effective isolation from structure-borne noise.
- The integration of air conditioning ducts and external cabling is not achieved as easily as for a room of solid construction.

One of the earliest studios which could be considered to be a forerunner to the present-day modular type, was provided at the 2UW Theatre in George Street, Sydney in 1942 to cater for the requirements of special drama broadcasts made from the Theatre such as the 8 pm Sunday night Lux Radio Theatre show which began in 1939 and continued until 1951.

Unlike other radio plays which were performed in studios live, or recorded for later broadcast, producers of the Lux Theatre involved the audience, making them as much like live theatre as possible.

Station Engineers devised and constructed a special stage studio. Two side walls and the back wall were made to slide into position from the wings while the complete ceiling was lowered down from above. The whole studio could be set up in seven minutes. The studio contained all the necessary lighting built in and flush with surfaces, with all walls and the ceiling being appropriately treated to provide optimum acoustic properties.

CONSOLES

THE ANNOUNCER'S ROLE

Consoles for Announcers and control booth Operators did not come into widespread use until some years after the commencement of broadcasting. Announcers were provided with very few control devices. The control of all the technical facilities was carried out by the Technician, even to the extent of fading the microphone in and out for speech and record playing purposes when the microphone was placed in front of the phonograph horn. It was considered that the Announcer had no role in operating the technical facilities. This was the work of technically qualified Operators.

Practices varied widely over the years, and even in the 1950s, there was considerable reluctance on the part of some Commercial station Chief Engineers to allow Announcers to operate technical equipment. Some stations had a firm policy that only technically qualified staff were allowed to operate the facilities. At one Victorian country station, the rules allowed the Announcer to switch the microphone on and off, but even this function could be over-ridden by the Technical staff. The Announcer could also play 78 RPM records and operate a switch for left or right turntable but only the Technical Operator could adjust the volume level to line. All transcription records were played by the Technical Operator as also were LP records when first introduced. The Technician was responsible for operating wire and tape recorders during interviews and playing to air, and also for switching OB circuits to air.

Some Engineers considered it unwise to provide a VU meter on the Announcer's desk or even for the Announcer to observe one on rack equipment which may be installed in the studio. In the case of one studio in Western Queensland, the VU meter was located behind a locked metal panel on the rack. The Technician had the only key.

The introduction of modern technology has changed significantly the role of the Announcer/Presenter. In many studios, digital technology has replaced analogue technology which had been in use since the introduction of broadcasting. Digital audio systems have revolutionised techniques for pre-recording and pre-mixing, with the employment of the mini-disc recorder/editor being a typical example. Program Producers can now combine in advance, advertising or promotional material and programs in a more planned manner, so making the life of the Announcer/Presenter less hectic than in previous years.

ANNOUNCER'S CONSOLE

The provision of a console for the Announcer began to become regular practice during the 1928–29 period when microphones were fixed in position and electric pick-ups were coming into widespread use. However, in the true sense, they were not consoles as the term was to later mean. In the majority of cases they were simply timber desks with two small boxes sitting on them in front of the Announcer. One box contained switches and two faders fitted with large knobs, somewhat like door knobs which were turned by gripping the knob with the whole hand. Faders which could be turned with the fingers came later. The other box which sat on top of the fader and switch box contained the microphone.

The Announcer's control panel provided with the WE 8B speech input equipment installed at the 3AR Elizabeth Street studios in 1927, consisted of a signal and control unit mounted in a wooden cabinet with the front panel sloping at 45 degrees. The equipment consisted of an assembly of apparatus units required to control from the studio, the switching relays of the studio control system mounted on racks in the control room. The Announcer's unit accommodated incoming telephone call circuit with lamp, a direct line to the transmitter, a talk-back circuit to the control room, and an 'artist call' push button. The Announcer had no control over levels. The microphone rheostat and first stage amplification control potentiometer were mounted on the amplifier in the control room. The microphone 'on-off' switch was also mounted on the amplifier. As initially supplied from the manufacturer, there was no facility for playing records using a pick-up but this facility was added by the installation staff.

As program presentation became more complex, additional facilities were gradually fitted to the Announcer's console. Training in the use of the console became an important part of the Announcer's work but because each studio, even within a common building often had different facilities provided or the layout was different, even experienced Announcers frequently made operation mistakes. Even today, it is not uncommon to hear an Announcer criticising the complex technology with which he/she has to cope.

Whereas today, the majority of broadcast transmitters are no longer manufactured in Australia, studio equipment is still being made in large quantities by companies specialising in this type of work. In fact in some areas of studio technology Australia is among the leaders in the world's broadcasting industry. Typical is the outstanding design and development work undertaken by Engineers of the Australian Broadcasting Corporation where equipment produced for the Corporation's own studio needs is now being employed by many overseas broadcasters.

THE TECHNICAL CONTROL ROOM

Even as late as 1930, some newly commissioned B Class stations did not provide a console for the Technician. The equipment was mounted on small racks with a shelf attached to the panel and the Operator sat on a chair or stool and carried out his duties by observing the Announcer through a double glazed window.

Where more than one studio was in operation and the hours of operation began to be increased, it soon became evident that a control booth was required with each studio, with each booth being self-contained so that it performed the function of the control room by enabling a complete program to be produced.

Even during the War when radio parts were difficult to obtain, some broadcasters were able to produce a table mounted unit which replaced the racks and mixer panel. The table mounted unit was known as a consolette and included all the basic functions including multi channel mixers, preamplifier, A amplifier, B amplifiers, faders, talk-back circuits and OB circuit control. The consolette also incorporated relays associated with operation of door warning lights and studio speaker system. Typical construction was a plug-in arrangement. Units slid on guide rails to mate with connectors fixed on the table.

The consolette provided a neat and useful arrangement in small studio installations where the program facilities were not extensive, but it had a number of operational and maintenance problems. About 1947, from it was developed the desk console, a compromise between the old rack and mixer combination and the consolette.

In this arrangement, the usual rack mounted units, such as preamplifiers, A and B amplifiers were reduced in size and made up as plug-in units and fitted into the pedestals of a specially manufactured control desk. The plug-in technique ensured quick replacement in the event of a technical problem and also enabled easier maintenance by removing the unit from the control booth and taking it to the maintenance area. Doors — usually of the lift out type — allowed easy access to units, terminal strips, power distribution points, jack panels etc., for maintenance or test purposes. Because of the limited space available, care had to be exercised in the design and wiring up of the desk to ensure that there was adequate heat removal arrangements and that the wiring layout minimised pick up of hum and noise from stray electromagnetic fields.

Facilities fitted to the main control panel included an electric clock, volume indicator, faders and master control, switching keys, indicating lamps and a jack field. The switching keys provided for monitoring of the various circuits, such as normal booth output, outside broadcast lines, incoming lines from the switchroom, time signals, master switching, preset extension to the Announcers desk, talk-back between Announcer and booth Operator and door warning lights.

The facilities provided for the control booth Operator enabled the performance of the following functions:

- Selection and mixing of a number of sources.
- Switching of outlets from studio to studio as required for the operational program.
- Control of program levels by means of VU meter and faders.
- Program monitoring using loudspeaker or headphones.
- Switching outside lines to program, and feeding programs back to OB points for cue purposes.
- Intercommunication with switchroom, other studios, Announcer and OB points.
- Providing a warning light to the Announcer prior to commencement of the program.
- Lighting 'on air' lamps in the studio and on entry door.

The Announcer's desk of the same period had facilities to allow performance of the following functions in presentation of the program:

- Selecting and mixing of one or two microphones, (Announcer and person being interviewed), and the output of two gramophone pick-ups.
- Transmission of the program to the transmitter or network.
- Switching of outlets in association with the booth Operator.
- Switching of OB lines, gongs, time signals, receiver off-air programs etc., into the program.
- Monitoring of the program with loudspeaker or headphones.
- Intercommunication with various points, including the studio PBX.
- Control of regional or relay station switching.

Where more than one studio is provided, a studio switching centre is required so that program from any of the studios can be fed to the transmitter or the network. Originally, this was handled by patch cords and jack fields on the equipment racks. However, with growth in studio numbers and complexity of facilities available, a studio switching centre became part of studio equipment designs. With a large network of transmitters such as used in the National Broadcasting Service, the switchroom became the nerve centre of the studio complex. The principal facilities provided in the 1950s included:

- Presetting arrangements for switching outlets from one studio to another.
- Testing and equalising outside broadcast lines and routing these to the studio.
- Communication with studio control booths, recording rooms and the Post Office program line or Trunk Test centre.
- Performance of routine tests on all studio equipment and permanent outside broadcast lines.
- Monitoring of outgoing programs to line.
- Control and distribution of time signals.
- Switching of outlets as required.

To cater for these activities, a large amount of equipment was provided. This included line terminating rack, amplifier racks, switching panels and relays, branching amplifier racks, monitoring loudspeakers, test equipment and power distribution bay.

It has been standard practice from the earliest days of broadcasting to provide a glass window between the technical control room or booth, and the studio. Where more than one studio was controlled by a particular control booth, more than one set of windows would be provided. At one centre, four studios were controlled from a single control booth. In recent years, studio designers have provided observation windows to allow visitors to observe activities in studios particularly orchestral studios. The ABC Collinswood studios is typical.

The design of these separating windows has been the subject of much study over the years. Early designs using double glazing set the two sheets of glass parallel, with an air separation of about 100 mm. By the mid 1930s, the majority of windows were constructed so that the pane adjoining the studio was inclined towards the ceiling at an angle of about 10 degrees for reflective purposes. Breather holes were placed between the glass panes to allow equalisation of air pressure. Some designers provided three sheets of glass, but tests showed that there was little improvement over a two pane installation.

The problem with placing one pane on a slant compared with the other, is that the average air space between the panes is reduced, and in many designs was little more than half of what it would be if both panes were vertical. The sound attenuation through the assembly is highly dependent upon the width of the air space so the acoustical benefits of slanting one pane was reduced considerably. However, tilting the glass allowed the reduction of reflections of sound from the window, although it did not remove them. The main advantages of angled glass in double pane windows is that it alleviates flutter echo between the window and an acoustical hard surface and it also reduces multiple visual reflections. The contribution of double pane glass to sound isolation is influenced by the acoustical characteristics of the glass itself, the design of the glass supporting system and the interior perimeter absorption.

When the ABC built its Ultimo Centre in Sydney in 1991, windows adjoining control rooms were constructed using triple glazed 16 mm panels of glass, each set separated by 500 mm, providing a total air space between the control room and studio of more than one metre.

Internal insulation in the studios is provided by perforated masonite panels overlayed on 185 mm thick fibreglass insulation pads. To absorb low frequencies, a material fabricated from vinyl impregnated with barium has been provided.

MODERN CONSOLES

In a modern broadcast studio, several aspects of design are considered to be of prime importance. These include firstly, the employment of equipment of the highest quality to meet the stringent technical standards required, equipment with high mean time between failure, and ease of operation by announcing staff. Secondly, the housing of the equipment, facilities and consoles should be designed with the utmost attention to both pleasing appearance and harmony with the studio interior appearance and treatment. The use of small plug-in modules and push or touch buttons and the subsequent need for less jacking facilities has enabled considerable improvements to be made in this regard and the earlier bulky consoles, floor mounted tape recorders, key switches and huge monitoring speakers with their sand filled enclosures have disappeared from modern studios.

Program sources in a typical studio may be grouped under the following headings:

- Continuity suites.
- Production studios.
- Outside broadcast lines.
- Program lines.
- Miscellaneous.

The types of program originating in the continuity suites can be announcements, news readings, replay from cassette, cartridge, standard disc or compact disc, or talks from a special talks table within the studio. In addition, programs from production studios, remote tape recorders, outside broadcasts, etc., are usually routed through a continuity suite. Production studios are the source of most live and rehearsed programs; that is, music, variety, drama, group discussion etc. The equipment associated with a production studio is different from that of a continuity suite in that more microphone channels are provided and material on disc, cassette and cartridge replay facilities is available for insertion into live programs.

Outside broadcast lines are used to send program material to the studios from specific points throughout the city and country areas. These may terminate in churches, concert halls, weather bureau, stock exchange, markets, police and many other points. The number entering the studio control room may be 100 or more, but only a small number, typically 6 or 7 would be extended to the Announcer's desk. Miscellaneous sources would probably include a line from an associated television studio for simulcasts, etc.

At one recently upgraded studio, the mechanical packaging of the console utilises aluminium extrusions to provide a low silhouette structure of high mechanical strength and attractive appearance. The console package has been designed to 'drop-in' to a rectangular table cutout making the console compatible with any design of customised control room desk furniture. All electronics are contained in plug-in modules which mount from the top and front of the console and no rear access to the console is necessary. Console terminal blocks are below the desk level and hinge forward for easy console interconnection.

The console is fully wired for stereo operation and complete input channel module interchangeability. Mono or stereo operation is determined solely by the modules installed and a mono console may be converted to stereo operation by the studio engineer at any time.

Three types of input modules are available — MIC, LINE and STEREO. All three types have stereo output assignment capability and the MIC and LINE Modules provide transformer coupled mono inputs. Two levels of input module sophistication are provided to allow console facilities to be tailored to studio requirements for program production or continuity. Input modules feature a novel and ergonomic layout, placing the fader above the channel ON/OFF and machine START/STOP control pushbuttons. All pushbuttons are silent and vary in shape and size for tactile recognition by the Operator.

A series of ancillary modules is available providing switching, mixing and processing functions. The console can be fitted with optional equalisers, filters and limiter/compressors, either fixed in specific channels or used with an insertion switcher or jackfield. A redundant power supply is also available as a console option.

Dual master modules provide all of the master bus functions for the console. Each module provides two identical and independent channels consisting of an active summing amplifier, a balanced insertion point, a rotary level control and a line output amplifier. Two modules are normally used for stereo program.

The console at one station is wired for three stereo monitor channels using three modules. Each module provides:

- A 5 pushbutton stereo monitor selector.
- A direct input talkback.
- A stereo input amplifier.
- A stereo rotary level control.
- A stereo ouput amplifier.
- A stereo direct output for driving headphones.
- A stereo mutable output for feeding an external monitor amplifier.

One of the latest overseas studio consoles to become available to Australian broadcasters is the Studer On-Air 2000 Digital Continuity Console manufactured by Studer Professional Audio AG, Zurich Switzerland and launched in June 1997 by Australian distributors, Syntec International Pty Ltd, Sydney.

The On-Air 2000 is a completely new concept which combines the technology of digital signal processing with the advantages of a digitally controlled operation surface. Touch sensitive LCD displays enable a fast and direct command acceptance. The concept 'Touch'n Action' is covered by a Studer patent. All time critical operations are effected via conventional elements like linear faders, rotary encoders and pushbuttons.

One of the Australian manufacturers who design and manufacture studio consoles for broadcasting purposes is Audio Video Communications (AVC) in Malaga, Western Australia. Director of the company is John Gouteff. The company was established in 1981.

In 1998, the AVC family of professional broadcast mixing consoles included BM300 Trio, BM200 Duet and BM100 Brolga.

The BM300 Trio is the top of the range designed for metropolitan and regional broadcasters and incorporates the ultimate in fully featured flexibility. It was said to be the first console in the world to combine the ease of external I/O connectors with a MasterBus module independence system, giving maximum flexibility to add or move devices to suit station operational preference.

The BM300 uses a MasterBus digital serial control bus system which allows a large number of independent devices to communicate with each other. Each module in the mixer contains a microprocessor with its own unique address. This allows any module to address and communicate with any other module along the MasterBus system. Because no one processor controls the whole mixer, any module can be added/subtracted to suit station operational requirements.

The unit eliminates the need to hard-wire audio and control signal devices into the console. It features a minimum of 34 plug and play DB15 connectors located under the console. It can be configured for 12,18 or 24 modules. Major features include Mix-1 output on every channel; switched A and B stereo inputs with jumpers for 600 ohm terminations; high level post fader, balanced send output on every channel; three relays per input card with floating contact closure for machine control; provision for RS232 remote control of many console functions; balanced line driver circuitry for stereo program, stereo auxiliary and program output monitoring; eight monitoring inputs; three guest headphones outputs; provision for five remote intercom stations; auxiliary outputs on every input channel; phase error detection and correction; opto isolated control for each input card and stereo program and auxiliary (audition) buses. The mixer was displayed at the NAB Convention held in Las Vegas USA in 1998.

The BM200 Duet broadcast mixer console has been designed specifically for broadcasters intending to install new facilities to replace old equipment. It provides all of the essential features required in a traditional broadcast mixer plus many options. It is available in 10,12 or 16 channel configurations. One was recently installed at 7LA. The MB100 Brolga was developed to meet the demand for a small economical console with a professional 'on-air' performance. A simplified switching system is used in the control software design for the Program-On, Off, and Cue functions. Only two buttons are used to implement all channel controls, greatly simplifying 'on-air' operation.

In addition to consoles for the broadcasting industry, AVC designs and manufactures a comprehensive range of audio switching, routing, metering, amplification and distribution equipment. It recently designed and provided for the Western Australian Government, radio broadcast consoles and other studio facilities for 13 remote studio sites for use by teachers who use the Royal Flying Doctor Service HF radio network to talk to students in remote areas.

Equipment design and development work is carried out by Rod Henderson and John Gouteff both of whom have had many years experience in the broadcasting and communications industries.

Recent customers of AVC equipment and services include ABC Radio, 6NR, 3AW and Western Australian School of the Air.

DIGITAL TECHNOLOGY

In recent times, there has been a trend towards the application of digital technology in broadcast audio facilities particularly in studios. Digital audio equipment widely employed includes CD players and recorders, reverberation and effects systems, DAT equipment, delay systems, audio storage, STL's, stereo generators and others.

Some digital audio devices are now so common even in home entertainment equipment such as the CD player that they are taken for granted and seldom classified as new technology.

The next stage is the implementation of Digital Audio Broadcasting (DAB) or Digital Sound Broadcasting (DSB). This will see the completion of the loop in the digital chain. Programs recorded digitally on CD or DAT will be played through studio digital equipment, broadcast digitally by a new range of specially engineered transmitters and received in the home or the car, by state-of-the-art receivers designed for the new technology.

The development of technology as it relates to the transmission and reception areas is being watched with interest by broadcasters throughout the world. Transmission is well suited to satellite distribution and this is of concern to many terrestrial broadcasters in both the AM and FM bands. Delivery by satellite would ensure coverage of the entire continent and would be a boon to people in isolated areas, and particularly, for long distance travellers. A consortium of European broadcasters and companies were among the first to demonstrate a digital audio broadcasting system with the Eureka Project 147/DAB in 1984. It showed that CD quality sound could be broadcast without the need for excessive radio spectrum. The Eureka in its various possible formats, calls for 12 to 16 stereo channels to be multiplexed in a spread-spectrum-like method, across 4.5 MHz to 7 MHz. A transmitter power of 1 kW would provide the same area of coverage as a standard 50 kW transmitter. Although the Eureka system has the support of broadcasters in Europe and many other areas, In-band systems have much support in the USA.

Whereas the Eureka system requires a new spectrum allocation, the In-band systems can be employed with existing AM and FM bands. Even though the World Administrative Radio Conference (WARC-92) held in Spain during February-March 1992 defined the band 1452-1492 MHz for digital broadcasting services, some countries including USA and Japan preferred the use of the 2 GHz region. In the meantime, the USA is pursuing further studies into In-band technology and is planning for early testing with fixed and mobile receivers.

If the test program is successful, it is likely that an In-band USA digital standard compatible with current AM/FM services may be in force in the very near future.

The Australian Department of Communications and the Arts has thrown its weight behind the Eureka system, and is planning to test the system over an extended period. The ABC and FARB have also supported the Eureka system.

Should the Eureka system be adopted as the Australian standard, it would require an extended period of simulcasting of AM/FM and DSB services and clearing the L-Band (1452-1492 MHz).

The rate at which it would be introduced would be influenced by public demand. Receivers are likely to be complex and potentially expensive at first.

At a Conference held in Sydney in early 1993, it was revealed that the Department of Communications and the Arts expected to have a pilot scheme operational by early 1994 and that it was likely that a DSB service would be in service in Australia within a few years of completion of trials.

During early 1994, staff of the Communications Laboratory of the Department of Communications and the Arts carried out tests in Canberra using third generation Eureka 147 DAB equipment developed by a group of European manufacturers. A Philips DSB transmitter and Thomson DSB receiver were employed in the tests. The transmissions were carried out from the Black Mountain Tower site in the L-Band using 1481.8 MHz and conducted in parallel with normal FM transmissions on 105.5 MHz. Common program material was used and transmissions adjusted to ensure received signals were of equal audio level and time synchronised.

A Committee set up to be involved in the study of the technology included representatives from the Department, ABC, SBS, NTA, FARB and CBAA.

Because DAB is the registered trademark of the European Eureka Group, DSB (Digital Sound Broadcasting) or DRB (Digital Radio Broadcasting) is now being employed as the preferred terminology for all types of digital radio broadcasting systems in Australia.

On 27 July 1994, the Australian Broadcasting Corporation hosted the first industry Conference on Digital Sound Broadcasting. The Conference took place at the ABC Radio complex at Ultimo, Sydney. The Conference was told that two contrasting approaches to DSB have emerged.

In some countries, particularly Canada, the UK and in Scandinavia, there is a strong commitment from government and industry to provide both the legislative framework and technical infrastructure to introduce DSB with the full support and protection of the existing radio broadcasters. In others, notably the USA, there is strong resistance from the established broadcasters to any technology that challenges the status quo, and indifference by governments to the introduction of these new systems.

At the ABC Conference, the Australian position was summarised by Paul Elliot, Parliamentary Secretary to the Minister, and the keynote speaker. He pointed out that the means already exists to introduce DSB into Australia since both the recent Broadcasting Services Act and the Radiocommunications Act are intended to be 'neutral to technology' and both have means of providing the necessary licences. This approach was reinforced by Tony Shaw from the Broadcasting Policy Unit of the Department of Communications and the Arts, who cited the recent auctions of licences for Microwave Distribution Systems as setting the pattern for the introduction of new services. In effect, these speakers said that it was more a matter for the industry than for the Government to oversee the introduction of DSB into Australia, and that the process would be market driven rather than incorporate any privileged position for the established broadcasters.

Whilst this may seem to leave the Government position equivocal, other speakers outlined some very significant work being carried by their agencies. Colin Knowles spoke about how the Australian Broadcasting Authority was at the forefront of setting technical standards; Geoff Hutchins of Spectrum Management Agency indicated how spectrum at 1.5 GHz might be made available; David Soothill, formerly with ABC Radio but then with SBS explained how Australia had registered a satellite system with the International Telecommunications Union in Geneva to preserve our frequency bands; Ennio Ravanello described how the Communications Laboratory in Canberra was researching radio propagation models; and Vic Jones outlined how the National Transmission Agency would be ready to provide transmitting facilities for the new services. Robin Blair, Telecom Broadcasting commented that one of the perceived problems with DSB had been that it is essentially a multi-channel system, with each transmitter carrying a number of programs sourced by implication, from a number of program producers. He said it breaks down the established pattern of, one program, one style, one sound, one radio channel. He also pointed out that in his opinion, this view of the program provider would soon become untenable since the cable networks to be provided by Telecom for video, also have capacity to deliver a huge number of very high quality audio channels. He argued that broadcasters had no choice but to migrate to delivery systems with very high quality and a multiple program capability. For radiated services this was DSB/DRB.

The Australian Broadcasting Authority as the Australian body with responsibility for handling radio and television matters with the International Telecommunications Union and for overall broadcasting planning functions in Australia, convened a task force including ABA and industry representatives to consider broadcasting requirements for the development of DRB services in Australia. Convener of the task force was Colin Knowles, General Manager Planning and Corporate Services of the Authority. The group contributed to the Digital Radio Advisory Committee (DRAC) established by the Minister. Hendrik Prins, Technical Consultant of the Federation of Australian Radio Broadcasters convened a working party of the Authority's task force to undertake detailed Engineering studies into DRB.

In late 1995, Michael Lee, Minister for Communications and the Arts announced that DRB would be managed in two phases. Phase 1 would involve the establishment of experimental Eureka 147 standard terrestrial DRB stations in the L-Band for a 12 month period in Melbourne and Sydney configured for eight programs, and a Committee of experts to advise the Government on the introduction of DRB services. Phase 2 would involve establishment of DRB stations to operate in parallel with existing AM/FM stations.

The Minister in his statement indicated that no planning decision would be taken on the use of the L-Band until all policy options for introduction of DRB had been addressed.

In a subsequent development, the National Transmission Agency announced that in January 1996, the NTA, the Communications Laboratory of the Department of Communications and the Arts, and Telstra Broadcasting were co-operating to provide facilities for a planned series of DRB trials in Sydney, with NTA and the Laboratory installing equipment at a site in Dural, and Telstra providing transmissions from the Sydney Centrepoint Tower. Full-scale tests of the technology began in early 1996 with the arrival of equipment from overseas suppliers. Tests were later planned for Melbourne and Brisbane. Cost of NTA equipment associated with the trials was estimated to be $1.5 million.

During 1995–96, a series of tests on the direct reception of digital radio signals by satellite was conducted by the NTA and the Communications Laboratory.

On 24 March 1998, Senator the Hon. Richard Alston Minister for Communications, the Information Economy and the Arts announced that the Government had plans in place to allow establishment of digital radio services in Australia in 2001.

Commercial, Community and National radio broadcasters would be able to convert to digital but would be required to simulcast for a period to ensure listeners were not disadvantaged.

The Minister proposed to invite the ABA, the ACA and broadcasting industry representatives to participate in a Planning and Steering Committee to develop a framework for implementation of the service in 2001.

It was intended that planning would proceed on the basis of the employment of the Eureka 147 system operating generally in the L Band but with consideration of using the VHF spectrum in regional areas. Existing broadcasters would share a multiplex facility to allow provision of five CD quality radio services.

MICROPHONES

PRE BROADCAST ERA

Reginald Fessenden of the USA, is generally credited with being the first person to carry out sound broadcast transmissions of any significance. From his Brant Rock station, Massachusetts, he broadcast programs on Christmas Eve and New Year's Eve in 1906.

Fessenden was a prolific inventor, having 500 Patents to his credit. One of the Patents covered the microphone which he built for the broadcasts. It used platinum electrodes separated by carbon granules with a flowing water system taking the heat away from the electrodes. It operated satisfactorily with currents up to 15 amperes.

It has to be appreciated that this was many years before the availability of valve oscillators and amplifiers. Transmissions were basically variations in radiated power.

The method of modulation was to simply put the microphone in series with the aerial coil and ground. The variation in microphone resistance as a result of the sound wave impinging on the diaphragm varied the aerial current in sympathy.

Before the First World War, carbon granule types microphones capable of handling relatively large amounts of power, were available from a company in Germany. The microphones were so designed that they would be bridged into nests of two to six in series/parallel combinations. Heat was removed by a water recirculating system.

Two units were brought to South Australia by an early German settler in the Barossa Valley and were later given to Ern Stanton an active wireless telegraphy experimenter with his station XVN at Prospect. Roy Cook, a friend of Ern Stanton later acquired the microphones and for a time used them without water cooling with his experimental station 5AC during broadcast trials.

During the First World War, some development work had been done with carbon microphones in England in connection with listening devices for locating aeroplanes, and advantage of this work was taken in post War broadcasting work.

Carbon Microphones

In 1921, the Western Electric Co., in USA produced a double button stretched diaphragm microphone. It was the first microphone designed to take into account the special requirements of broadcasting such as a flat frequency response over a wide range, low distortion, a high degree of sensitivity, a wide dynamic range for orchestral broadcasts and suitability for outside broadcast work.

In England, the Peel-Conner carbon granule microphone was the first type used there for broadcasting. It was basically a telephone single-button type made by the General Electric Company. The microphone was mounted on an adjustable steel bracket to allow it to be moved up or down to accommodate itself to the height of the person speaking. Dame Nellie Melba used this type in her historic broadcast of 15 June 1920.

Fred Williamson with his experimental station 5AH at Kent Town, Adelaide used a modified Peel-Conner microphone during one of the first successful transmissions of speech and music in South Australia in 1922.

Although British Engineers experimented with an electro-magnetic Sykes microphone developed by Captain Round of the Marconi Company, they reverted to the carbon granule type in 1926 with a Marconi-Reisz microphone which originated in Germany from the work of Dr E Reisz, but made in England. In this unit, the rubber diaphragm as first used, was discarded and replaced with a thin sheet of mica to keep the carbon granules in place.

Electrodes were carbon rods about 5 mm diameter and 25–37 mm long. The container was a block of marble, octagonal in shape, with a cavity on one side in which the granules were placed.

Unfortunately, it had a peak response between 4 and 6 kHz causing violins to 'scream' and overload the transmitter. In later models, the mica was replaced with rice paper to reduce this problem. The Reisz microphone was first used for broadcasting in Germany on 2 November 1925. During January 1927 extensive trials were carried out at 3LO on a model obtained from the BBC.

On the Australian scene, the Experimental or Amateur Licences were restored shortly after the First World War and with the use of War surplus valves, the airwaves were soon active with experimental transmissions.

By 1922, the transmission of speech and music transmissions were routine and anyone with a receiver had no trouble in finding a program being broadcast somewhere in the band. The 200 metre band was widely used for this purpose.

The microphones used were generally adapted telephone types. Whilst these were reasonably satisfactory for the speech part of the broadcast, they left much to be desired for the musical part of the program. As electric pick-ups were not available at the time, the microphone was placed in front of the horn type loudspeaker for broadcast of recordings.

In early 1923, prior to the official commencement of broadcasting, Oswald Anderson, Concert Manager of Palings arranged, in association with New System Telephones Pty Ltd for a series of broadcasts from Palings Concert Hall, Sydney. Leading Artists, including Lee White and Clay Smith were invited to contribute. Ray Allsop who arranged the technical facilities had a parabolic reflector microphone made up for the broadcasts. It employed a solid back carbon telephone transmitter suspended by springs in a large wooden basin to concentrate the sound at the microphone point. It was suspended from a stand about 1.8 metres above floor level, with the Artist standing back about one metre.

The parabolic reflector microphone continued to be used by broadcasters for many years but more efficient microphones were employed and the parabola scientifically designed. They found wide application in capturing the songs of birds and other bush sounds. Frequently, they were used in conjunction with acoustic baffle types. They were also employed for broadcasts from studio auditoriums with audience participation shows. Station 5KA in Adelaide had one such microphone comprising a spun dish about one metre in diameter supported by two microphone stands. The microphone — a dynamic type — was suspended at the focus of the parabola by three long wire springs. It was constructed by the station staff about 1950.

Post Office Technicians at the Brisbane ABC studios also developed one along similar lines about 1953. One officer associated with its development and field application was Jim Todd. Jim commenced work with the Postmaster General's Department in Brisbane on 9 June 1924 as Junior Mechanic-in-Training, working on telephone equipment until 1935 when he transferred to 4QG studios, then located in the old Taxation Building. In later years, he became involved in the installation and commissioning of VLM and VLQ, the high frequency inland transmitters located at the Bald Hills Radio Centre. Jim served many years at the ABC Penny's Building, Alice Street and Toowong studios, and when he retired on 21 August 1964, he was Officer-in-Charge of ABC Studios technical facilities.

The Western Electric Double Button Microphone

When Government licensed A Class broadcasting stations went on air in the early 1920s, the type of microphone most widely used was the Western Electric double button model.

The WE microphone was of the push-pull type consisting of two heavy metal rings supporting a thin stretched duralumin diaphragm which acted on two carbon buttons, mounted one on each side of the diaphragm. On each side of the diaphragm was a gold plated area against which the carbon rested. The push-pull action gave minimum distortion and maximum output.

The resistance of each button was about 100 ohms and as the two were in reality in series for the voice currents, the output impedance of the transmitter was approximately 200 ohms.

The unit was normally mounted in a No. 1B mounting, but could also be fixed on a microphone stand.

It was usual studio practice to carry out electrical tests before the commencement of each transmission. If the station was on air for three short periods as was the usual broadcast times, say 9 am – 11 am; 1.00 pm – 3 pm; 6 pm –10 pm, then tests would be carried out prior to the 9 am, 1.00 pm, and 6.00 pm transmissions by the studio Technical staff.

The specification required that the operating current in each side of the transmitter should not exceed 35 milliamperes (Ma). The difference between the values of the current in the two sides of the circuit had to be kept below 5 Ma. A typical operating current was 30 Ma per button. This gave a good compromise between high output and long life. If the current in either side of the circuit exceeded 35 Ma or if the difference between the current in the two sides of the circuit exceeded 5 Ma, it was a sure sign that the granules had become packed or permanently aged. It was essential to keep each button balanced, otherwise the output would be distorted.

Packed granules resulted in a loss of sensitivity of the microphone. If the measurements indicated that the granules had become packed, the microphone would be brought back to normal by gently rotating or tapping the body lightly with a pencil to loosen the granules.

Frequently, the granules had to be dumped and the chamber refilled. Granules were supplied in a vacuum tight bottle and were relatively expensive at the time.

In areas where high humidity was a problem, the microphone had to be kept in a desiccating chamber in between broadcasts. The desiccating chamber was typically a large glass battery jar about 50 cm high and contained a bag of silica gel with a square of glass serving as a lid. Station 4QG in Brisbane was one that had this set-up. If the carbon granules were allowed to absorb moisture, it caused havoc with the microphone response. The output would drop, and the background hiss would rise.

Most of the WE microphones required by broadcasters were obtained from Western Electric Co., (Australia) Ltd, Sydney. Harry Pearce organised a Radio Department to handle the importation of WE radio equipment from USA and the UK. In addition to the WE microphones the company handled amplifiers, valves, receivers and accessories.

The WE microphone was developed to meet the specific requirements of broadcasting and initially was not sold as a separate unit. In 1922, it was only available with WE manufactured broadcast transmitters. One American broadcaster Powel Crosby purchased a WE transmitter in order to obtain one of the microphones for use with a high power station he was building.

A photograph of the store room of one broadcasting station in the USA in 1925 showed 16 WE microphones on the shelf.

TRANSVERSE CURRENT MICROPHONE

Probably the most widely used locally designed carbon microphone was the Transverse Current Microphone described by Chris Cullinan, a well-known Australian Sound and Radio Engineer, in a magazine in 1934. Many station Engineers built their own, as the article contained full construction details. Engineers often referred to it as a 'Reisz' or 'Cullinan' microphone.

It was very similar to the BBC Marconi-Reisz in many respects, being made from a marble or wooden block and using a mica diaphragm. Frequency response was reputed to be reasonably flat 100 to 7000 Hz with no resonance in this range. Typical impedance was 600 ohms and a 6 V battery was used for the DC current. Instead of mica for the diaphragm, some models were constructed using dental type rubber sheeting. Microphones at 2UE employed this technique.

One of the problems was to ensure that carbon particles were very small. They had to be ground to the texture of good quality face powder, using a pestle. If granules were too large, the microphone generated a high level of hiss.

Both the Cullinan and BBC-Reisz microphones found widespread use throughout National and Commercial stations. Staff at the 2UE, 4QG and 3BA studios were among those who built Cullinan type models for studio work using marble or wooden blocks. These types of microphones were not suitable for holding in the hand while broadcasting, as physical movement would generate excessive noise. For OB work, they were spring mounted inside a support ring or placed on a table or stand in front of the commentator.

Kit sets could be purchased by the hobbyist from Murdochs in Sydney as late as 1939 with a machined teak block being used to house the carbon granules.

Some locally manufactured microphones now in vintage radio collections show the electrodes being gold plated sixpence coins.

The Reisz microphone was also produced commercially in Australia. AWA acquired a BBC-Marconi-Reisz model from the Marconi Company and produced a limited quantity. The marble blocks were provided by a local monumental mason and the company manufactured its own carbon granules in its Laboratory. A number of Commercial stations installed these microphones in studios where they were suspended inside metal rings by wire springs.

In an undated report by a panel of 3LO Technical and Production staff following test on an AWA manufactured model the report concluded:

> 'The advantages of this type of microphone are considerable. There is no hissing or blurring as is the case with other microphones when this type is over amplified. It gets nearer to absolute fidelity of reproduction than any other microphone so far available.'

Technical staff who maintained the studio facilities of 3LO were AWA employees.

Chris Cullinan who developed the 'Cullinan' transverse model was a well-known operator of experimental station VK3XW. He worked in the Engineering Department of 3DB/3LK in 1937 joining the organisation when Chief Engineer was Edgar Hooper and 3DB Technical Supervisor was Harry Kauper. In early 1938 he left 3DB to move to Tasmania where he was associated with the establishment of 7EX Launceston which was commissioned on 5 February 1938. He remained at the station for many years being Chief Engineer when he left in 1955 to take up an appointment with 3CS Colac as Chief Engineer. He was an active member of The Institution of Radio Engineers (Australia) being a foundation member of the Launceston Division and Chairman for three years. He became an Associate Member of The Institution in 1941, Member in 1945, Senior Member in 1949 and later a Fellow.

BLASTING

A major problem encountered in many studios with the employment of early carbon microphones was blasting, and consequent harshness and distortion in the quality of transmission. The judicious placement of the performer in relation to the microphone helped to reduce the effect. At 3LO, and also 6WF, this was accomplished to some extent during performance of an item by display cards which were held up by the control Operator at the observation window. The cards were designated 'Nearer', 'Further', 'Louder', 'Softer', etc. Sudden increases or decreases in volume had to be taken care of, by operation of control panel equipment, even to the extent of switching in and out, an additional amplifying valve.

At Commercial station 2MK Bathurst which began operation on Armistice Day 1925, a light signalling system was installed in the studio to advise Artist or Announcer of listener reactions from telephone calls or to give instruction to the Artist. The equipment was operated by the control room Operator.

The system comprised a network of 12 pigeon hole type boxes with a lamp bulb mounted inside each box which had a glass front on which was painted words or signs. If a report on the performance of an Artist was received by telephone, the Artist was notified immediately. A box lit up which read 'Phone Report' and another box would be illuminated with the word 'good' or 'excellent'. There was no provision for announcing a bad report.

The system was also used to instruct the Artist when to commence and where to stand in relation to the microphone. Typical lamp designations were 'Commence', 'left', 'right', 'forward', 'back', 'back further' and others.

There was also the problem of adjusting the microphone to the correct height to suit the Artist. Telescopic stands of today were not readily available. Technicians at several studios erected a cord and pulley system suspended from the ceiling or beam. With a lead counterweight of approximately the same weight as the microphone, a pull on one of the cords enabled the microphone to be raised or lowered to the appropriate height.

Some station Managers and suppliers of studio technical equipment issued guidelines to announcing and technical staff on the correct use of the microphone for various purposes. It was unusual to employ more than one microphone even for broadcast of a large orchestra. The following guidelines were set out in the handbook provided with the studio equipment installed at A Class station 5CL Adelaide in 1927:

'* Announcements.
For making announcements, the microphone is used in the same manner as for ordinary telephone transmitter. The speaker should talk in a normal voice with his lips about four inches (100 mm) from the microphone.

* Lectures.
The speaker should stand in front of the microphone at a distance of about half to one yard from it. He should speak as though he were addressing a small audience in the studio and should be strongly cautioned against raising his voice unduly.

The use of a manuscript should be avoided, for the noise made when turning over pages is highly objectionable.

* Instrumental and solos.
  With a piano, the microphone should be placed two to three yards from the small end of the piano and in line with the keyboard. In general, the Artiste should stand one to two yards from the microphone. (The word "Artiste" was preferred to "Artist" by many A Class station Announcers at the time.)
* Choirs.
  No singer should be nearer than 1.5 yards from the microphone. To avoid undue prominence of any part, the singers should be arranged in radial lines with tenors in one sector, baritones in another and so forth.
* Orchestras.
  The bass drum should never be part of the orchestra because the fundamental tones will not be transmitted.
  The studio should preferably have two pianos. This is because, for a large orchestra, the piano should be placed at the back of the orchestra but for solos and accompaniments the microphone should be placed only two to three yards away. If only one piano is available, it may therefore be necessary to move it from one end of the studio to the other during transmission.'

Notwithstanding the disadvantages of the carbon microphone for broadcasting purposes, it held its own for well over 10 years and during that period beat off many challengers, mainly the electromagnetic and condenser types.

CONDENSER MICROPHONE

The Western Electric Company introduced another type of microphone in the 1920s known as the condenser microphone or condenser transmitter. It had been invented in 1914 by E C Wente. Instead of relying upon the available resistance of a carbon granule button, it operated by variation in capacitance between an insulated metal diaphragm and the metal casing. However, although broadcasters had high hopes that it would solve many of the problems encountered with the carbon microphone, it did not live up to expectations. It required a low noise amplifier close to the element, and moisture in the condenser air gap caused frying problems.

The condenser microphones provided with the Western Electric 8B program input equipment installed at 3AR in 1927 were WE 394 type, supplied for use with 48A or 47B amplifiers. The two amplifiers were identical electrically but differed mechanically. The 48A amplifier was housed in a 7A mount of cast aluminium finished in black lacquer and used for desk or table operation. The 47B amplifier was housed in a 8A mount on an adjustable floor type microphone stand and finished in dull black japan.

An improved design which followed the WE 394 type was released about 1928 and widely employed at A and B Class stations throughout Australia.

In 1932, the company released a miniature condenser microphone the 640A type with a diameter of only 25 mm, with a flat frequency response of 40 to 10000 Hz.

Even as late as 1933, the condenser microphone was used exclusively at the ABC studios in Adelaide. The units were Standard Telephones and Cables capsules mounted in a case containing the amplifier. The amplifier used a single 4102D valve with an output transformer suitable for working into a load of 200 ohms.

The output level from these microphones was about 40 dB below the standard reference level, at the time, of 5.9 milliwatts. This level was quite low and in order to avoid difficulties with induction from power mains circuits and other equipment circuits, each microphone output circuit was wired in shielded leads to the control room.

Power for the valve was provided from batteries. The filament batteries comprised two 6 volt accumulators, each consisting of three cells of 120 ampere hour capacity at the 10 hour discharge rate. The cells were contained in glass jars. The anode supply and polarising potential for the condenser unit was provided by a 130 volt accumulator system in glass jars having a capacity of 10 ampere hours at the 20 hour discharge rate.

The microphones were mounted on stands of various heights with flexible cords terminated in six pin plugs to suit the fixed sockets on the studio wall. This facilitated changing microphones when necessary. Spare microphones were kept in the control room, and spare capsules were kept in a small chamber containing absorbent chemicals to keep moisture from the capsule.

Because the microphone was costly, some Engineers at B Class stations constructed their own microphones. Some of these well-made units can be seen in Museums today. One constructed by 5AD staff was on display in the Adelaide Telecommunications Museum for many years.

At least one condenser microphone was manufactured for 4QG Brisbane by an Engineering firm in West End. When the PMG's Department staff took over the station in 1929 they found drawings prepared for manufacture of a condenser microphone and documents to indicate it had been delivered to the station. However, there was no trace of the microphone in the equipment handed over.

The condenser microphone was also available in kit form and a number of station Chief Engineers purchased these kits to assemble their own units. One popular kit set of USA origin was the CK-1 Condenser Kit which comprised accurately machined parts, easy to handle and simple to assemble. When assembled as per instructions, there was a precise clearance between backplate and the diaphragm. A selected alloy sheet 0.001 inch in thickness which was stretched beyond the resonant point was used for the diaphragm. The diameter of the microphone was 3.25 inch (81.25 mm), the case was alloy, aluminium sprayed and served as protection for the diaphragm. It was so constructed as to avoid cavity resonance in the working frequency range.

A pre-amplifier comprising two stages of resistance coupled amplification employed two valves and fitted inside an aluminium housing with sufficient space to accommodate the microphone was also available in kit form. Batteries required for the facility comprised two No. 6 dry cells, 135 volt B battery and 7.5 volt C battery.

One station known to have employed one of these assembled kit sets was 5KA Adelaide in the mid 1930s, when the station was located in Richards Building, Currie Street, Adelaide under Chief Engineer Charlie Tareha.

The Rola condenser microphone was also employed at some early Commercial stations. Ron Hipwell who built 3SH Swan Hill in 1931 and operated the station from his home on behalf of Swan Hill Broadcasting Co., Pty Ltd with a 50 watt transmitter on 1080 kHz procured a Rola condenser microphone for the studio. Programs were basically local Artists, bands, recorded music and speeches. It was reported to provide good frequency response and low distortion even with a loud brass band playing in the small studio. No blasting effect occurred as was the case when using Phillips carbon microphones. The unit included a three stage amplifier employing valve types UX 859 and two UX 199. It was housed in a vertical metal cylinder with a hinged top and the condenser unit mounted at right angle on the side of the cylinder. The microphone was mounted on an adjustable floor type stand with a friction bushing.

Over the years, particularly with the introduction of solid state technology, many improvements have been made to the condenser microphone and it is widely employed in present day broadcasting as well as for other purposes. A recent introduction is the Sony ECM 510 electret condenser microphone. It can operate for some 8000 hours from a single AA size alkaline cell. It is coated with a special matt black finish which eliminates handling noise when held in the hand.

Another recent addition to the range of condenser microphones is the Beyer MC834 model introduced during 1993. It is a large diaphragm type offering low self-noise level and a frequency response virtually flat from 40 Hz to 20 kHz. It has been designed to withstand SPL levels of 130 dB extendable to 150 dB using an internal two position pad. The microphone features a fixed cardioid pickup pattern, elastically suspended condenser element, switchable low frequency roll-off and operation from a power source 12 to 48 volts DC.

Condenser technology has also produced highly efficient shotgun stereo microphones. One model, the Sanken CSS-5 is designed around an array of five directional condenser elements with polyphenylene sulphide diaphragms to provide optimum humidity/temperature stability. High directivity is achieved in a unit less than 30 cm in length. When used in stereo mode, the unit uses 48 volt phantom power. When used in mono mode, power is supplied to the left hand channel only.

Condenser microphones are available in various polar patterns. For example, in the 1993 Sennheiser range, patterns include omnidirectional (model MKH20); figure of eight (model MKH30); cardioid (model MKH40); supercardioid (model MKH50); supercardioid/lobar (model MKH60); Lobar (model MKH70) and switchable (model MKH80).

Designs are adapted to the characteristics of human hearing with enhanced response at 3.5 kHz and all models feature a 10 dB attenuation switch (6 dB and 12 dB for the MKH80) and are phantom powered. The MKH80 features 3 dB and 6 dB boost at 10 kHz, and 3 dB and 6 dB attenuation at 50 Hz.

Notwithstanding the introduction of solid state technology into condenser microphone equipment, valve types have not been entirely replaced. Some radio producers favour valve amplifier types as they value the 'subtle warmth of their natural sound which is perfectly captured particularly by the transparency of digital audio recording'. The widespread adoption of digital recording has created a renaissance in the use of condenser microphones with associated valve amplifiers. Heat generated by the valve is removed by semiconductor cooling devices.

One model introduced in 1993 and employing a valve amplifier is the Microtech Gefells UM92S featuring the classic M7 capsule which gave the original Neumann its special sound. The microphone uses two large diameter gold spluttered plastic membranes. The valve amplifier using a high impedance triode is of conventional design with integrated heater voltage stabilisation. A selector switch provides for omni, cardioid and figure of eight pattern characteristics.

A microphone introduced about 1994 is the AKG C12VR microphone manufactured in Austria. The C12VR (Vintage Revival) is a reproduction of the C12 model. The new microphone is a dual diaphragm valve type with switchable polar pattern providing omnidirectional, cardioid and figure of eight as well as six intermediate positions. Frequency response is 30 Hz–20 kHz ± 2.5 dB.

In 1996, Neumann released its M149 condenser microphone with a valve amplifier stage. It was the first valve amplifier produced by Neumann in over 30 years. It was claimed to be the world's first transformerless valve microphone and to have the lowest self noise of any other valve condenser microphone on the market. The microphone features nine switchable polar patterns including omni, cardioid, wide angled cardioid, hypercardioid and figure of eight patterns; acoustically transparent grille inspired by the original M49 design and a seven position high-pass filter (20Hz–160Hz).

VOLTAGE GENERATING MICROPHONES

Another group introduced in the early 1930s was called voltage generating microphones and included types such as moving coil, ribbon and crystal. They were capable of generating their own voltages without requiring an external source other than sound waves.

Moving coil types included STC 4017A and WE 630A types. The STC 4017A introduced about 1932 was extensively used by the ABC for many years particularly on OB work. It had reasonably flat frequency response 35 Hz to 10 kHz. The moving coil was of aluminium ribbon, wound on edge and secured and insulated with varnish. In 1935, STC introduced their 4021A microphone. The frequency response was similar to the 4017A but the microphone was designed for use with the diaphragm uppermost. The arrangement resulted in an equal angle of incidence for all sound in the horizontal plane ensuring that the frequency characteristic was common for all horizontal components of the sound field.

In 1931, the motion picture industry in Hollywood introduced the RCA ribbon microphone to meet a particular need of the industry, and broadcasters were quick to realise its potential for broadcasting. Within two years, they were in widespread use in studios. Before the use of the ribbon microphone, all microphones suffered from inferior directional characteristics. The ribbon type response was double sided and was ideal for interviewing purposes and plays. The RCA 44B was one of the first models in service. It was followed by the RCA 77A type which allowed the pick-up of sound arising from one direction — or more accurately, from one side — while almost completely rejecting sound from the other side. Other pre World War 2 models employed in studios included Amperite RE-1, RAE and RS models, Bruno RA2 and RA3 model and Universal RL model.

The characteristics of the ribbon microphone were such that it was ideal for broadcast commentaries as it had the ability to exclude extraneous sounds. By 1937, the ribbon microphone had been developed into the form of a lip microphone which when held close to the Commentator's mouth gave good discrimination between wanted speech and the ambient noise. Although somewhat inferior to the standard studio type, it was superior to the performance of moving coil microphones then in use for outside broadcasting. In 1951, following work by the BBC, an improved version was introduced and became available in Australia soon after.

Byer Industries Pty Ltd well known for their Byer tape recorders, manufactured copies of the RCA 44B ribbon microphone in their Dorcas Street workshops in South Melbourne for AWA who employed them in studios of AWA stations and also sold them to other Commercial station operators.

Although the ribbon microphone is not found in as many studios as in years gone by, it has maintained a core of followers. Early models were somewhat unreliable because of the breakage of the long thin ribbon if handled roughly but designers have overcome this problem with a much shorter longitudinally placed ribbon which is much more durable.

A printed ribbon version is also available and it is claimed that this new design combines the best qualities of ribbon and dynamic microphones.

The crystal (piezo-electric) microphone had many supporters soon after its introduction. The sound cell consisted of a frame, usually bakelite, supporting a thin Rochelle salt crystal bimorph element. Astatic, Brush and Shure were all well-known manufacturers of a wide range of models. Station 3AK had a Brush piezo crystal microphone as part of its original studio facilities in 1931. The most popular Brush microphones in service at the time were the 2S2P model which had an output level of -74 dB and the 4S6P model which had an output of -68 dB. For auditorium work where the Announcer had to move around, the Astatic model L1 was employed. Due to its double sided construction, a wide range of head movement was possible without appreciable variation in output. It had an impedance of 80000 ohms and was often used with up to 15 metres of cable.

A problem encountered with Rochelle salt crystal microphones was that performance was sometimes affected by high ambient temperature and high relative humidity. Modern crystal types using a wafer of barium titanate ceramic are unaffected by heat and humidity.

MICROPHONE SELECTION

When studio broadcasting first began, there was no difficulty in selecting a microphone for a particular application. There was only one available — the carbon granule type — and it was used for all purposes.

With the later introduction of condenser, dynamic, ribbon, crystal and others, the problem of selecting the best microphone for a particular application arose. Today, with studios striving for better, higher quality audio, the selection of the proper microphone is even more important. No one microphone is best suited for all broadcast applications. Each application has its own set of requirements.

Experience over the years indicate that factors which have a major influence on the choice of microphone include:

- Adequate frequency response for the program to be broadcast or recorded.
- Possession of electrical and mechanical ruggedness.
- Appropriate directional response characteristics to satisfy the program requirements.
- Similar performance, particularly frequency characteristics, where a multiple microphone set-up is to be employed.

Certainly, since the late 1920s, broadcasters have been acutely aware that the reproduction of speech and music is dependent upon the acoustic properties of the room containing the sound sources and the placement of the microphone with respect to these sources requires a knowledge of the particular technique of microphone placement. The days when the placement of the microphone was left to the Technician are gone. The present day Producer has made a detailed study of techniques and his experience is an important factor in achieving a high quality broadcast. Where a dozen or more microphones are involved in a large symphony orchestra broadcast, the Producer and Technician may spend an hour or even more in setting up the microphone arrangement.

Multiple microphone set-ups introduce a number of problems including the likelihood of phase distortion due to the path length differences between the sound source and the pick-up positions and also with the greater number of mixer channels there is always a greater chance of the sound Operator making errors.

The same transducer principles are employed today as sixty years ago, but microphone performance is, of course, far superior. Each of the transducers, the dynamic or moving coil, the condenser and the ribbon types are each more appropriate for particular applications.

The dynamic microphones have low noise levels, are rugged, are suitable under high humidity conditions, require no power, are reliable and most designs are cheaper than other types of transducers.

The condenser microphone which now only requires a polarising voltage of 9 to 48V DC compared with 200V in the 1920s has excellent transient response which makes it ideally suitable for orchestral performances where there are percussion instruments, cymbals, etc. Because the transducer can be made small, they are widely employed as tic-tac microphones.

Although the ribbon type has enjoyed wide popularity since 1931 and still has its supporters, its use is declining. They are more fragile than the two other transducers and also produce the lowest output level.

Each microphone has a unique directional or polar pattern. Each pattern has its advantages and disadvantages and this has to be taken into account in selection of a microphone to cater for a particular broadcast. Directional microphones develop their patterns through phase shifting. Included in the unidirectional patterns are supercardioid and hypercardioid. These patterns find application where acoustic feedback or noise is a problem.

By 1938, there was a large range of microphones available for studio, OB and public address applications. The most widely used at the time included ribbon, velocity, crystal and dynamic types. Ribbon types popular with Commercial station operators included Amperite SR80 and SR80H, Philips 9514 and RCA 74B. These had gains about -65 dB and in the case of the Amperite models, a frequency response reasonably flat 40 to 15000 Hz.

Velocity types included Amperite RBSN and RSHN, Electro-Voice V2, V3 and V4 and Bruno SK4 and SK2. The Bruno models were directional types with a frequency response 50–12000 Hz ± 1 dB, for the SK4, and 60–10000 Hz ± 2 dB for the SK2. The Electro-Voice with a frequency response 40–14000 Hz was widely employed in recording studios.

Of several crystal type brands, the Shure 720A, 700A, 701A, 702A and 85A were in service at a number of stations. The 702A and 85A which had a frequency response 30–10000 Hz ± 3 dB, had non-directional characteristics. The Piezo Astatic D104 and the Brush single cell were other crystal types in use. The D104 had an impedance of 80000 ohms at 60 Hz and a gain of -65 dB.

The Clipper Dynamic D7T, a semi directional type with a gain of -56 dB and frequency response 70–8500 Hz ± 3.5 dB was in service at several Melbourne and Sydney Commercial stations. Other dynamic types included STC 4021A and 4017 models.

To assist Production and Technical staff in selecting an appropriate microphone for a particular application, one of the Sydney radio networks issued the following guidelines to staff in the early 1960s:

'(i) Studio Announcer.
It is an advantage for this type of microphone to be unidirectional as this facility helps in amplifying the Announcer's voice in relation to any noise created in other areas of the studio. A typical type is a moving coil microphone with a unidirectional cardioid response pattern obtained by an acoustic phase shifting network.

(ii) Studio interviews.
As the two people are usually seated on opposite sides of a table, the microphone has to pick up sounds originating from two directions and like the Announcer's microphone, have little or no pick up in other directions. A high quality ribbon type specially designed for broadcast use is frequently employed.
Alternatively, the Announcer may conduct the interview from his control panel position with the Interviewee being provided with a separate microphone.

(iii) Drama production.
In drama production it is usual for several people to be speaking at various times and as they require quite a deal of space to move about when striving for certain quality of sound, an omni-directional microphone is generally used. The microphone has to be of high quality and, as various speech effects have to be created from some distance away, the microphone needs to be a very sensitive one. A typical type is a condenser type with a pattern which can be varied remotely from the Control Room. The variable pattern enables special effects to be introduced in the production.

(iv) Studio recital.
To obtain better control of balance of sound between the Soloist and the Accompanist in a studio recital, a separate microphone is used for each person. These have to be high quality models to enable a faithful reproduction of the musical sounds. So that each microphone will pick up mainly only one source of sound a cardioid pattern type is generally used.

(v) Orchestral concert.
For orchestral concerts broadcast from a large auditorium several microphones are usually needed to obtain a balance between the various instruments of the orchestra.
For a general coverage of the orchestra, a high quality microphone with a cardioid pattern is frequently used. In locations where orchestral concerts are regularly held, this main microphone is usually suspended in some way. To supplement the pickup of this microphone, several other microphones, with cardioid patterns response, are used.

(vi) Sports commentary.
For field broadcasts of sporting events a fairly small robust

microphone is preferred. It should be lightweight if the Commentator has to hold it for long periods, slightly unidirectional, and be designed for use fairly close to the mouth.'

There has not been much change in microphone technology for many years and the choice of a microphone for a particular broadcast or recording is often made on the basis of personal preference of individuals or past experience. Well-known brands in the early 1990s included Electro Voice, AKG, Shure, Sennheiser and Neumann.

Many broadcasts such as productions at the Sydney Opera House require a great deal of planning in the selection and placement of microphones. For example, the 1989 Emmy Award winning production of La Boheme by the ABC was the culmination of many years of close co-operation between the Australian Opera, the Elizabethan Philharmonic Orchestra and the ABC production and technical staff to overcome the varying technical requirements of a live production for television and sound broadcast audiences. A major problem was the necessity to conceal all microphones from the activities on stage and the audience's view. The problem was also made difficult because at least half of the orchestra was underneath the front section of the stage. This required that the mixing process be controlled by a delicate addition of reverberation and equalisation to get the best sound balance. A total of 23 microphones were employed. They included two Sennheiser MKH415 located left and right of Chorus No. 1, AHG type C414EB panned for off stage band, two Sennheiser MKH816 located left and right of Chorus No. 2, five Crown PCC160 panned for lead vocals, two Neumann K83i panned for strings, Neumann KM83i panned for viola, two Neumann U89i panned for violins, Neumann U89i panned for celli, Neumann U89i panned for celli/basses, Neumann KM86 panned for horns, Neumann KM86 panned for harp, Neumann KM86 panned for percussion, Crown PZM panned for woodwind, Neumann KM83i panned for brass and Neumann U89i panned for brass.

In addition to interviews, etc, microphones employed in field work cover a wide range of application. One such application is bird sound recording.

For some years, Vic Le Pla specialised in recording bird calls for a program that was regularly broadcast over ABC stations 2KP/2TR. It was still being broadcast in 1998. Vic, a former member of the ABC Technical staff prior to retirement developed equipment specifically for his needs. One item of particular interest was the parabolic microphone which consisted of a dynamic microphone facing into a parabolic dish. It was very directional with a narrow angle of acceptance. In order to obtain a wide frequency response with this type of system the diameter of dish needs to be large for good low frequency response and the diameter of the microphone needs to be small for the high frequencies. However, as most bird calls occupy the middle and upper frequencies of the audible spectrum, a small diameter dish proved to be satisfactory for recording bird calls, since roll-off of the lower frequencies eliminates a considerable amount of unwanted noise without affecting the frequency range of the call.

The dish was made from fibre glass, a non-resonant material with the back being covered with sound absorbing material in the form of plastic foam to reduce sound entering from the rear. In cases where it was not possible to get close to some birds, he set up a suitable radio microphone close to the bird's habitat and made the recording some distance away.

A problem experienced with all microphone arrangements is the high background noise created by wind in the canopy of a forest when recording the sounds of birds that frequent the higher branches of tall trees. However, by the employment of suitable equipment during the post recording process, it is possible to filter most frequencies outside the range of the particular bird sound.

In recent times, so called 'wireless microphones' have been widely employed for studio work particularly with outside broadcasts of stage musicals. A typical system in use in 1994, was the Sennheiser Mikroport Wireless System. It comprised an EM1046 UHF receiver and SK50 UHF transmitter.

The receiver unit operated in the frequency band 450–950 MHz with switching bandwidth being 25 MHz with tuning range in 5 kHz steps. It was an eight module diversity receiver with options including a computer display and remote control.

The transmitter accommodated up to 16 frequencies in the range 450–960 MHz with switching bandwidth of 24 MHz. Frequency response was 70 Hz–20 kHz and dynamic range 108 dB.

Although much emphasis has been placed on the application of digital technology for many studio functions, no satisfactory truly digital microphone had reached the commercial market as at 1997. Most development models have used a standard microphone with an analog-to-digital converter mounted inside the housing to provide a digital signal to a digital console.

RECORDING

DISC RECORDING

Sound recording had its origins in 1877 when Thomas Edison recorded his recital of 'Mary had a little lamb'. The sound was vertically cut on tin foil wrapped around a cylinder. The cutter was attached to the diaphragm and the sound caused the cutter to vibrate. Although the technology had nearly half a century lead on the advent of broadcasting, it took much development work before it was suitable to meet the specific requirements of broadcasters.

One of the first gramophone companies in Australia to undertake large scale disc recording and processing was Columbia Graphophone (Aust.) Ltd of Homebush in 1926, headed by Reg Southey. Reg had worked with the Bell Telephone Laboratories USA; Standard Telephones and Cables London; General Electric Company of London and with the Columbia Graphocone Company in London before coming to Australia to head the Australian office in 1923. During 1956–57 he served as President of The Institution of Radio Engineers (Australia).

Although broadcasters played commercially produced records to air from the start in 1923, even before the availability of electric pick-ups, they were unable to make records for their own use for program purposes on site because of the processing problems. They had to wait 10 years before instantaneous recording technology became available.

The Presto Recording Corporation in USA was among the pioneers to produce instantaneous recording equipment suitable for use in broadcast station studios. The equipment was widely used in Australia in Commercial and National station studios.

It is not known when the first Presto system was installed in Australia but the equipment was widely employed in the mid 1930s in Recording Studios providing transcriptions etc. for the broadcasting industry. However, the discs used required processing from masters. In 1937, recording studios with Presto equipment included Broadcasting Advertising Pty Ltd; Broadcast Services; Chas E Blanks Pty Ltd; Fidel-A-Tone Sound Productions; Legionnaire Sound Productions Pty Ltd; Shearman Sound Recording Studios; The Prestophone Playback Service and others.

George Saliba Chief Engineer of Presto in USA was responsible for development of the equipment for instantaneous recording at broadcasting station studios.

Although an instantaneous record, that is one which could be played immediately it had been recorded without damage to the record and without intermediate processes, could be produced in the 1920s, it required an acoustic phonograph with a pre-grooved metal disc formed from an aluminium/zinc compound.

About 1927, Roy Buckerfield in charge of the laboratory of the Transatlantic Wireless Manufacturing Company, Prospect an Adelaide suburb, attempted to produce instantaneous recordings for broadcasting station 5KA operated by Sport Radio Co. He employed an acoustic phonograph and a pregrooved disc. The disc was about 10 inches (250 mm) diameter, made of annealed copper sheet about 20 SWG thickness and spot soldered to a steel base. A 45 degree groove was cut in the copper disc by a local Engineering firm using a lathe with traversing being done manually. Sufficient grooving was provided to allow about one minute of recording time.

When recording, no metal was removed. The needle simply distorted the walls of the groove in sympathy with the applied sound. Although comments at the time indicated it worked 'in a fashion', it was never put into service. The problem was associated with the use of copper for the recording disc. Although it was softened by annealing, the action of cutting the grooves hardened the copper on the walls of the groove, so making it difficult for the recording needle to make sufficient impression on the walls during the recording process. Attempts to anneal the copper disc after formation of the grooves caused warping of the disc, so further development work was abandoned.

With the development of feed mechanisms in 1928 to cut their own grooves, some improvement in the technology was possible, but all-metal discs were still required.

Broadcasters had to wait until about 1932 before researchers found a method to allow production of instantaneous recordings that would give quality acceptable for broadcasting purposes. The use of gelatin showed promise but had a short shelf life. Moisture dried out and the disc became very brittle. Celluloid was used for a couple of years but it too, had short comings when used by itself.

The solution came with the coated disc. This involved the application of a coating of cellulose nitrate or cellulose acetate to both sides of a metal disc with the metal providing rigidity. For convenience, they were called acetate discs.

Presto produced the Presto Green Seal Disc but other companies such as Columbia, The Gramophone Company, EMI and HMV produced their own labels.

The major components of the Presto studio disc recorder included the cutting head, feed screw, lever for raising and lowering the head, heavy cast iron turntable, microscope, playback arm, shielded audio input lead, synchronous alternating current motor, overhead mechanism carrying the cutting head with its carriage, and a heavy cast metal frame on which all components were mounted.

The cutting stylus was either a steel needle or a jewelled needle such as a sapphire, with the sapphire being used for high quality recordings.

The heavy cast iron turntable acted as a flywheel to ensure constant speed of the disc on the turntable. A feed mechanism moved the cutting head across the disc with the feed mechanism being operated by worm gears driven by the rotating turntable. The depth of the cut could be adjusted and a microscope facilitated inspection of the groove. It was usual practice to make a test cut without modulation and examine the groove with the microscope before proceeding further. Swarf during the cutting operation would be cleared off with a sash brush.

Bill Smith, a member of the PMG's Department NBS staff in Adelaide was one person who had wide experience with the operation of Presto disc recording equipment. He worked at the ABC Hindmarsh Square Studios for many years. Bill became interested in radio while still at school and doing part-time work at Wallaroo, a wheat port in South Australia's Spencer Gulf. He became friendly with some Ship's Wireless Operators who encouraged him to study Radio Technology and to learn the Morse Code. He bought some text books, built a crystal set and learnt the Morse Code by listening to transmissions from the Adelaide Coast Radio Station VIA.

In 1921, Bill joined the Postmaster General's Department and worked as a Telegraphist until 1927 when he made a change in direction in his career path and took up a position as a Ship's Wireless Operator after resigning from the Department.

Bill left the life aboard ships and returned home in 1929 to set up a Radio and Electrical business in Wallaroo where he was distributor for AWA Radiola, Stromberg-Carlson and Raycophone receivers and various brands of components and electrical home lighting plants. Radio Servicing was a major part of the business activities.

In 1938, he rejoined the PMG's Department and worked at the ABC Adelaide Studios at Hindmarsh Square on various duties including booth operations, switchroom control, recordings, outside broadcasts, plant maintenance and field strength surveys. He remained at the Studios until 1944 cutting many hundreds of discs on the Presto installation. It was policy during the War years for all talks to be pre-recorded on disc before going to air.

Bill retired from the Department in 1968 but maintained an active interest in Broadcast Technology as an Attendant at the Adelaide Telecommunications Museum for many years.

Staff in the ABC Sydney studios who also spent many years on disc recording work included Ted Mosely and HAG Stanford.

In addition to the large studio model, the Presto Company produced a portable model, which found wide application in the field. It came in two portable cases, and could be set up for recording in a few minutes. It was widely employed by War Correspondents during the Second World War with 16 inch diameter transcription discs rotating at 33⅓ RPM. Although classified as 'portable' a unit weighed more than 180 kg and it was an exercise in weight lifting for the poor Technician who had to carry it long distances in the field.

Another well-known brand in service at some stations was the Neumann disc recorder. It operated on much the same principle as the Presto machine. It was the first disc recorder installed at the ABC studios in Melbourne and Sydney in 1935.

Commercial station 3KZ where 'Snow' Grace was Chief Engineer had disc cutting equipment manufactured by Precision Engineering Company Pty Ltd, Collins Street, Melbourne and fitted with a Neumann cutting head. The machine produced discs for replaying 33⅓ or 78 RPM and had capability for cutting 93, 112 and 130 lines per inch.

In addition to the Presto and Neumann systems, there were others in service at Commercial stations in the 1930s with AWA equipment being favoured by many stations. Studios fitted with AWA facilities included 2CH, 2GF, 2GZ, 3DB, 4BK, 5AD, 6ML and 6WB while those with access to Presto recording equipment included 2HD, 2SM, 3HA, 3TR, 3SH, 4LG, 7EX and 7HO. Stations 3KZ and 3UZ had Neumann equipment. The 4BC studios had both Presto and Neumann facilities. Other types in operation were the American manufactured Universal system at 2WG, 3AW and 4GR and a Marguerite system made in England and installed at 6PR and several other stations. The Marguerite system was a portable discs recording unit of professional standard, manufactured by MSS Recording Co. Ltd. The unit had a moving iron cutter head with separate sapphire stylus, swarf brush and long-bar head-lowering mechanism. The heavy turntable was rim driven and as was normal on such equipment, the blank was clamped to the turntable. The unit contained a four valve amplifier with volume level indicator, and a needle armature pick-up for replay.

Another system which had a reputation for high quality precision engineering was the Telefunken system made in Germany. Models were in service at several stations in 1935 including 2UW and 2UE.

One Australian manufactured disc recorder popular with some recording studios and used at one Victorian country Commercial station was the Royce model produced by Playback Recording Supplies, Melbourne. Date of introduction is not known but some models in private collections appear to have been manufactured during the late 1940s. It was still being advertised in technical magazines during the mid 1950s. The unit comprised standard overhead traversing gear precision built for standard or micro-grooving and equipped with a Hi-Fi cutting head and stellate or sapphire stylus.

Another Australian manufactured disc recorder was produced by Max Byer, Proprietor of Broadcast Recording Supplies, Dorcas

Street, Melbourne. It was a portable unit known as Byer Junior and made in the 1930s. It featured 12 inch (30 cm) diameter turntable rotating at 78 RPM and rim driven by a compact motor unit; an arm served as combined pick-up/cutter; interchangeable play/cut stylii; the turntable spindle drove the cutter radially across the disc employing a worm and sector mechanism; the stylus was driven from label towards outer edge of the disc.

The company also manufactured acetate disc recording blanks with aluminium base but during the War years when aluminium was scarce, bases were made of steel or glass.

Shortly after the end of the Second World War, Victor Harris a pioneer in gramophone pick-ups manufactured a number of disc cutting units. Some of these well engineered units have been preserved in vintage radio collections.

One disc cutting recorder developed for the home recording enthusiast in the late 1930s was the Maynard Homerecorder. Input to the device was made by connecting the output of the receiver to the cutting head terminals. In this way the receiver AF stage could be used to provide sufficient power to drive the cutting head. The company produced blanks of sizes 6,8,10 and 12 inch diameters. The units were available from John Martin Pty Ltd, Radio and Electrical Supplies, Sydney, and others.

A number of station Technical staff endeavoured to manufacture their own disc recording equipment but with varying degrees of success. One Sydney station Engineer developed a cutting head from a Blue Spot loudspeaker movement made about 1935. Other design approaches by do-it-yourself Engineers are also of interest. These included, the use of a powerful motor coupled through a large flexible coupling to a heavy turntable, the use of a large central nut with left hand thread for securing the blanks, engagement of the lead screw by a lever protruding from below the turntable and cutter head stylus pressure being adjusted by means of a movable weight on the tone arm.

In 1936, Val Sydes Chief Engineer, 7LA Launceston constructed a disc cutting machine which saw service for many years.

Although most recording was done using the lateral cut technique, the vertical cut or 'hill and dale' technique had its supporters. One of these machines was installed at 5DN Adelaide and used for several years. Its main advantages were that it enabled the recording of an extended frequency range about 60 Hz to 10 kHz and the record had a long playing life due to the lightweight reproducing head. Andy Fisher who later transferred to the PMG's Department was one of the 5DN Technicians who worked the machine.

After the Second World War, there was some refinement of the coarse groove technology then being used. Frequency response was improved, surface noise and distortion reduced and some changes made in disc material composition.

In 1948, the Decca company in England applied Full Frequency Range Recording (FFRR) to its Commercial recordings and other firms followed with similar technology until Columbia researchers in the USA developed a practical 33⅓ RPM microgroove long playing record which had a major impact on the future direction of recording technology.

Although tape recorders made great inroads into the recording work carried out in radio studios, manufacturers of disc recording equipment took up the challenge. For example, the Georg Neumann G.m.b.H. works in West Berlin developed and manufactured a Teldec stereo cutterhead with the advent of stereo, and several Australian Commercial stations installed their type AM32B machine in the early 1960s. The machine, a lathe type, incorporated fully automatic groove pitch and depth control, and was fitted with the Teldec stereo cutterhead.

MOBILE RECORDING UNITS

With the availability of disc recording equipment in their studios, broadcasters soon saw scope for use of the equipment at locations away from the studios. Mobile recording units were set up with the ABC having its first unit on the road in May 1939 in Sydney. The vehicle housing the equipment was a 30 CWT Bedford chassis on which a special body was built. The facility was constructed in the PMG's Department Melbourne Workshops and driven to Sydney with a number of recordings of interest being made during the journey. Engineer-in-Charge of the project was Horrie Hyett.

The equipment comprised a pair of Presto stationary recorders similar to units already in service in the studios. The units were mounted on rubber blocks on the recording table. Recording could be carried out at either 33⅓ or 78 RPM.

The amplifier rack which was also floated on rubber blocks housed a preamplifier and recording amplifier as well as a gramophone record equaliser and loudspeaker level control. The power converter was mounted on a separate rack to minimise hum problems.

The preamplifier was a two stage transformer coupled design using a 6C6 valve operating as a triode in each stage giving a gain of 50 dB and power capability of 100 mW. The recording amplifier was a three stage amplifier push-pull throughout with a gain of 60 dB. The final stage used a pair of 2A3 type valves.

The recording technique was similar to that employed in the studio but owing to the unit being operated in the field, its operation actually combined the functions of the pick-up operation with those of a recording operation, so that two operators were employed.

The use of portable recorders in the field during the Second World War brought much prestige to the ABC, particularly in relation to the news service. Correspondents in the Middle East battle zones sent back over 8000 reports on acetate discs and although made under extremely difficult conditions, very few were rejected as being unsuitable for broadcasting, on technical grounds. One mobile recording unit operated by Engineer Reg Boyle and Mechanics G Gallway and W T MacFarlane left Australia for Palestine during June 1940. Officer-in-Charge of the Unit was Captain Lawrence Cecil MC, a former World War 1 veteran and ABC Producer.

Mobile recorders were also employed in the Pacific War zone with one unit being modified to fit inside a RAAF bomber and operated by Technician Len Edwards.

During the War years the ABC ran a session 'Voices from Overseas' in which Servicemen recorded messages in the field on mobile recording units. Due to the acute shortage of metals, most of the records were made on a glass base and arrived at the Studios in a badly damaged or broken condition. Senior Mechanic Jack Moore of the Sydney Studios spent many hours making temporary repairs so the material could be transferred to new discs.

TAPE AND WIRE RECORDERS

While developments were taking place with instant disc recording techniques, magnetic recording was under study. About 1933, a Blattnerphone was acquired and installed in the Melbourne studios of the ABC for trial purposes. The recording device was named after Louis Blattner, a German who had settled in England. Blattner improved an office magnetic dictating machine using steel wire invented by a fellow German, Dr Kurt Stille in 1924. By 1929, he had replaced the steel wire with a steel tape and the BBC acquired a machine for assessment. Reports revealed that it was satisfactory for speech but unsatisfactory for recording music. The tape was 6 mm wide and weighed about 8 kg. The machines were made in Germany but later models using 3 mm wide tape were made in England. In 1933, the Marconi Company purchased the Blattnerphone rights and substantial research and developmental work was undertaken.

A Blattnerphone or Marconi-Stille recorder, as it was called, was provided for the ABC from about 1936 and operated until the early 1940s but it did not have a great deal of use. Its use was limited to the production of recordings that required transportation around the Commonwealth for reproduction from more than one studio. Joining broken tape was a problem. The broken ends were shaved down to feather thickness over about 20 mm by means of emery paper and the two tapered ends joined together with soft solder. The aim was to produce a join of the same thickness as the tape and if this was not achieved, a bad join could cause deformation and excessive wear of the heads.

In 1992, the machine was put into working condition by staff of Telecom Research Laboratories and used to play 11 reels of steel tape brought to Australia by the Archivist of the Canadian Broadcasting Corporation for identification of material on the tapes.

After the War, wire recorders using 4 mil medium carbon steel wire became available, but like pre-War metal tape recorders, were not suitable for recording music. They were soon replaced by plastic tape recorders because considerable advance in the technology had been made in Germany during the War. In fact, even as early as 1936, the German BASF company had made a recording of a concert on plastic based magnetic tape.

Technical details of magnetic recording equipment was readily available but units were expensive and difficult to obtain. Some station Technical staff took up the challenge and made their own machines. Harry Fuller, Chief Engineer of 3YB Warrnambool was one of the early pioneers. A booklet on the history of the station stated that the wire recorder constructed by Harry was, 'the first such machine made in Australia'. It was soon followed by a tape recorder initially using paper tape embedded with iron filings.

Harry Fuller, after attending Technical College, obtained his Commercial Wireless Operators licence in 1932. In 1933, he was a Radio Operator with Howard Kingsley Love with the Aerial Survey Expedition into Central Australia. After the expedition, he worked for Love at Kingsley Radio in Spring Street, Melbourne. In May 1937, Harry joined Argus Broadcasting Services Pty Ltd, joining 3SR and transferring to 3YB Warrnambool in February 1939 as Chief Engineer. He became Chief Engineer of Argus Broadcasting Services in August 1948.

Staff at 5AD Adelaide were also early on the scene in the construction of a studio wire recorder. Alan Matthews constructed a workable wire recorder in 1945 and it was soon in regular use for outside recording work.

An early commercially produced wire recorder was the Pyrox model widely employed in the broadcasting industry over the period 1948 to 1953. Wire was typically 4 mil medium carbon steel. Although great expectations were envisaged for the wire recorder, its limited frequency range and other difficulties restricted widespread application.

By 1950, a number of quarter inch (6 mm) tape recorders appeared in many metropolitan studios. They had satisfactory performance up to 15 kHz at 19 cm/sec. At some studios, the tape recorder quickly replaced the large diameter transcription discs.

Included among the brands of professional reel-to-reel tape recorders employed by the ABC and Commercial stations were Ampex, Byer, EMI, Magnecorder, Rola and Studer.

Byer, Magnecorder and Rola were Australian made models.

The company which manufactured the range of Byer, and later Rola tape recorders, was Byer Industries Pty Ltd, 8 Dorcas Street, South Melbourne which was incorporated in 1947.

In 1951, the company released a basic adaptor deck which operated in conjunction with a studio record turntable. The unit was designated Byer AT12 Magnofilm Tape Adaptor. A supplementary tape bias/preamplifier unit was provided. It enabled tape speeds of 7½ and 15 inches per second to be employed.

The first reel-to-reel tape recorder manufactured, was the single motor Model 55 aimed at the domestic market. The next machine was Model 66 aimed at the professional market. Amplifiers were made by Zephyr Products. This was followed by Model 77 Mark1 designed to meet a PMG's Department contract for the machines to be used by the ABC at the Melbourne Olympic Games in 1956. It was the first three motor plus solenoid to be manufactured by Byer.

After the Games, the recorders were distributed throughout the ABC metropolitan and regional studios, and saw service for many years. They also saw service at some transmitting stations carrying emergency program material.

The design was later upgraded to become Mark 2 with the main features being:

- Easy 'wrap-round' tape threading with no pressure pads.
- Finger tip control.
- Full editing facilities with variable speeds in fast forward and rewind.
- Instantaneous stop and start.
- Suitable for direct rack mounting.
- Comprehensive input and output facilities readily accessible on the front panel.
- Three motors.
- Three heads.
- Precision ground satellite capstan.
- Record and play channels — less than 1% distortion.
- Signal to noise ratio better than 50 dB at 3%.
- Wow and flutter better than 0.3% at 3¾ IPS, better than 0.2% at 7½ IPS and better than 0.15% at 15 IPS.
- Frequency response ± 3 dB in the range 50–6000 Hz at 3¾ IPS, ± 4 dB in the range 30–15000 Hz at 7½ IPS and ± 2 dB in the range 40–15000 Hz at 15 IPS.

From the early 1950s, console or static tape recorders imported from Electric and Music Industries Ltd, UK became available. They were of professional quality and were widely employed at Commercial and National studios. With early models, performance provided overall frequency response ± 2 dB from 40 Hz to 10 kHz at a speed of 30 inches per second. At 15 inches per second, the response was within these limits up to 8 kHz. Unweighted signal-to-noise ratio was 54 dB at either speed, and harmonic distortion at maximum input level was 1 per cent at 30 inches per second and 1.5 per cent at 15 inches per second. With subsequent design improvements and better quality tape, performance was improved. The EMI was accepted for many years as having no rival for broadcasting work.

One of the first units installed in Australia was provided at Parliament House Canberra for use by the ABC.

They were frequently installed in pairs with a matching control console being installed between two recorders.

When the ABC studios at Rosehill, Perth were commissioned in 1960, ten console units were arranged in five pairs. Each pair was installed in a recording booth and a control console used to channel and control programs to and from each machine. Access to the program banks was provided through one switch per machine. Alec Cohen of the PMG's Department was in charge of the Rosehill installation.

A popular studio tape machine manufactured by Rola and in service in the early 1960s was the Rola 777 Studio Console.

Features included:

- Precise cueing feature.
- Starting time less than 0.1 second.
- Force draught cooling to ensure temperature stability over long operating periods.
- Designed for 7 and 10.5 inch spools.
- Air damped compliance arm to prevent tape overshoot on tape start up.
- Mechanical deck and amplifier unit could be easily withdrawn for maintenance purpose.
- Large storage space available for spools.
- Independent control of Record and Play amplifiers.
- Simultaneous replay monitoring provided via an inbuilt monitoring loudspeaker.
- Direct comparison of original and recorded signals by means of A-B control.
- Switching facilities to provide meter reading across Record or Play channels.
- Switching facilities to provide for meter readings of VU, line input, bias voltage, valve currents and AC input mains voltage.
- Equipment tropic proofed to ensure reliable service under tropic conditions.

- Optional extras included Remote Control Equipment and Rola Auto Q Automatic Cueing Equipment.

Another tape recorder was the USA designed Magnecorder manufactured by Byer under licence. It was employed throughout Australia at many National and Commercial stations.

Two staff who played a major role in the development of the Byer recorders were Leon Sebire, Engineer and Jack Richardson, Factory Foreman.

Byer Industries Pty Ltd was taken over by Rola with production continuing at Dorcas Street but administration being handled from the Rola Head Office at Richmond. Recorders were then marketed under the Rola label.

Byer Industries eventually disappeared as an organisation when further change in ownership took place. Plessey took over Rola and later, Philips took over Plessey.

Of the many small portable types suitable for studio work, Commonwealth Electronics Pty Ltd developed a battery operated recorder employing quarter inch tape at 7½ inches per second in response to a tender issued by the Postmaster General's Department for use by the Australian Broadcasting Commission during the 1956 Olympic Games in Melbourne.

The mechanical design, development, manufacture and acceptance testing were carried out in the company factory at Derwent Park near Hobart with work associated with the electronics being undertaken at the company works at Baulkham Hills near Sydney.

The unit provided good performance over the range 50-7000 Hz and met CCIR Specifications. The tape transport mechanism comprised a spring wound mechanism with governor control of speed. The valve amplifier unit was powered by dry cell batteries.

Tasmanian people associated with the work at Derwent Park included Bill Nicholas, John Dodds and Dave Hildyard.

An important advance in technology associated with the operation of portable tape recorders was the availability of rechargeable batteries and chargers. One early tape recorder employing rechargeable batteries was the Fi-Cord 202. Station 3SR Shepparton was one station which had one of these models in service for many years.

By the 1960s, a large range of tape recorders was available for professional and domestic use and included Avon, AWA Magictape, Belle, BSR Model TR3, Clarion, Classic, Collaro, Elizabethan, Ferrograph, Ferry, Fi-cord, Geloso, Gramdeck, Grundy, Magnetophon, Nova, Philips, Princess, Pyrox, Rola Model 66, Simon, Stellavox, Stenorette, Studio Deck, Tandberg, Telefunken, Walter and others.

By the 1980s, stereo and mono tape recorders in use by broadcasters and recording studios included models manufactured in Australia, USA, Japan, Switzerland, Norway and UK with brands including Ampex, CEI-Cuemaster, Ferrograph, Fostex, Lyrec, Nagra, Otari, Revox, Sonifex, Sony, Soundcraft, Stellavox, Studer, Tandberg, Tascam, Technics, Telefunken, Telex and others.

Popular portable stereo tape recorders in service in the same period included Nagra and Stellavox, both made in Switzerland; Sony made in Japan; and Uher manufactured in West Germany. Nagra was one of the leaders in the design and manufacture of high quality miniature tape recorders. Many were in use by ABC staff.

With the availability of cartridges and cassettes, many broadcasters preferred these to reel-to-reel tape recorders for some programs. The first tape cartridge was made in 1958 and broadcasters quickly adopted the endless loop cartridge for short commercials. Philips cassettes appeared in studios in 1963. The high order of performance of cartridges and cassettes had resulted from a number of technological improvements particularly improved manufacturing techniques, high resolution fine particle tape, precision tape transport mechanisms and advances in recording and playback head designs.

Cartridge tape recorders in use at broadcast studios during the mid 1980s included Broadcast Electronics, CEI, Harris, ITC, Pacific, Sonifex, Stellovox, and others. The CEI made in Australia by Consolidated Electronic Industries was available in the 910 and 990 Series. The 910 Series comprised mono Models 916A, 913A and 913R. Features included modular design, direct motor drive, crystal locked speed control system and automatic post-cue-fast forward. The 990 Series comprised stereo Models 996A and 993 A&R. Features were similar to the 910 Series.

Considerable improvement has taken place in recent years with cartridge machines. For example, machines now feature an automatic non-encoding phase correction circuit which continually monitors and corrects the phase relationship between each channel's playback. The phase relationship is corrected regardless of what machine was used to produce the cartridge originally. This is achieved automatically. Other features include a DC servo controlled motor and varispeed operation.

Analogue cassette decks are rapidly approaching an economic limit to performance improvement and designers have been developing a rotary digital audio tape recorder (R-DAT) which they hope will replace top end cassette decks in the same way that CD players have replaced conventional turntables. The R-DAT uses a rotary head similar to a VCR to achieve adequate writing speed.

The system uses a 3.81 mm wide tape travelling at a speed of 8.15 mm/s. The high writing density needed is achieved by using metal tape and a 30 mm drum rotating at 2000 RPM. Dual rotating heads are employed.

Most of the modern designs are being produced using digital format. Typical is the Swiss Nagra digital audio field recorder displayed at the Society of Motion Picture and Television Engineers Convention held in Sydney during 1992. It was produced principally for film production needs and employs its own helical head system to provide four 16-bit tracks together with time code onto a 6.35 mm tape. Speed is 49.6 mm/sec for two track or 99.2 mm/sec for four track working.

An exciting development in audio technology was unveiled in Australia by Philips on 1 March 1993 following release overseas. It is the Digital Compact Cassette (DCC). Just as the Compact Disc — also a Philips contribution to audio technology — supplanted the Vinyl LP, many observers are of the opinion that DCC will replace the old analog cassette.

Because of the incredible success of the analog cassette, and the fact that development has gone about as far as it can go, Philips set about development of a new system which would provide the same flexibility, universality and portability as the normal audio cassette, but incorporating digital sound. The DCC concept was co-developed with a Japanese company which controls Panasonic and Technics brands, and major record companies.

The system incorporates a new digital coding system which eliminates signals the human ear cannot hear. It has a very wide frequency response from bass to at least 22 kHz, a dynamic range of up to 108 dB, wow and flutter are absent, music is encoded on eight parallel tracks and the player is auto reversing. Machines are fitted with a management system which allows the Operator to make a fully digital copy from original pre-recorded sources, including compact discs but prevents further digital copies being made from this copy. It features information display technology so that the name of the album and Artist appear on an illuminated display. As each track is played the song title also appears.

The system has been designed for home, car, personal and portable use.

In 1993, Sony Australia announced the introduction of Sony Mini-Disc cart machines, the cart player (PMD-C1P) and player/recorder (PMD-C1). They provide the ability to record and randomly access of almost CD quality of up to 74 minutes on a 2½ inch rewritable optical disc.

In 1992, about 25% of albums sold in Australia were recorded on cassettes but by late 1997, the figure had fallen to 6% and people in the recording industry were predicting that the audio cassette was set to go the same way as the vinyl record and become a museum item.

The demise of the cassette was being hastened by promotion of the mini CD and rewritable compact discs and players.

Another factor was that modern technology allows music fans to download albums from the Internet and from other sources via modems and save them on computer hard discs for replay through the computer loudspeakers.

One of the best Museums of Audio Recording in Australia in 1996 was located at Malvern, an Adelaide suburb. It was known as the Ellison Museum of Magnetic Audio Recording and Playback. It was established by Neville Ellison a former associate of Jack Ferry, one of the pioneers of tape recording technology in Australia. The equipment in the Museum comprised a rare collection of antique recording equipment over the period 1940 to 1960. It included wire recorders, 36 reel-to-reel tape recorders, 10 recorders manufactured by Jack Ferry, dictation machines, cartridge players, cassette players and tapes. There were also samples of disc recording equipment and antique radios.

Neville Ellison constructed his first radio receiver, a Duplex Single employing a twin triode 19 type valve using a circuit described in Radio and Hobbies, while living in a South Australian country town.

After returning to Adelaide he worked as a Fitter and Turner before joining the Army Education Unit during the War years. After the War, Neville took up a position with Ralph Turner, Flinders Street, Adelaide being employed for about 12 months on transformer winding projects and radio receiver Servicing. He then joined Harris Scarfe in Grenfell Street as Electrical Salesman spending three years in the Department before transferring to the Radio Department where he acted as Salesman and Radio Serviceman for about 4½ years.

About 1952, he met Jack Ferry and wound oscillator coils at home for Jack Ferry's tape recorders. He left Harris Scarfe in March 1953 to work full time for Ferry with responsibilities including winding tape deck heads, sales, material purchasing and making cabinets for recorders. Neville remained with the business until Jack Ferry died in 1966.

Prior to setting up his manufacturing business, Jack Ferry had been involved in Radio Engineering activities for many years. Before joining the AIF during the Second World War when he worked on Radar equipment, Jack had been employed by National Radio Corporation Ltd, Adelaide on the construction of domestic radio receivers.

After the War, he worked for A W Dobbie producing Peerless receivers at a factory in Mitcham. Included among the range were models designed for operation from 32 volt home lighting systems. The local Dunlite business marketed them with their Freelite wind generators.

When Dobbie shifted his business to Prospect in 1947, Jack Ferry began business on his own account beginning operations in a workshop at his home at Clapham producing turntables, pick-ups, amplifiers and disc recording equipment before manufacturing wire and tape recorders.

Electric motors for the turntables were manufactured by Gilbert Johnson of Beulah Park. The turntables were hand started 78 RPM synchronous types.

A Fitter and Turner was employed to make mechanical parts and to machine the turntable aluminium castings. The castings were made in a small backyard foundry in Adelaide.

The business operated as Ferry Sound Industries, with the first tape recorders being single speed, full track, with no fast forward facility.

In the early 1950s, new models featured variable speed, fast forward and rewind, followed by designs with twin speeds, half track and built-in radio tuner. The recorder employed a single motor with figure-of-eight pattern belt drive linked to clutches for take-up and rewind functions.

Initially, Record/Play heads were made in the factory but by the mid 1950s, commercially produced heads became available and these were incorporated in the recorder units.

About this time, the top line recorders were fitted with English made BSR three motor units.

Production of tape recorders averaged five per week until about 1960 when production was scaled down and resources diverted to other activities.

Further details are included in the publication Adelaide's Early Radios and Tape Recorders by Neville Ellison, 1996.

Improvements in Tapes

Improvements in audio recording technology have not been as spectacular as those in the video area. Until about 1977, audio tape technology changed little over about 20 years.

Many brands of tapes were available for studio and outside broadcast work with two well-known brands of the 1960s being BASF and Irish.

The BASF tape was a Luvitherm PVC base type which maintained high quality performance over a temperature range -58°F to 122°F with up to 100% relative humidity. It was available in 3,4¼,5,5¾ and 7 inch reels in Standard, Long Play and Double Play formats.

The Irish brand was available in reel sizes 3,5,5¾,7 and 10½ inch in Brown Band (acetate), Green Band (acetate) and Long Play (Mylar). The Green Band and Long Play were popular with studio Engineers for their wide range frequency characteristics. The Green Band was a Ferro-sheen processed 1½ mil acetate tape which met EIA and NAB Specifications. The Long Play was made on 1 mil Mylar polyester film base for long storage life plus improved strength and tear resistance.

The digital audio mastering tape was the first new format introduced for high quality concert and musical recital recordings and in more recent times metal particle tape used in rotary digital audiotape (DAT) is finding a place in studio recording booths. Metal particle tape uses core metal particles which are more uniform than ferric oxides used in analogue mastering tapes. Although metal particle tapes were used in the late 1970s they resulted in a number of problems including instability mainly because of corrosion. However, modern tapes do not have this drawback. Oxidation reaction between the metal particles and atmospheric oxygen has been overcome by using a thin layer of iron oxide to protect the inner metal core. Also, corrosion which resulted from the presence of high humidity and high temperature has been eliminated by the development of alloying techniques. The overall result is a tape of high magnetic stability.

Optical Recording

The optical or photographic method of recording had its origin in sound motion films but some application of its principles was tried for broadcasting use.

The system was created by Fred Miller in USA in 1931 and consisted of a minute cutter making a sound track in the gelatine layer of the film. However, the work of development of a practical machine for large scale use of the principle was undertaken by Jan Hardenberg of Philips in Holland. The system known as the Philips-Miller system was produced in 1933, and found application where top quality sound recording was required.

The London studios of Radio Luxembourg and the BBC, purchased a number of the early machines and during the War, speeches of King George VI and Winston Churchill were recorded on these tapes and broadcast by the BBC transmitters.

The system was a variable width sound-on-film technique, produced mechanically by engraving rather than photographically and reproduced by a photo electric cell process. The cutter incorporated a very obtuse angle and was given vertical movement at audio frequency and cut into an opaque film which travelled past the cutter at a uniform speed.

One of the first stations to install an optical system in Australia was 2UE Sydney in the late 1930s. The ABC also had a unit in their Sydney studios. It was operational until the late 1940s.

In the late 1930s Charles Fry was one of the experts in the application of optical recording. He was Philips-Miller Engineer in the Transmission Department of Philips Lamps (A/Asia) Ltd having been Philips-Miller Engineer with Philips in Holland in 1937. He transferred to Sydney in April 1938 to take a similar position. He had been involved in sound and film work since 1932 with a number of British film companies, including Gaumont British Studios where he was Sound Engineer during 1933–35.

DISC REPRODUCING EQUIPMENT

RECORDS AND BROADCASTING

From the earliest days of broadcasting, recorded material has formed a large part of programs. The first known record to be broadcast was titled 'College Life', and was played to air by Reginald Fessenden in the United States on Christmas Eve 1906, when he conducted an historic broadcast using a mechanically driven high frequency generating system before the days of the thermionic valve.

When the Australian authorities began to issue experimental licences after the First World War, many Operators were soon on air playing recorded music in test transmissions.

One of the early pioneers was Harry Kauper in Adelaide with Amateur station 5BG. He had served with the RAF during the War, and brought back to Australia some souvenirs in the form of German Telefunken valves. Using these valves, he began transmissions in 1920 playing recorded music from records made in Canada. They were provided by Roy Cook 5AC, another experimenter who had obtained the records from a friend who was a Ship's Wireless Operator. The Operator had purchased the records from Kent Piano Co., Ltd, in Vancouver. They were Phonola labels and included in the selections were, 'Hunting Song', 'Coronation March', 'Russian Boy', 'Chu Chu San' and other songs. These were played regularly during test transmissions.

In 1926, when Kauper became Chief Engineer of the A Class station 5CL Adelaide, he donated the records to the 5CL record library and it is likely that they went to air through that station, using its imported gramophone.

When broadcasting commenced officially in Australia in 1923, electric pick-ups or reproducers were not available for playing gramophone records. The studio Operator cranked up the spring driven gramophone, wheeled it in front of the microphone and turned it on. At that stage of development, neither the records nor the microphones were of good quality and the broadcast music sounded very scratchy and noisy. Programs of this nature developed a bad reputation and consequently program Producers resorted to the use of live studio performances by Artists or groups which were often costly and difficult to arrange.

In 1924, when the Radio Corporation of America developed a magnetic pick-up unit, they saw the benefit of marrying the radio receiver to the phonograph or gramophone, by producing a radiogram. Despite premature funereal orations when broadcasting was introduced, the radiogram ensured that the phonograph and the record business had a new lease of life and quickly headed for unprecedented prosperity.

Between 1924 and 1926, four record manufacturing plants were built in Australia with the aim of taking advantage of the newly developed technique of recording using the electric pick-up. They recorded Australian Artists and also made pressings of English and American masters.

The first company in Australia to issue locally recorded Artists on disc was World Record of North Brighton, Victoria in 1924. To ensure wide exposure to its records, the company established its own broadcasting station using callsign A3PB. Unfortunately, the business closed at the end of 1926 and was sold to Unbreakable Disc Records Ltd. However, many other small manufacturers sprung up, resulting in imported records slowing to a trickle for some time.

Initially, there was some antagonism between record companies and broadcasters just as there was between sporting bodies and the broadcasters. In Canada, the situation was particularly bad. The record companies prohibited recording Artists from taking part in live radio broadcasts.

The Depression years 1930–33, had a major effect on the recording industry in Australia, and many companies collapsed. The sole major survivor was Electrical and Musical Industries (EMI), an amalgam of HMV, Columbia and Parlophone which battled on through the lean years. It was joined by Decca in 1935.

As well as purchasing records, many broadcast stations installed recording facilities for producing records for their own special needs. However, with the establishment of networks and the high demand for recorded serial material, the gramophone industry and recording companies took up the challenge to provide a service specifically for the broadcasters. It was soon a boisterous offspring in the form of radio drama, musicals and variety.

The record companies were soon hard pressed to meet the demand of broadcasters for such popular serials as Dad and Dave, When a Girl Marries, Fred and Maggie, Superman, Yes What, Biggles, Search for the Golden Boomerang and many others.

Broadcasting also called for the production of a special type of record to meet its requirement for uninterrupted half hour plays etc. This brought about the development of records called 'electrical transcriptions' but fortunately a lot of work had already been done in this area by the film industry. Since about 1926, film Technicians had been using a 16 inch disc played at 33⅓ RPM and synchronised with the film as part of the change in technology from silent films to 'talkies'. These records were ideal for broadcasting purposes as they provided the required 30 minutes of recorded material.

There was for some time, confusion amongst some of the studio people when transcriptions were introduced. In preparing program material the words 'transcription' and 'record' were not correctly applied. The term 'transcription' was used to classify disc recordings made primarily for broadcast transmissions whereas the term 'record' was used to classify disc recordings which by virtue of their size, electrical and mechanical characteristics could be used for broadcast transmission, but which were not primarily manufactured for that purpose.

Although transcription discs were originally 16 inch diameter cut at 33⅓ RPM with a wide groove they were later produced in diametres either of 12 inch or 10 inch following the development of microgroove technology.

In Australia, Columbia installed its first 16 inch presses at Homebush in 1930, and although initially used for sound on talkie films, the equipment later produced transcriptions for broadcast purposes.

Great numbers of transcriptions were produced over the years to meet the needs of broadcasters. The National Film and Sound Archive, Canberra had more than 87000 16 inch discs in its collection by 1993.

Many of the discs were produced with the groove starting at the centre. Recording Engineers adopted this practice because of changing characteristics as the steel needle gradually lost its sharpness. Better overall distortion figures were obtainable with a sharp needle reproducing at the slow speed at the disc centre and the relatively well worn needle on the outer grooves at a higher speed.

By 1938, there were a large number of recording organisations, transcription producers, talent and program services catering for the broadcasting industry.

Those organisations with technical facilities for making records included, Amalgamated Wireless (A/Asia) Ltd, Sydney, with AWA high fidelity equipment; Australia Record Company, Sydney, with plant for recording and the manufacture of copper matrices and records; Broadcast Advertising Pty Ltd, Sydney, with STC, Presto and Western Electric recording equipment; Broadcast Services, Brisbane, with a standard Presto recording installation; Chas E Blanks Pty Ltd, Sydney, with Presto recorders, Amperite and Brush crystal microphones and four stage rack mounted amplifiers; Columbia Graphophone (Aust.) Pty Ltd, Sydney, with Columbia recording equipment; Featuradio Sound Productions Pty Ltd, Melbourne, with commercial recording and dubbing equipment; Fidel-A-Tone Sound Productions, Melbourne, with Presto recording equipment and RCA accessories; Legionnaire Sound Productions Pty Ltd, Melbourne, with dual heavy duty Presto recorders and portable equipment; Macquarie Broadcasting Services Pty Ltd, Sydney, with disc recording equipment developed and patented by the company's Engineers to produce processing and instantaneous recordings; Reaudio Productions, Perth, with Telefunken equipment; T H Shearman Sound Recording Studios, Sydney, with Presto equipment; Sound Recording Studios Pty Ltd, Sydney, with Universal recording machines and facilities for recording on either acetate instantaneous or processed discs of various diameters at speeds of 331/3 and 78 RPM, and The Advertiser Network in Adelaide with a dual AWA high fidelity installation for direct lateral cut or processed discs 10, 12 or 16 inch at 33⅓ or 78 RPM.

Some of these organisations employed a large staff of Administrative, Production and Technical people to meet the high demand of the broadcasting industry. For example, The Advertiser Network, just prior to the outbreak of the Second World War in 1939, comprising 5AD Adelaide, 5MU Murray Bridge, 5SE Mt Gambier and 5PI Port Pirie, employed a staff of 40, excluding Announcers to cater for its broadcasting and recording commitments. During a period of 12 months, it released a large number of transcriptions including 97 episodes of 'Fourth Form at St Percy's', 45 episodes of 'Bringing up Sally', 31 episodes of 'Lord and Lummee' and others. Chief Engineer was Don Gooding, and other Technical staff included Al Smythe, Lew Schaumloffel, Bob Grundy, Len Porter, Tom Welling, Frank Miller, Bill Forgan, 'Darby' Tostevin, Bob Parasiers, Eric Halliday, Bill Gill, N Growden, R Withall and Ben Wilson.

One of the major distributors of overseas manufactured recording equipment was A M Clubb and Co., Pty Ltd, Clarence Street, Sydney. The company represented Presto Recording Corporation and the German company Telefunken. The proprietor was Alex Clubb, a qualified Electrical Engineer who came to Australia in 1922 and worked with Scott and Co., (A/Asia) Pty Ltd which represented AGE and Telefunken, both large German companies. In 1929, he started his own business becoming agent for Telefunken Radio and Presto Recording Corporation equipment. He was a pioneer in the use of acetate disc recording technology in Australia.

One of the recording companies located in Melbourne was Featuradio Sound Productions Pty Ltd, one of the largest companies in Australia serving the radio industry in the late 1930s. It was founded by George Sutton a Director of the Board and Managing Director. He was also a Director of Suttons Pty Ltd, a well-established Radio Retailer in Bourke Street, Melbourne with branches at Bendigo, Ballarat, Geelong, Adelaide and Sydney.

The company was located at Featuradio House, 32 Market Street, Melbourne and possessed some of the most up to date recording facilities in Australia. Facilities included two specially designed large recording studios, control rooms, recording benches and dubbing tables. The technical equipment was under the control of Rex Roseblade. During 1938, transcriptions released included 13 half hours of 'Grand Hotel', 13 half hours of 'Emile Zola', 52 quarter hours of 'David Copperfield', 26 quarter hours of 'The Elusive Pimpernel', 52 half hours of 'Tower of London' unlimited recordings of 'World Cavalcade' and others.

Thirty years later, developments in technology brought about the demise of this type of recording business due to change in programming formats. In the 1930s, programs catered for the family group listening to recorded programs such as serials, quiz shows, serials etc. from a fixed home radio receiver permanently linked to the house power mains or bulky batteries.

With the invention of the transistor in the 1960s, radio receivers became so cheap, so small and so portable that station programmers had to cater for a radio audience of individuals rather than groups. Recorded serials, dramas etc. gave way to music and information formats.

At its peak, the technology of recording sound on disc had reached a high standard of development in Australia. Most recording systems in service were designed to provide for an overall frequency response reasonably flat over the range 250 to 5000 Hz. In practice, the equipment was designed to accentuate frequencies above 4250 Hz and to attenuate those below 250 Hz.

Only a few organisations provided a complete service ranging from high class recording studio rooms for single Artists or full orchestra to supply of the finished record. The provision of facilities of this order required the investment of considerable capital.

In the recording process, the width of the groove in an average lateral cut record was 0.006 inch with the distance between grooves when the cutting stylus was receiving no signal from the driving amplifier, about 0.004 inch and the depth usually about 0.0025 inch. The radius at the bottom of the groove was of the order of 0.0025 inch while the wall angle varied between 60 and 90 degrees depending on the shape of the stylus, with 75 degrees being typical. For an average 12 inch record, the length of the spiral groove was about 650 feet (198 m) which meant that at the periphery of the record, the linear speed at the cutting head at the beginning of the recording was 240 feet (73 m) per minute reducing to just under 90 feet (27 m) per minute at the finish.

The arrival of high fidelity tape recorders in the late 1940s resulted in disc cutting facilities being gradually phased out, and there would now be very few broadcast station studios with operational units in service, although the ABC was still producing selected vinyls during 1993. However, even in the mid 1970s, a number of Radio Production companies were still cutting discs. They included Amalgamated Wireless (A/Asia) Ltd with Neumann mono and stereo disc cutting lathes; Bill Armstrong Pty Ltd; BEA Recording Studios; Christopher Productions Pty Ltd; Bruce Clarke's Recording and Creative Services; EMI (Aust.) Ltd; Grace Gibson Recording Company with Neumann mastering lathe; David Koffee, Film and TV Productions with Presto equipment; Sheard and Co., Pty Ltd with Neumann recording lathe; Slater Production Pty Ltd with a Neumann recording lathe and others.

It is of interest that the Grace Gibson organisation which was originally known as ARTRANSA (American Radio Transcription Agencies) when formed in 1934 by A E Bennett Managing Director, 2GB with Grace Gibson as Manager, had produced some 40000 quarter hour episodes by the time the business was sold in 1978.

By the late 1980s it was evident that vinyl discs were on the way to museum collections. In mid 1991, CBS Australia announced that it had pressed its last grooved disc. Ten years earlier it was producing 10 million discs annually, but the technology of the compact disc had finally overtaken the vinyl era.

CBS Engineers had recorded their first Australian Artists under the Capital label in Sydney's Rocks area in 1938. In 1953, the company moved to Artarmon and underwent several name changes from Capital to Coronet to the Australian Recording Company and finally CBS Records Australia Ltd in 1977.

Just prior to its closure, services provided by CBS included disc and cassette mastering; custom tape compilation; complete printing service including record sleeve and label production. Technical equipment comprised Zuma computer controlled Neumann and CBS discomputer controlled Scully lathes fitted with Westrex 3D11AH cutterheads and electronics; JBL4430 and JBL4313B monitors; transfers from Sony PCM1610 and F1 digital or any analogue format; Dolby and dbx noise reduction plus a range of signal processing equipment.

The closure of CBS Records Australia Ltd followed by EMI in November 1990, left Festival Records Pty Ltd as the major company pressing discs.

Although the Radio Corporation of America had pioneered a 33⅓ RPM disc as early as 1931, it had not been introduced into the market and the 78 RPM disc reigned supreme. However, in 1948, Columbia also of the USA, introduced 33⅓ RPM recordings and this caused shock waves for the entrenched 78 RPM industry. Although RCA had the technology, it did not follow suit with 33⅓ RPM records, but after some research on playing time, disc diameter speed and the mechanics of a speedy auto changer, launched the 7 inch 45 RPM disc in 1949. This started the 'war of the speeds'. To cover the situation, broadcast station Engineers had to install multi speed turntables and turn-over stylii to cater for the different speeds and groove characteristics.

The 7 inch 45 RPM disc soon outpaced the standard 78 RPM disc, with the last 78 being issued in 1959, coinciding with the advent of stereophonic sound. The appearance of stereophonic sound heralded the demise of monophonic discs but required major studio modifications to technical equipment.

In recent times, the National Film and Sound Archive in Canberra has implemented a plan to preserve the nation's heritage of recorded sound by dubbing from a large collection of discs held in the Archive collection. In 1997, the Archive estimated its holdings of recorded sound and radio at 530000 discs and cylinders and 48500 tapes. About 101500 had been documented in the Archive collection management system MAVIS (Merged Audio Visual Information System).

Discs consist of an aluminium, steel or glass base coated with cellulose nitrate. The lacquer is an inherently unstable compound and results in cracking with the lacquer eventually breaking away from the base. Some of the delicate work undertaken by staff involves glueing loose pieces of lacquer back on to the base with the aid of a microscope.

A wide range of equipment was available to assist in the work and in 1992 was based around a DDA Series D Console configured with eight stereo and three mono input channels.

Two tape recordings were made from each disc which was placed on an EMT 950 direct drive turntable. One copy was made on a Nagra-T audio reel-to-reel tape recorder as a copy for future reference while the second was produced via a signal processing chain consisting of an audio noise processor, a dynamic noise filter, a graphic equaliser and a parametric equaliser and recorded on a Studer 810 machine.

Following cleaning of the disc in an ultrasonic bath, a number of techniques were used to obtain the best sound quality from the disc. These included the selection of an appropriate stylus, reduced speed playing and on occasions, reverse playing.

Whilst the majority of discs held by NFSA were originally produced by commercial recording organisations, many were made by Engineering staff at broadcasting stations using station recording equipment.

Towards the end of 1992, the Archive commissioned a new studio complex designed by Richard Priddle and constructed by International Technology Communications. The new facilities included six auditioning booths, a four room studio facility with tape dubbing room and a large recording auditioning room.

A number of records were also produced specifically for testing of technical equipment. These were known as Engineering Test Records and were not generally available from record shops.

The test records made as reference standards were employed not only to test pick-ups but to check equalisation of replay amplifiers. Records were cut at various stated levels of amplitude, and usually consisted of fixed or gliding tones at various frequencies.

In addition, there were so called Demonstration Records used for sales demonstration purposes and also by some Commercial Engineers for testing the overall facilities just prior to the commencement of transmission, in the days before round-the-clock broadcasting.

Special records were also produced to provide 'sound effects' for use during talks, documentaries, plays etc. This type of recording had been produced as early as the late 1890s and had found wide use with silent movies.

Although many of the sounds were recorded in the field providing sound carriers of trains, aeroplanes, fire engines, cars, church bells, industrial machinery, army drill movements, firing of artillery guns, thunder etc., simulated sounds were also made in the studios by staff known as 'sounds effects Operators' using mechanical and other devices. Sounds like kissing, slap on the face etc. were made by the script reader.

A considerable number of recordings were produced over the years on 78 RPM and vinyl as well as on CDs in more recent times.

PICK-UPS

One of the earliest reproducers was developed by Lee de Forest, USA pioneer broadcaster and inventor of the triode valve. In August 1919, he patented a phonograph pick-up called 'Current-Pulse Reproducer and Amplifier' employing either a diode or triode valve. The valve element was impelled directly by the reproducing stylus. In more recent times, other workers further improved the technique but with the demise of the valve as a result of the introduction of the transistor and improved pick-up technology, the device did not find application in modern broadcast studios.

Unfortunately, electrical reproducers or pick-ups as they were later called, were at a primitive stage of development when the broadcasters first required such devices. They were difficult to obtain, expensive and frequency response and distortion characteristics were poor. Most recorded material was broadcast with a microphone mounted on a stand in front of the gramophone acoustic speaker.

The following instruction issued to staff at A Class station 3AR Melbourne in 1925, is typical of the procedure adopted:

> 'In order to reduce the transmission of scratch present in most records, the microphone should be placed about one or two yards away from the opening of the horn, and slightly to one side.'

Even under the best conditions, the quality of the recorded music and voice left much to be desired and in order to reduce the high level of scratch noise, various devices were used which, in some cases, degraded the quality even further. Some studios were fitted with a so-called Integrating Condenser which was switched into circuit by a knife switch when a record was being played. The unit certainly reduced the high frequency scratch noise, but it also reduced the high frequencies of the music and the singer's voice.

The Western Electric Co., in the USA who developed a carbon microphone specifically to meet the needs of broadcasting was granted a patent in 1923 for an electrical reproducer and development advanced quickly to meet a worldwide demand for high quality pick-ups. Other manufacturers took up the challenge and by about 1927 broadcasters put their acoustic horns and wind up gramophones in the attic.

It is not known when the first electric pick-up was introduced into a broadcasting studio in Australia, but it is known that a representative of a Melbourne importer visited Adelaide in 1926 to demonstrate a Brunswick 'Panatrope' pick-up to broadcasters there. The 5CL staff who had been testing a prototype pick-up of their own design, ordered one from the Salesman.

Ern Hume, Chief Engineer of 5DN had already been investigating the possibility of installing such a pick-up in new studios he was constructing in Paringa Building, Hindley Street, Adelaide. He had made a pick-up from a description in an American magazine of a Kolster pick-up developed for Columbia Phonograph Company, and following exhaustive testing put the device into operation in the new studios when they were commissioned in August 1926. It remained in service until replaced by an imported Bosch Recreator model. He had earlier acquired an imported Electrola pick-up but it failed after playing a few records due to an open circuit in the coil unit caused by corrosion from faulty soldering during manufacture.

About 1926, Wally Coxon of 6WF constructed a pick-up using a modified telephone earpiece and put it into operation at the studios as an alternative to placing the microphone in front of a gramophone horn.

The date of introduction of the electric pick-up in the 4QG Brisbane studios is not known but Ray McIntosh a member of the station's Technical staff designed and constructed a model which was placed in service there, probably about mid 1927.

Ray had made a pick-up based on electromagnetic principles for use with his experimental station VK4RM which he frequently operated on the 250 metre band providing regular broadcasts which included playing recorded music. The 4QG model incorporated a number of design improvements on the original model resulting in improved frequency response characteristics and lower distortion. One feature of the design was the employment of a damping block made with natural rubber to prevent needle resonance problems.

Prior to installation of the electric pick-up at 4QG, recorded music was played to air by placing one of the studio WE, Reisz or Amplion microphones in front of the sound box of an Aerolian Vocalian gramophone.

Ray McIntosh's experimental station was one of the best constructed installations in Queensland at the time and had a large following of listeners who enjoyed the high standard of programs broadcast and the high level of technical excellence in the transmissions. Listeners from places as far away as Hobart, Longreach, Adelaide, Mildura and New Zealand wrote to Ray referring in glowing terms to the writer's reception of the station and the top quality programs broadcast.

The station was located at Uhlman Street, Hawthorne and technical facilities comprised separate transmitters for operation on 250 metres and 32 metres. To add professionalism to the programs on the 250 metre transmissions, Ray employed Mr C V Woodland a former 4QG announcer to present the programs. It was one of the main reasons why so many people tuned into his regular programs.

Although Ray had applied to the Government for a B Class station licence the authorities deferred the application as a Royal Commission had been established to enquire into broadcasting in Australia.

The 4RM aerial was a landmark in the district. It used a 95 ft (29 m) high Oregon mast painted white to support a three wire ship's type flat top aerial using Oregon spacer arms. The copper wire elements were each 80 ft (24 m) in length and terminated in Pyrex glass rod insulators. The earthing system was a copper plate 18 ft by 6 ft (5.4 m by 1.8 m) buried in the ground and connected to the transmitter by a copper cable.

The two transmitters were installed in two rooms of Ray's home with a temporary lead-out to the aerial via a long ebonite tube but he had plans to erect a separate building near the base of the mast to set up the transmitting and studio facilities there. However, with the deferral of his application for establishment of a B Class station, he did not proceed with the work.

The 250 metre transmitter was enclosed in a floor mounted cabinet about 0.9 m wide, 0.5 m deep and 1.4 m high with the entire equipment being enclosed in an earthed brass box to prevent interference with the studio equipment. The valve anode supply was provided by a large bank of storage batteries charged by a Tungar rectifier. The batteries provided a potential of 360 volts.

The 32 metre transmitter was also mounted in a floor standing cabinet and fully screened by brass sheeting.

The 250 metre transmitter employed two 7.5 watt valves in parallel in a Meissner oscillator circuit with 50 watts of power being available on the anodes. The 35 metre transmitter employed a split Colpitts circuit as oscillator.

A common switchable modulator and audio amplifying stages were employed for use with either transmitter when broadcasting with speech and music. Two stages of choke coupled units were employed using power valves, with 160 volts for anodes being supplied by a tap on the main 360 volt storage battery system supplying the oscillator circuits.

A control panel was fitted with a specially designed ladder type master fader, switches, jacks, lamps, a meter and a sub panel fitted to cater for up to 10 outside broadcast lines from remote locations. The microphone employed was one designed by Ray and was an improved Reisz model with a better frequency response than the one employed at 4QG which he also helped to construct. In 1928, he had a new design under evaluation using a moving coil and magnetic arrangement using an electromagnet powered by a battery.

Before coming to Brisbane from Sydney to work at 4QG under Chief Engineer Fred Stevens in January 1927, Ray had been involved in radio since the early wireless telegraphy era before the First World War. Prior to closure of all experimental wireless stations at the outbreak of the War he operated wireless telegraphy experimental station XFA at Pymble. Initially, the transmitter consisted of a 12 inch (30cm) spark coil, oscillation transformer, aerial inductance and Leyden jar capacitor. Power was provided by a bank of large accumulators. The spark gap voltage was estimated to be 12000 volts.

Like many other experimenters, he found the induction coil with its hammer breaking mechanism difficult to regulate and at the time the station was closed down by the Naval authorities, he was in the process of developing a rotary interrupter using an electric fan motor as driver. Ray and a fellow experimenter, Lance Jones living in Adelaide, had been in correspondence regarding progress in development of the interrupter and Jones said he had some success using a rotary brass wheel with protruding contact rods and a globule of mercury in a brass cup as the fixed electrode. Details of the receivers employed by Ray at the time are not available, but in one of his letters to Lance Jones he told of purchase of nitric acid and thin platinum wire, so it is possible he was using an electrolytic detector.

During the War years, he worked as a Ship's Wireless Operator for some time before joining AWA's experimental team which were developing the Australian terminal of an England-Australia wireless telegraphy link. It is understood that Ray was the Operator at the experimental station set up at Wahroonga when the first official messages were received from Marconi's Carnarvon station in England operating on 14300 metres (20.98 kHz). The messages were from Prime Minister W M Hughes and Minister for the Navy Sir Joseph Cook and sent in September 1918 following a visit to the battlefields.

After the War when experimental licences were restored, Ray operated station 2ZG at Pymble frequently on 380 metres providing transmissions of speech and recorded music. He was on a roster with other experimenters and during August 1923 his transmissions were conducted on Monday and Saturday evenings from 9 pm to 9.30 pm.

Ray was a very popular lecturer at Radio Clubs in Sydney with one of his talks to the Croydon Radio Club drawing a full house of members. He demonstrated to Club members a type pick-up he was developing employing electrostatic principles. Because of the low output from the device a four stage AF amplifier was used to drive the loudspeaker.

In early 1923, Ray joined the staff of Electricity House, 387 George Street, opposite Strand, one of the largest stockists of radio parts in Sydney. Ray was the company Works Manager and oversighted the assembly of a range of radio receivers sold as complete working units as one, two and three valve models.

While on the staff at 4QG for two years, he undertook many outside broadcasts using the Western Electric pick-up amplifiers. Ray modified the amplifiers to provide improved frequency response and lower distortion. Outside broadcasts from churches were a major part of the station programs. There were 14 churches in Brisbane connected to the studio via program circuits. Ray also oversighted the manufacture of Reisz type microphones widely used with many of the outside broadcast programs. At the time, 4QG was on air for 50 hours per week.

When the Government took over 4QG as part of the plan to establish the National Broadcasting Service in 1929, the station staff were offered the chance to join the Post Office but Ray, like other members, declined the offer and returned to Sydney where he later set up Raymac Supplies where son Peter was a member of the staff. The business was closed down during the Depression years and Ray became involved in other fields.

A number of problems were experienced with early pick-up designs. Record wear was excessive, output voltage was low and there were major resonance and frequency response problems. Heavy damping was a feature of most designs. Most of the early pick-ups were of the electromagnetic types whereby the mechanically vibrating needle induced an electromotive force in a coil of wire through the intermediary of a magnetic field. Another type known as the electrostatic pick-up depended for its action on the variation of capacitance. For a number of reasons, this model did not achieve the same success as the condenser microphone in use at the time.

Many different versions using electromagnetic principles were developed. However, the essential object of all designs was that the mechanical motion of the needle created a change of magnetic flux through a coil. This object was attained either by making the coil move in a magnetic field or by arranging for a magnetic armature to alter the flux through a fixed coil. The two basic types became known as moving coil and moving iron or moving armature types.

The moving iron or armature type was the more practicable and rapid development soon followed. The coil was arranged either around the armature or on the pole pieces of a magnet depending on designer preference. The Marconi, Varley, Brown, Whiting, HMV, Celestion and others were examples of the latter type, while the BTH, Igranic (Phonovox), GEC and Crosley Merola were examples of the former. A Whiting brand pick-up was used at the 5CK Crystal Brook transmitting station emergency studio when it was commissioned in 1932.

In order to provide a satisfactory method of resistance termination to a pick-up wave filter, an oil damping system was employed with some models. The most widely used models employing this technique were the HMV and Western Electric 4A reproducers. The interior of the unit containing the moving assembly was filled with a viscous oil. The Western Electric 4A reproducer was one of the most common units employed in Australian broadcasting and even in the late 1950s still served a role at the emergency studios of transmitters. An alternative to the oil damped pick-up was the rubber damped type.

Another type of pick-up widely used in broadcast studios was the crystal type. It was used extensively in the 1930s because it was low cost, gave high voltage output and had low distortion characteristics. Many designs were fitted with sapphire stylii which were mounted at 90 degrees to the record rather than about 75 degrees as with other pick-ups, particularly steel needle types, and this made the crystal pick-up very popular with Announcers. It enabled them to cue the record more easily as the record could be moved backward or forward by hand with the stylus in the playing position in the disc groove. In 1935, station 4IP Ipswich employed a pair of Model H12 Piezo-Astatic crystal pick-ups similar to models used at many other stations. They were also used in ABC studios for many years until about mid 1940s when they were replaced by Australian made moving coil units with improved performance.

Designers continued to improve crystal cartridges and their popularity increased with mass production of microgroove records and the introduction of stereo recordings in the late 1950s. ACOS cartridges were among the many brands available in the 1960s, and included GP67-1G, a high quality monaural turnover unit with an extended frequency range and excellent tracking capability; G67-2G, a high quality turnover cartridge suitable for reproducing standard and microgroove recordings; GP67, a turnover ceramic model specially designed for tropical areas; and the GP71 series non-turnover types designed for stereo and LP records. Ortofon and Decca were other brands used in studios at the time.

In the early Post War era, designers also made considerable progress in the improvement of lightweight magnetic pick-up technology. Units fitted with miniature needles became available with capability of playing more than 50 records without change. The 5KA studios in Adelaide were amongst the first to employ these types, when it built new studios in the Central Methodist Mission building in Franklin Street, Adelaide. The new studios included the most modern technology available at the time in building design and technical facilities. One item of equipment was a film machine for reproducing the sound track of films.

Listening to records on the phonograph was a popular form of entertainment in the home before the advent of broadcasting, and even 10 years later, when broadcasting receivers had been installed in tens of thousands of homes, many people still kept their phonograph. With the development of electrical pick-ups for use with records in broadcasting studios, many owners of phonographs wished to take advantage of the new technology, but were not keen to dispose of the original horn and reproducer. Many novel devices were developed to overcome this problem.

Philips was one of a number of firms which produced models to suit these requirements. They developed the type 4003 pick-up for attachment to the tone arm of the phonograph. However, it was found to have some short-comings with some phonograph models, with the main problem being difficulty in obtaining rigidity with particular machines in the connection to the tone arm. They undertook development work over a period of time and produced the type 4040 unit in which the tone arm and pick-up were integral. The base which held the tone arm pivot was of solid metal and mounted on green baize. It could therefore be placed alongside the old tone arm on the phonograph without the use of screws for mounting, although it was drilled for the purpose if permanent fixing was desired. The heavy weight of the base kept it in position while the pick-up arm traversed its arc across the surface of the record. Two flexible adaptor leads were included with sockets at one end and eyelets at the other so that connection could easily be made to receivers not having a standard pick-up socket, the eyelets being slipped over the valve pins.

A range of Australian high quality pick-ups widely employed during the lat 1940s and 1950s were designed and built by hi-fi pioneer Vic Harris, Croydon. In 1947 some 100 units had been sold to Commercial station operators for use in their studios.

By the mid 1950s, a new design labelled Model MBH Type D comprising six mono cartridges ranging in impedance from 200 to 50000 ohms were available.

With the introduction of stereo recorded discs, Victor Harris designed and manufactured the MBH type L stereo pick-up employing a moving magnet principle and fitted in Equidyne series arms. It provided a frequency response of ± 2 dB in the range 20 Hz to 20 kHz. The unit was normally fitted with a spherical diamond stylus but an elliptical tip was available as an alternative.

STYLII

Stylii used with pick-ups can be categorised into a number of groups including ordinary steel needles, semi-permanent needles such as chromium plated steel; permanent stylii employing jewel tips of diamond, sapphire or ruby; thorn needles, fibre needles and bamboo needles. The thorn needles known as Burma thorn, together with bamboo needles were employed with aluminium discs in use before the introduction of acetate and colloidal discs.

The ordinary steel needles used in early gramophone mechanical reproducers and later in heavy weight electric pick-ups were made in various sizes, sometimes designated loud tone, full tone or soft tone types. Fine groove records required permanent types, with diamond tips having the longest playing life.

An early stylus with a miniature moving iron pick-up was the Telefunken TO 1000 imported from Germany by one of the

Melbourne station's Chief Engineer. It was fitted with a sapphire stylus and a semicircular roller for lowering the stylus to the record. Station 5DN Adelaide also trialed this model for some time.

Another imported pick-up was a Ferranti type with a ribbon, imported from England. The ribbon enabled very light stylus pressures to be realised for long playing records. Don Gooding Chief Engineer 5AD Adelaide installed one of these units in the studio recording room for assessment.

The introduction of long playing microgroove records about 1948 required some changes to the stylus. Because stylii for microgroove and the standard 78 RPM records had different radii, the turn-over type such as Collaro, Ortofon and Ronette, and plug-in cartridges such as Decca, and Leak types were produced to accommodate both LP and 78 recordings. The Decca units were widely used in the ABC studios.

Dust on the surface of the record was a major problem as it caused excessive wear of the stylus and the record grooves, as well as increasing noise and distortion. Although storage jackets were provided, the very action of playing the record, resulted in the formation of a static electric charge on the surface. This electric charge attracted minute dust particles which stuck to the surface.

Some ingenious devices appeared from time to time to deal with the dust problem. One device used in the 1960s, was the ACOS Dust-Bug. The device was clipped to the record player or changer arm and the only attention required was an occasional damping of the plush pad with an anti-static solution. The Dust-Bug with accurately shaped points of nylon bristle swept the groove in advance of the stylus and the foreign matter removed was trapped and collected on a plush pad which discharged all static at the moment of playing. The device was counter-balanced to ensure tracking performance was maintained.

TURNTABLES

The early electric pick-up units simply replaced the gramophone acoustic unit with the pick-up being mounted on the gramophone cabinet and making use of the spring wound motor to spin the record. Because not all records were recorded at the same speed, the motor had a speed control mechanism which acted on a centrifugal governor.

Electric motors when introduced, included squirrel cage, induction and multi-pole synchronous types. The synchronous type was a good motor when operating, but had the major disadvantage that it had to be spun by hand to exactly synchronous speed to start. These were in widespread use in the mid 1930s in ABC studios, and employed a Simpson synchronous motor. They upset many Announcers. If spun too fast it produced sounds like a cage of over-excited canaries, while if spun too slow, the sound died away at low frequencies as the turntable speed wound down. All early direct drive models had problems with wow, flutter and rumble which detracted from the high quality recorded program.

This type was subsequently superseded by four pole and two pole shaded pole induction motors. To mechanically isolate the motor from the turntable, a small pulley on the motor shaft with a spring loaded jockey pulley conveyed the drive to the inside surface of the turntable rim. With the need for more than one speed, a stepped pulley was fitted to the shaft of the motor. Another turntable motor was known as the Induction Disc Motor. Two of these manufactured by AGE were installed at the 5CK Crystal Brook emergency studio at the transmitting station in 1932.

A popular model installed at many Commercial station studios during the mid 1930s was known as the 'Green Flyer', a governor controlled two speed motor. It was an induction type that could be adjusted to play either 78 or 33⅓ RPM records. The motor incorporated a lever control that permitted shifting from 78 to 33⅓ RPM. The spiral cut gears were made of laminated bakelite and completely immersed, and run in oil. Special self lubricating bearings assured constancy of speed and long life. It was furnished with a 10 inch (250 mm) turntable and had facility for automatic stop condition. Adelaide station 5AD was one station which had this model in service in their studios.

One of the most widely employed models in radiograms was the Paillard Induction Electric Gramo Motor, a European manufactured unit distributed in Queensland in 1930 by Edgar V Hudson. In the first year of the unit being available, about 500 units were sold to receiver manufacturers in the southern States by distributors in Melbourne and Sydney.

The motor was designed to operate on AC of 200 to 250 volts at 40 to 60 Hz so it was suitable for radiogram units in country areas with a range of power supplies.

The induction motor had neither collector nor brushes and therefore there was no sparking to cause interference with the receiver amplifier stage. The motor had an automatic stop switch which could be preset to stop the motor at the end of the record playing. The turntable was velvet covered, ribbed for rigidity and steel work nickel plated.

The motor was available in two styles of mounting to meet most radiogram designs. One had the speed regulator and automatic stop separate for mounting on the cabinet top board by means of rubber anti vibration pads. The other had the motor in rubber suspensions and controls mounted on a steel plate ready to be fixed to the cabinet.

The Paillard pick-up incorporated a tilting jointed head to simplify needle replacement.

A popular model available in 1934 as a Radio-Gramophone Converter was the Univolt Unit. It could be easily fitted by the receiver owner as it required no cabinet of mounting fixtures. Insulated feet allowed the unit to be placed in any convenient position. Screws were provided if the owner wished to make a permanent fixture of the unit. The design and construction of the governor and speed control assured uniform running at any speed between 70 and 90 RPM. It was suitable for 40–60 Hz power supply systems and was available as AC or Universal types. The AC model was designed for supply 200–250 volts and could also be operated from supplies of 100 to 130 volts by a simple tap adjustment. The Universal models were similarly adjustable for operation from 100–130 and 200–250 volts for either AC or DC mains. The Univolt Super pick-up had a relatively wide frequency response range, was fitted with a weight adjustable arm, a swivel head for needle replacement and a square law volume control.

The unit was available from several Radio Shops including Fox and McGillycuddy Ltd, Sydney.

One of the major problems for many years with the replay of discs was wow and flutter. Wow is a slow rhythmic variation in pitch due to non-musical causes which may occur as a result of deficiencies in the recording or replay facilities. It is usually described as the percentage of speed which occurs in a single cycle of the wow.

Until the 1950s, the majority of turntables for both recording and replay were imported designs which reflected the standards employed in the country of manufacture. USA Standards for recording turntables required that for wow factor, the instantaneous peak deviation from the mean speed of the recording turntable when making the recording should not exceed +0.1% of the mean speed and in the case of reproducing, it required that the instantaneous peak deviation from the mean speed of the turntable when reproducing should not exceed ± 0.2% of the mean speed.

Besides turntable speed variations, wow which is more apparent on middle range notes than those in low pitch, could result from eccentricity of the groove on the pressing, due to the hole not being in the centre of the disc or being larger than the spindle. Also, a warped or physically deformed disc would frequently result in wow. Standards required that the record centre hole be concentric with the recorded groove spiral within 0.002 inches and that in the case of warp, the maximum departure of the surface of the record from a true plane because of warping should not be in excess of 1/16 inch.

Flutter is a much more rapid fluctuation in which the speed variation results in a change of quality of sound particularly on steady notes. One of the causes is due to the drive spindle being off centre.

If the recording Engineer detected wow or flutter following a recording, there was no way to fix the problem, so the disc had to be discarded.

Included amongst companies which manufactured professional turntables for broadcasting stations in the late 1950s, was Commonwealth Electronics Pty Ltd in Tasmania. Founded by Bill Nicholas, John Dodds and Dave Hildyard the firm manufactured many turntables for both National and Commercial station studios as well as for emergency studio facilities at transmitting stations. Two stations which were fitted with transmitters and turntables made by the company were 8TC Tennant Creek and 8KN Katherine both commissioned during 1960.

Usual turntable speeds at the time were 33⅓, 45 and 78 RPM. Technical staff verified correctness of speeds by means of a stroboscopic disc illuminated by a neon lamp or equivalent, operated from the same power source as the turntable.

Another Australian manufacturer of high quality turntables was High Fidelity Products, Flemington, an industrial suburb in western Sydney with Vic Harris being the Proprietor. In addition to supplying Australian broadcasters, the company supplied several hundred units to All-India Radio during the 1960s.

More recent developments have seen the introduction of the direct drive brushless DC motor which incorporates a rotor revolving at turntable speed. A major advantage of this type is that normal operating speed can be obtained almost immediately on application of power. Manufacturers have their own construction practices for direct drive units but typically they comprise a light mass glass fibre turntable attached directly to the rotor of the motor. The large mass necessary for low rumble and flutter values has been replaced by so called 'electronic mass' in the control circuit.

The Technics SP10 Mk II was one of the popular turntables used in broadcast studios during the 1980s. It had quartz locked reference and brushless DC motor.

TRACKING

The conventional pivoted pick-up arm moved across the record in an arc of a circle. However, this differed from the mechanical arrangement used in the studio when cutting the master disc. In this case, the cutting arm moved inwards along a radius towards the centre of the disc so that the cutting path was in a straight line and not radial like the replaying stylus.

The basic difference therefore was that the cutting stylus was at a tangent to every groove being cut on the disc whereas the conventional pivoted reproducing stylus in the replay mode could be in a tangent situation at only two places. Except at those two tangent points, there was an angle between the direction of relative movement and a tangent to the groove.

Although some linear tracking systems had been developed with several early record players, they were superseded by pivoted pick-up arm turntables. Because of the later upsurge in interest in high fidelity reproduction, a number of manufacturers produced improved linear tracking systems to meet the demand for superior tracking, better dynamics and lower distortion compared with conventional pivoted systems.

With one linear tracking device, the pick-up arm travelled along a fixed bar at the back of the record causing the stylus to move in a straight line along a radius of the record so that tangential tracking was achieved for all grooves.

Whereas the pivoted arm was a free wheeling device and did not require a drive system to move it over the grooves, an accurately designed pick-up arm motor was required for most linear tracking systems to move the stylus across the surface of the record. This was one of its major disadvantages.

One interesting approach to overcome the tracking problem of a conventional pivoted arm was a dual arm device using parallelogram rods manufactured in England and branded 'Tangential'. It was designed for employment with a wide range of turntables including Chancery, Acos, Decca and Garrard. It was suitable for 33⅓, 45 and 78 RPM records and was accurately adjusted in the factory to ensure optimum performance when using a template provided with the unit. A unit was held in the Adelaide Telecommunications Museum collection.

One of the earliest known Australian dual arm devices using parallelogram rods to minimise tracking error was developed by Howard Kingsley Love of Kingsley Radio Pty Ltd using an Astatic crystal pick-up and fitted to a deluxe broadcast receiver/record player in 1932. In an interesting article by Neville Williams in Electronics Australia with ETI, March 1995, photographs were shown of the device and the receiver which was still in existence in working condition, and owned by Jim Davis, Latrobe in Tasmania.

In recent years, many manufacturers have marketed linear tracking systems, most of which have excellent technical performance and are available in a wide price range.

In one popular Japanese made model, the pick-up or tonearm is driven in its path across the record by a precision engineered high torque coreless motor coupled to the pick-up arm carriage via a gear and pulley system and a noise damping belt. The motor itself is encased in neoprene and supported by a butyl base to minimise transmission of mechanical noise, while the belt, formed of specially selected materials, further dampens mechanical noise so it transmits only smooth power to the pick-up carriage.

The pick-up arm position is controlled by a highly sensitive tracking error sensor that is accurate to within 0.15 degree and an advanced servo system that maintains perfect tracking throughout arm travel.

THE COMPACT DISC

The compact disc, a recent technological development has only been on the scene since about 1982 following development by Philips/Sony, but there is every indication that in both the broadcasting studio and home entertainment unit it has already ousted the standard pick-up, the turntable and the vinyl record. It utilises a semiconductor optical laser to read digital information on a tiny 120 mm compact disc. Since there is no physical contact between the disc and the laser stylus, the disc is immune to wear.

A typical studio CD player like the Shure PDP100E unit has autocue and autostop, permitting precise and instantaneous cueing to the downbeat of a musical program and an automatic stop at the end of the current track. Other control facilities include complete skip-scan capability, random access programming to any track on the disc, a 15 stack memory that allows the programming of up to 15 tracks, in any order, for automatic or semiautomatic playback. Individual channel filters eliminate ringing, graininess and harshness in reproduction.

In addition to studio and home entertainment equipment, the CD is now very popular with car installations and as a personal 'walkman'. The Sony Walkman which made its debut in early 1980, enabling sports fans and others to enjoy music on the move is now available as the Sony D451SP Sports Discman enabling the playing of CDs. The problem of hops, skips and jumps has been overcome using Electronic Shock Protection (ESP). In the system, the laser head reads the disc at twice the normal speed, then stores a buffer of information in a memory. After a bump or jolt, by the wearer, the laser quickly regains position and begins filling the buffer again to prepare for the next shock. The unit which is water resistant, features three position Digital Mega Bass settings and 10 mode play. It has sports headphones that virtually injects the ear with sound.

The broadcasting world is now in the digital age and like the compact disc, future sound producing systems are certain to incorporate digital principles in one form or another. There are so many advantages in digital processing that the compact disc has, indeed a bright future and the pick-ups, stylii and turntables will soon all be confined to the attic to gather dust with their cousin the gramophone and its mechanical reproducer, acoustic horn and spring wound motor.

During 1992, Sony released the Mini Disc (MD) player but five years later in 1997, demand was below expectation.

Although the CD has revolutionised recording, sound archivists who are involved in the preservation of early shellac and vinyl records are questioning the long term durability of digital sound carriers. There is some concern that with the passage of time, today's CDs and also digital tapes may deteriorate as a result of a number of factors to the stage where the recorded information may not be retrievable. Notwithstanding all the shortcomings of the shellac and vinyl discs, facilities available to sound archivists enable at least some representation of the original recording to be retrieved even in the case of very old, badly worn or damaged discs. A major problem with the digital process is that in the case of a very old and badly treated disc or tape, enough of the encoded information may not be available, so rendering playing impossible.

MONITORING LOUDSPEAKERS

EARLY LOUDSPEAKERS

The first practical loudspeakers were developed about 1920 when broadcasting was becoming a reality overseas. There was a great demand for loudspeakers for use with home valve receivers and the same loudspeakers were used at broadcasting stations to monitor studio and transmitter signals.

Transmitters in use at the time, and also studio amplifiers and microphones, had very restricted bandwidths and there was not much pressure to develop high quality monitoring apparatus. Typical loudspeakers in use for monitoring purposes included Amplion, Federal Pleiophone, Magnavox Telemegafone, Vocarola, Western Electric and others. They were all horn types and although photographs of early stations show some horns with a straight axis in use, most were of the folded horn variety.

Within a couple of years, they were followed by models with improved frequency response such as AJS, Atwater Kent, Baldwin, Brandes, BTH, Burndept, CAV, Efesca, Ericsson, Fuller, Gecophone, Kellogg, RCA, Rola, Siemens, Sterling, Thompson, Utah and others. They were made mainly of metal, wood petals, papier mache, ebonite, diecasting alloys etc., with bells which varied up to nearly 600 mm in diameter. The graceful curved neck and wide bell became the symbol of early radio.

By the time broadcast transmissions began in Australia, cone loudspeakers and folded horns in wooden cabinets became available. Even though a USA company, Rice-Kellogg produced a moving coil loudspeaker as early as 1925, it was some years before this type was used for studio monitoring purposes. It was not until about 1928 that permanent magnets became practicable for loudspeakers. Even so, care had to be taken in connecting up those loudspeaker types where the driver unit coil was connected in the anode circuit of the valve. Correct polarity had to be observed with battery connections otherwise the driver permanent magnet could be demagnetised.

The USA based Western Electric Company devoted considerable development work to the transmission chain of broadcasting including transmitters, microphones, program amplifiers and monitoring loudspeakers. Their monitoring loudspeaker which became an integral part of WE studio equipment much of which was installed at early Australian stations was the WE 540AW Model released in 1924. It was a double non metallic cone type and built as 18 inch (450 mm), 24 inch (600 mm) and 36 inch (900 mm) models. When 4RK Rockhampton was built in 1931, a 24 inch model was provided at the transmitting station for program monitoring purposes. The loudspeaker was quite fragile and easily knocked over resulting in damage to the cone. The majority of units held in vintage radio collections today show evidence of repair work having been undertaken.

TODAY'S REQUIREMENTS

In the early years of broadcast studio and control room design, proper attention had not been paid to the monitoring environment, its acoustical properties and integration of the loudspeaker into the space.

Control room operation where the actual quality monitoring took place, was the responsibility of the Technician-in-Charge of the control room, the rooms were small with no attention being paid to acoustic properties, walls were at right angles and the monitoring loudspeaker was placed wherever space was available. This space was usually, on the wall above the control desk, on the floor in a corner, on the control desk or in some studios, the loudspeaker was hung from the ceiling. At 3LO Melbourne control room in 1924, two loudspeakers were available. One was an Amplion cone type AC12 in a Mahogany case which sat on top of the telephone manual switchboard which was used for OB lines, while an Amplion Radiolux Model RS5 with a Rosewood finish sat on top of the instrument cupboard.

These conditions were far from being ideal for program monitoring purposes.

In more recent control room designs where monitoring takes place, the trend has been towards an environment which provides flush mounting loudspeaker units, specification of similar absorption characteristics throughout the frequency spectrum, and aesthetic considerations. The broadcasting industry has Acoustical Consultants and Architects who specialise in studio design, and can provide designs for rooms where monitoring takes place which are not only acoustically functional but visually attractive.

Today, the complex and sophisticated audio equipment used in broadcast studios is capable of top performance with flat frequency response over a wide range, very low distortion and high reliability. Carefully selected monitoring loudspeakers integrated into the control room overall design are essential to check quality of the program being sent to the transmitter or being recorded.

The loudspeaker is a vital component in the overall broadcasting chain but as it is relatively imperfect compared with many other facilities, manufacturers and designers are continually producing more efficient and better quality units.

The ultimate objective of realism is still generally accepted as the criterion for a loudspeaker and the introduction of stereo has taken the art one step closer to this objective. In the search for realism, it is usual practice to measure such basic loudspeaker properties as frequency response, harmonic distortion, transient distortion and polar response. A good loudspeaker must be satisfactory in all these respects.

NEW FORMS AND MATERIALS

In recent times designers have been experimenting with various new forms and shapes of loudspeaker diaphragms. This has primarily been aimed at reducing the magnitude of the flexural vibration which is often perceived as the second, third and higher order harmonics, particularly when the unit is subjected to high drive conditions.

Manufacturers are employing a wide range of new materials including carbon fibres, glass epoxy laminates, lightweight beryllium domes, composite laminated structures and aluminium honeycomb structures of the type developed for the aerospace industry.

One range of loudspeaker diaphragms using aluminium honeycomb as the basic structure, has a square configuration. The woofer diaphragm is supported on its periphery by a flexible roll surround which ensures that the woofer achieves an extremely long throw and also minimises the risk of voice coil polling. The diaphragm is supported at four points on its rear face by means of the extended ends of the folded ends of a curved cruciform element. This is neatly fixed to the aluminium honeycomb structure. The bowl shaped cruciform driving element is directly terminated on to a semi-conventional circular voice coil.

Cabinet or enclosure design has also received much attention in recent times. High performance units provide excellent damping for the loudspeaker systems by using acoustic resistance elements in association with reflex or other type enclosures.

LOCAL DESIGNS

Although some monitoring loudspeaker systems are imported models today, up to about the late 1960s many systems were designed and built by local studio Engineers. The National Broadcasting Service was a typical example. It used several hundred loudspeaker systems with its studio and transmitting facilities. In 1962, it developed and manufactured in the PMG's Department Workshops, a high quality system called the Type 3 loudspeaker system. It incorporated some innovations in the arrangement of the middle and high frequency units although the bass region was conventional. The system had excellent objective and subjective characteristics in a cabinet of moderate size and good accessibility. Some of the units and also an improved earlier model, the Type 2, were still in service at some transmitting stations during the late 1980s.

Departmental staff associated with the development and testing of these loudspeakers included Eric Brooker, K J Drew, C N F Jenkins and W M McNaught.

Among Australian designers and manufacturers of high quality studio monitoring loudspeakers in 1994 was Australian Monitor Pty Ltd, Gladesville. Included in the company range were Landmark studio monitors and the Opal S-1 Project studio monitor.

HEADPHONES

HEADPHONE TECHNOLOGY

The headphone or head set had its origin long before the advent of broadcasting, and even before wireless telegraphy. It was part of the telephone service in use many years before wireless. However, it was broadcasting with its transmission of music and in more recent years, high fidelity (hi-fi) that has brought headphones to their present stage of performance.

The receiver with headband was a direct development of spark wireless telegraphy when signals were of low level, there were no amplifiers or loudspeakers, and the operator needed to keep both hands free to write down or type the message received by Morse Code and frequently, to adjust the receiver.

The first headphones were initially low resistance types, but to meet improved circuit requirements, receivers of 1000 ohms resistance soon became available. At first, only one receiver was in a headset, but later, another was added and in most cases except for some special studio applications, is still the practice today.

Receiver technology followed the practice of the telephone industry initially, but a major breakaway from using an iron diaphragm was made when Nathaniel Baldwin, a devout Morman in the USA made receivers using diaphragms of mica and later, aluminium. They had 2000 ohms resistance and the USA Navy tests showed they were twice as sensitive as iron diaphragm types in service at the time. The diaphragm was actuated by an armature driven by a solenoid. This meant that the diaphragm did not have to be of ferro magnetic material.

The cost of a headphone set was expensive in the 1920s, and for a crystal set, the most expensive component. For a receiver with parts costing about £5 ($10) the cost of the headphones was about thirty-five shillings ($3.50). The most popular makes sold in Radio Shops included Acme, Audion, Baldwin, Brandes, Britcent, Brownies, Brown's, DW, Featherweight, BTH, Economic, Eisemann, Ericsson, Federal, Fellows, Frost, Gecophone, Kellogg, Kennedy, Magniphone, MEL, Mesco, Murdoch, Rayton Adjustable Diaphragm, Red Head, Siemens, Sketophone, Sparta, Spitfire, Stella, Sterling, Stromberg-Carlson, Supreme, TMC, Trimms Dependable, Western Electric and others. All these models were imported from overseas sources but Australian manufacturers were soon producing high quality units from about 1927.

Although headphones are rarely used with domestic receivers today, they are an essential part of studio equipment for Announcers and Presenters and also for personal AM/FM radio stereo cassettes.

HEADSETS FOR LADIES

In addition to the standard dual receiver headset with headbands of aluminium or iron wire, aluminium bands, leather straps etc., there were units made especially for ladies so that the ladies' elaborate coiffures were not disturbed when they wished to listen-in to the wireless. They were known as handphones or handsets rather than headsets and were available as a single receiver attached to the end of an ebonised or hardwood handle, or as a double set with the band connecting the two receivers mounted in such a way that the band went under the ladies jaw and not over the head. The lady held the receivers in position over the ears with a small rod fixed to the band. They disappeared from the scene with the advent of the loudspeaker.

One Radio Shop in Adelaide which had a selection of ladies handphones or handsets in 1925 was Varcoe and Co., Gawler Place. Models included Ericsson double handphone in 2000 and 4000 ohm resistance, Ericsson single handphone of 4000 ohms, Sterling 2000 ohm handphone with ebonised hardwood handle and 6 foot flexible cord and Sterling handset with spring band of duralumin fluted handle and 6 foot flexible cord with a range of 120, 2000 and 4000 ohms resistance. They also stocked several designs produced by a retired Marine Engineer in Port Adelaide with the receivers being built around Frost earpieces.

MODERN HEADPHONES

Modern headphones are not inferior to commercially produced loudspeakers in regard to transmission bandwidths, non-linear distortion, maximum acoustic pressure etc. They can provide the original sound intensity without difficulty and their performance is independent of the acoustics of the listening area. In addition, headphones can considerably attenuate the ambient noise in the reproduction area so that the dynamic range of the program signal can in fact be achieved without any additional constraint.

Like many pieces of radio equipment, the design of headphones involves a number of conflicting requirements. Two of the important requirements are the weight and size because headphones may be worn by Announcers for several hours and are likely to produce fatigue or discomfort with the wearer. However, for high quality performance at the very low frequencies, size is very important.

A very powerful magnetic circuit is an essential requirement for a dynamic type sound reproducer in order to produce a high sound pressure. Sound pressure is proportional to the square of the radius of the diaphragm and the excursion. Hence, if the diameter of the diaphragm is reduced in order to reduce the overall weight or size, the sound pressure will fall sharply. Fortunately, the drop in pressure can be restored by increasing the strength of the magnet. The greater magnetic flux will allow the diaphragm excursions to be increased.

Modern technology has come to the rescue of the designer to enable the production of permanent magnetic materials vastly superior to earlier Alnico and other types. Samarium-cobalt alloys are now widely used. They have a very small permanence factor (1 compared with 12 for Alnico) and this makes it possible to produce a very small but powerful magnet.

Another important development is the production of an extremely thin diaphragm. The use of the very thin diaphragm enables the compliance of the system to be increased considerably, so improving the bass response. Modern units are capable of frequency response 20 Hz to 20 kHz with a rated input power of 300 mW.

There are two basic methods of fitting headphones to the ear. They involve the circumaural type of headphones and the supra-aural type. The circumaural type uses a large soft pad which completely surrounds the external ear and acts as a seal. Because of the seal they have very good low frequency response characteristics.

The supra-aural headphones rest on the outer ear and use soft foam filled plastic rings or discs. The type of driver used is arranged so that the movement of the diaphragm increases as the frequency is reduced making up for the cancellation due to the huge leakage.

A lot of attention has been given to the design of foam earpads in recent years. Foam pads are necessary for wearer comfort but they can impair the quality of the sound if not correctly placed or inferior materials are used. Studies have indicated that the cavities in many foam earpads contain cell walls that impede the sound wave going through the cavity. To reduce the acoustical filter effect, foam materials for high performance headphones are manufactured by a special chemical process to eliminate walls in the cavities across the sound path.

In addition to headphones which fit over the ears, there are high quality types which fit inside the ears. The introduction of the Sony Walkman resulted in considerable developmental work by the company in improvements to the headphone system. The original headphone introduced about 1979 was a lightweight foam pad type weighing 40 grams. In 1982, a new design was produced with the phones being small enough to fit inside the ear without the need for a headband. It weighed 5 grams. Another design was introduced the following year with a lightweight headband but with a vertically constructed unit which could slip in the ear canal. In 1984, the company introduced an ear insertion headphone with small chambers and tubular ports to enhance response.

TYPICAL TYPES

Typical headphone types used for broadcast studio application include the following:

- Electrostatic type.
  This type requires a power supply unit to provide a polarising voltage. An externally polarised transducer provides the highest quality without the need for compromise. Typical frequency response range is 10 to 25000 Hz.
  Electrostatic headphones have the attractive feature of a very low-mass diaphragm which provides good acoustic match to the surrounding air. Because the drive to the diaphragm is distributed evenly over the surface, distortion due to break-up is eliminated.
- Dynamic type.
  One model featuring an open design of the headphone system has an extremely broad range of transmission frequencies with relatively uniform response. Range is 10 to 25000 Hz and nominal input impedance 600 ohms for each system. The ultra lightweight corrugated disc diaphragms reproduce the cleanest bass and extremely clear treble ranges.
- Electret type.
  Another type finding increasing application for studio monitoring work is the electret headphone. It combines the advantages of electrostatics with the convenience of dynamic types. An electret is a permanently polarised material carrying a permanent electrostatic charge. In a typical headphone, a thin metallised polyester diaphragm is stretched between two perforated electret plates. The system operates in push-pull mode.
- Single type.
  The single headphone unit is preferred by many Announcers and Presenters as it allows them to cue up the next record while still keeping an ear on the record already playing. One side is completely open and the other has an acoustically sealed earcup for high isolation. The system has a frequency response range of 30-20000 Hz, and is available in nominal impedances of 8, 50, 100, 200, 800 and 2000 ohms. Ambient noise isolation is about 20 dBA. This headphone type is also available with a noise cancelling lip microphone for remote broadcasting work or for use by the studio Director.
- Cordless type.
  Modern technology has resulted in the production of cordless headphones combining freedom of movement for the Announcer or Presenter, with high audio performance characteristics.
  Typical is the Beyer IRS890 Cordless Infrared Headphone. It comprises a cordless headphone featuring automatic level control, individual left/right channel volume controls, switchable stereo, mono-left or mono-right and powered by two 1.5 volt AA batteries. The infrared transmitter is mains powered. Frequency response is 18 Hz to 24 kHz with maximum SPL of 110 dB.
  Other cordless types available in 1998 included AKG K211R, AKG K311R and Sennheiser RS6. The latter being an FM radio type.

In the 1980s, popular brands of headphones in service in broadcast and recording studios included Audiotechnics, Audiotelex, Beyer, Clear Com, Fostex, Koss, MB Electronics, Pioneer, Sennheiser, Shure, and Sony. Most brands were available in a number of models with special characteristics. For example, the German manufactured Sennheiser models included HD4004, a stethoscope type with frequency response 100 Hz–6 kHz and SPL 94 dB/mW; HD430, open type and SPL 94 dB/mW; HD424X, a featherweight open type suitable for high quality music reproduction covering the frequency range 16 Hz–20 kHz and SPL 102 dB/mW; HD420, adjustable open type with frequency response 18 Hz–20 kHz and SPL 94 dB/mW; HD414X, open type with a selection of connections and covering the frequency range 20 Hz–20 kHz and SPL 102 dB/mW; HD400 open type with selection of connections and covering the frequency range 20 Hz–18 kHz and SPL 90 dB/mW; HD224X, closed type with excellent isolation properties and covering the frequency range 16 Hz–20 kHz and SPL 94 dB/mW; HD222, adjustable closed type covering frequency range 20 Hz–20 kHz and SPL 94 dB/mW, and others.

PROGRAM LINES

TELEPHONE CIRCUITS

The need for the use of Post Office telephone circuits began immediately broadcasting stations were established. In addition to circuits to various places for outside broadcast programs originating at churches, town halls, sportsgrounds, etc., circuits were required for the transmission of the studio program to the transmitter in those cases where the transmitter was located remote from the studio.

Program sources soon reached out beyond the immediate station area. On 20 August 1925, the first broadcast of a national character occurred when a speech of Mr J R Collins, Secretary of the Treasury was broadcast simultaneously by A Class stations in Sydney, Brisbane, Melbourne and Adelaide. Not only was it the first occasion in Australia of simultaneous broadcasting from capital cities, but it was the first occasion outside the USA where such long distances were covered by program lines. The facilities were again used on 29 October 1925 when Mr Collins made a second speech.

The first event of great national importance broadcast using the program line system took place on 9 May 1927 when His Royal Highness, the Duke of York officially opened the Commonwealth Parliament in Canberra amid ceremonies and pageantry befitting the occasion. To cater for the large crowd at the scene and radio listeners, a complex communications system was set up monitoring a combination of public address systems and a specially connected network of long-distance trunk line circuits feeding the program to six broadcasting transmitters in four capital cities. The external public address system was provided by Standard Telephones and Cables Ltd, while the PMG's Department provided the program circuits to the A Class stations, 4QG in Brisbane, 5CL in Adelaide, 2FC and 2BL in Sydney and 3LO and 3AR in Melbourne. The STC No. 1 Public Address System employed five sound projectors each 10 ft 6 ins (3.1 m) long to provide for the crowd of 65000 people.

As the standard telephone repeaters were not suitable for transmission of a broadcast program because of their restricted bandwidth, specially designed amplifiers designated Type R1-A were made up for the occasion and installed at Glen Innes, West Maitland, Wangaratta, Ararat and Bordertown. They were patched into service at the Post Office repeater stations just prior to the broadcast.

One of the most complex hook-ups of circuits took place with the Empire Broadcast on Christmas Day 1932 when His Majesty King George V spoke on the Empire Service transmitted from the BBC station at 5SW Daventry. The program was received by a newly established receiving station at Mont Park in Victoria and transmitted over the Post Office land line network to all the principal stations in service in Australia at the time. There were 12 National and 43 Commercial stations in service.

In the early stages of broadcasting, dedicated channels solely for program transmission purposes were not available and consequently each time a program was to be transmitted from some distant point or a simultaneous transmission from two or more stations was desired, it was necessary to provide the links by diverting trunk line channels from their normal purposes of carrying telephone and telegraph traffic. The circuits were specially lined up for program purposes. The overall circuit was lined up on a zero loss basis, in which the repeater gain was made equal to the loss of the preceding line and equipment. There were, of course, requirements for permanent program lines to those transmitters in country areas which relayed programs originating in metropolitan studios and also to the metropolitan transmitters located away from the studios.

With the commissioning of the National stations 2NC Newcastle, 4RK Rockhampton, 2CO Corowa and 5CK Crystal Brook over the period 1930 to 1932, program lines were provided from the associated ABC metropolitan studios. Although 4RK, 2NC and 2CO were provided with local studios in nearby centres, the 5CK transmitter was a full-time relay station. Lengths of the program lines were — Brisbane to 4RK, 640 km; Sydney to 2NC, 240 km; Melbourne to 2CO via Albury, 400 km; and Adelaide to 5CK, 240 km. The program line to 5CK was a 3.4 mm diameter copper open wire line with a short entrance cable at the Adelaide end. No intermediate repeater was provided. The telephone circuit to the station comprising a 2.8 mm copper wire line could be patched in as a program line, should a fault develop on the main circuit.

DEDICATED PROGRAM CIRCUITS

The lack of suitable program circuits between the eastern States and Western Australia and Tasmania in the early 1930s was of much concern to the ABC programmers. It placed restrictions on the availability of important programs generated in Melbourne and Sydney.

Although telephone conversation to Perth was possible in 1930, it was not until 12 June 1933 that a program circuit became available for broadcast purposes. Even so, it operated in one direction only, east to west.

In October 1942, a reversible program circuit was commissioned. This enabled programs to be relayed in either direction but only in one direction at a time. It was not until 1 July 1947 that programs could be relayed in both directions at the same time.

There were no cable telephone circuits between the mainland and Tasmania until 1936 and any mainland programs broadcast over 7ZL were derived from receivers tuned to mainland transmitters. Receivers were located at Davenport and Kelso in the north, and at Hobart.

At the time it was laid, the Mainland-Tasmania submarine cable was the longest telephone type cable in the world. All earlier cables carried telegraphy traffic only. The cable initially catered for two trunk telephone circuits, seven telegraph channels and one channel for broadcast program. Carrier systems carried the circuits with the broadcast channel being in the top end of the band on 34 to 42.5 kHz. Filter groups separated the broadcast carrier from the carrier telephone and telegraph frequencies. Amplification was provided by two amplifiers in cascade with keys being installed to allow the circuit to be used for transmission in either direction as desired.

Standard Telephones and Cables (A/Asia) Ltd supplied the carrier, repeater and ancillary equipment for the link.

With the later introduction of radio telephone services, some additional capacity became available for voice frequency circuits to Tasmania and at the same time provided an alternative to the submarine cable system. One early system was a 6 channel VHF system linking Wilson's Promontory-Flinders Island-Mt Arthur. One Engineer involved in the design of the system, and who later transferred to broadcasting was Bill Beard of the PMG's Department Research Laboratories. Bill and his team subsequently undertook design modifications and extensions including power amplifiers and higher gain aerials to increase the channel carrying capacity of the system.

When it became evident that the submarine cable was about to fail in 1957, Bill designed and directed the installation of high gain aerial systems and other modernisation improvements to an old 3 channel 40 MHz AM radio telephone system across the Bass Strait linking Apollo Bay and Stanley. The cable carrying 12 channels failed just as the radio telephone system was put to air.

Land line circuits lined-up for broadcast program transmissions were capable of transmission in one direction only and had a reasonably flat frequency response over the range 50 Hz to 5 kHz compared with the standard telephone circuit of 300 Hz to 2.8 kHz. However, by 1937 the bandwidth had been expanded from 30 Hz to 7.5 kHz with repeating stations being located at about 240 km intervals. Line equalisers ensured compensation for variations in attenuation at different frequencies. Program lines between studio and transmitter of metropolitan stations transmitted a bandwidth 35 Hz to 10 kHz, so interstate music program quality was inferior to locally generated programs.

The demand for the use of trunk lines for the transmission of programs by both the ABC and Commercial stations increased rapidly as the number of stations increased. Major advertisers sponsored expensive programs in capital cities and these were relayed to country stations. During 1932, some 1043 circuits were set-up for National station relays while 1075 circuits were set-up for Commercial station relays. By 1940, these had grown to 12748 for National programs and 12706 for Commercial. Of the total relays in 1940, 4614 extended to two States, 894 to three States, 934 to four States, 3795 to five States and 4358 to six States. The remaining relays concerned only stations in the State of origin.

A wide range of programs were transmitted over the circuits. In 1937 they included race descriptions, 1288 relays; talks and speeches, 926 relays; news sessions, 624 relays; musical programs, 1,488 relays; stock exchange and market reports, 576 relays; cricket descriptions, 301 relays; overseas programs via receiving stations, 46 relays; operas, musical comedies and revues, 266 relays; other sporting events, 166 relays; concerts, 33 relays and miscellaneous items, 2 relays.

PERMANENT CIRCUITS

So constant was the demand for simultaneous broadcasts by 1940, that about 16000 km of channels were tied up permanently for broadcasting purposes. This included 5000 km of lines connecting National regional stations with metropolitan ABC stations, 7500 km of special carrier program channels on main interstate routes and 3500 km of lines between metropolitan and country stations leased by Commercial broadcasting organisations.

The permanent program relay channels in service for National transmitters included Sydney-Canberra (2CY); Sydney-Grafton (2NR); Sydney-Beresfield (2NC); Sydney-Cumnock (2CR); Melbourne-Corowa (2CO); Melbourne-Lyndhurst (VLR); Melbourne-Sale (3GI); Melbourne-Horsham (3WV); Brisbane-Dalby (4QS); Brisbane-Rockhampton (4RK); Rockhampton-Townsville (4QN); Townsville-Atherton (4AT); Adelaide-Crystal Brook (5CK); Perth-Kalgoorlie (6GF); Perth-Wagin (6WA); and Hobart-Kelso (7NT).

Permanent lines provided to Commercial station transmitters included Sydney-Katoomba-Orange (2KA, 2GZ); Sydney-Wollongong (2WL); Sydney-Canberra (2CA); Sydney-Maitland (2HR); Melbourne-Lubeck (3LK); Melbourne-Shepparton (3SR); Brisbane-Oakey (4AK); Brisbane-Kingaroy (4SB); Adelaide-Crystal Brook (5PI); Adelaide-Berri (5RM); Adelaide-Murray Bridge-Mt Gambier (5MU, 5SE); Perth-Northam (6AM); Perth-Katanning (6WB); Perth-Bunbury (6TZ); and Perth-Merridin (6MD).

When Prime Minister Menzies made an all-stations broadcast on 17 June 1941, in which 27 National stations, 3 short wave stations and 95 Commercial stations participated, nearly 30000 km of permanent and temporary program circuits were employed plus an additional 13000 km taken out of service for lining-up the program channels.

With such long distances of open wire and cable involved, faults and failures naturally occurred, but arrangements were made for the continuous monitoring of the programs as they passed through the repeater stations. In the event of failure or marring of the program, it was the practice to immediately patch the faulty section or faulty equipment with alternatives. Having in mind the long period in which the programs were being broadcast and the long length of the lines, the number of complaints received were surprisingly not great. Some long circuits passing through tropical areas were subjected to much more interference from static and breakage due to cyclonic disturbances than circuits in southern areas. The Manager of 4BK Brisbane on complaining about the service and the high rental of his line to 4AK Oakey, was moved to say that, 'he paid enough each year in rental for the Post Office to have a lineman standing by at each of the telephone poles between his Brisbane studio and the 4AK transmitter'.

Even as late as 1950 when there were close to 50 National and 100 Commercial stations in operation, the bandwidth of program circuits had not changed significantly, wideband circuits were very expensive to provide and it was considered that circuits with frequency transmission above 8 kHz could not be economically justified. Also, congestion in the broadcast band and the response characteristics of the typical domestic receiver added weight to restricting the upper frequency to about 8 kHz. Categories of program plant included equipment used in conjunction with broadband carrier systems, equipment which could be used independently of other carrier systems and splitband equipment.

In more recent times, with the use of highly reliable broadband systems in the Telecom/Telstra network, program circuits are extremely reliable and provide very high quality circuits, easily meeting the most stringent demands, such as the ABC Classic FM service employing the largest program circuit in the world.

In the late 1980s, terrestrial circuits were gradually giving way to satellite derived circuits which became the standard method of providing circuits to the ABC Second Regional Radio Network transmitters.

During 1995–96, terrestrial studio to Radio Australia transmitting station sites were replaced with ABC Delta satellite distribution system.

One program circuit of interest was that provided for National station 8GO Nhulunbuy in Northern Territory. The circuit was provided over a tropospheric scatter radio system linking Darwin with Nhulunbuy with repeater stations at Munmalary and Milingimbi. The system commissioned on 24 December 1971 utilised the property of the lower atmosphere to bend and scatter UHF radio energy over the horizon. The Darwin terminal was installed at the Radio Australia Receiving Station complex on Cox Peninsula. The system operated in the band 2450–2690 MHz band with RF output power of 1 kW provided by klystron and feeding aerial dishes of 10 or 12 m diameters.

The system initially catered for normal telecommunications traffic to meet the needs of the mining company based at Nhulunbuy, but with the installation of the 500 watt MF station 8GO on 21 December 1974 the tropospheric scatter system was expanded to provide a program quality circuit via the ABC studios in Darwin.

The tropospheric scatter system was taken out of service in 1988 with the provision of a conventional broadband radio-communications system across Arnhem Land. Today, 8GO is fed via a satellite circuit.

Engineers associated with the design, installation and commissioning of the tropospheric scatter system included Leon Sebire, Max Kimber, Volka Lange and Jack Ross, Supervising Engineer.

FIXED RADIO LINKS

In addition to physical lines and carrier circuits for conveying programs from studios to transmitters, radio links have been widely employed since about the 1960s. Links in service in the 1960s used VHF and UHF specially designed for program purposes. National metropolitan services were equipped with program radio links but mainly for emergency purposes. With expansion of the telephone network and the availability of circuits via alternative routes for patch purposes, the links were gradually removed. In the case of Adelaide where radio circuits were provided in 1961 to the 5AN/5CL transmitters at Pimpala, two UHF links were provided shortly after the station was established on the new site. The system had a repeater at Mount Bonython with one system operating with horizontal polarisation while the other employed vertical polarisation,

Modern link equipment employs digital technology. The system installed for 4TO Townsville was typical of Australian made systems. The equipment was designed and manufactured by AWA and installed by a local Townsville contractor. It operated in the 1.5 GHz band and the data input was in the standard 2.048 Mbps data stream. The facilities included a service channel 300 Hz to 2.2 kHz with a 2 kHz calltone and a supervisory channel. System frequency response was almost flat over the range 20 Hz to 15 kHz with worse distortion case being 0.3 % and the unweighted signal-to-noise ration -84 dB.

Another system put into service in recent times was supplied by Moseley Electronics with installations being provided for SUN FM Shepparton, 96FM Perth, TTT Hobart, 5DN Adelaide and an FM station at Geraldton. As installed, the system operated in the

950 MHz band. Both transmitter and receiver were fully synthesised with up to 40 channels per link. Both mono and stereo modes were available. System specification stipulated better than 76 dB SNR, ± 0.1 dB frequency response and 0.1% distortion.

As a result of the decision by the licensing authority to move STL band from 950 MHz to 850 MHz in order to cater for telephone service requirements, some station link equipment became obsolete. Many Engineers took the opportunity to upgrade to digital technology.

Systems installed during 1993 included Dolby digital studio transmitter links installed at 3MP Melbourne, 4KQ Brisbane and 2SM Sydney with the 4KQ installation including a repeater; a locally made 1.3 GHz D-Mux digital link provided by JNS Electronic Industries for 3MMM Melbourne providing two 15 kHz stereo circuits at 2.048 Mbps with signal to noise ratio better than 85 dB and frequency response of +0/-0.8 dB over the range 10 Hz to 15 kHz; and a DMM-92 system from TFT providing four CD quality channels plus two 3 kHz voice or data channels.

Combinations of open wire lines, radio links and cable circuits were not unusual particularly for NBS stations to carry program to the transmitter from a remote studio. One instance was 4TI Thursday Island, the most northern broadcasting station in Australia. When commissioned on 18 June 1979, program was fed via Cairns ABC studio to Bamaga near Cape York over open wire line, then via a UHF radio link across Torres Strait and on to the transmitter by cable via the local telephone exchange. In 1993, the program was being fed from Cairns via a digital radio link to Thursday Island and then via a local Torres Strait Islands Media Association studio to the transmitter at Tamwoy.

Earth stations and satellites employing microwaves are now widely employed as radio links for radio broadcasting purposes, particularly by the ABC. Although it has many fixed installations at centres throughout Australia, the ABC in conjunction with AUSSAT made history during June 1991 when a facility was established to enable television and radio news studios to broadcast from a number of railway station sites along the Queensland coast from Cairns to Brisbane.

A 15 carriage train called the Green Train was supplied by the Queensland Railways with the carriages being used to house the TV and Radio studio equipment and displays by the many sponsors which included large industrial organisations and groups with an interest in conservation and the environment.

ABC Television broadcast the Queensland news bulletins live from the train every week-night for a two week period, and ABC Radio broadcast more than 55 hours of program from the train over the same period.

The live broadcasts were made possible through AUSSAT's Transportable Earth Station (TES) which travelled with the Green Train by road, mounted on a 12.5 metre long semi-trailer towed by a large prime mover. The TES was a complete earth station in itself with uplink and downlink capability for television plus associated sound and also two by two-way voice circuits.

The project was designed to encourage the community to come together and learn more about the many areas of environmental concern in the world. A special program was presented on 5 June as part of World Environment Day activities while the train was on display at Townsville. The train was painted with a stunning 200 metre long mural featuring possums, dolphins, cassowaries, gekos etc., and created a great deal of public interest.

OUTSIDE BROADCASTS

OUTSIDE PROGRAM SOURCES

The first broadcast of a program from a source remote from a studio, following the official establishment of broadcasting stations, was conducted by 2FC Sydney in January 1924, a month later after the station began operation.

The outside broadcast equipment was installed in Her Majesty's Theatre, Sydney where Gladys Moncrief performed in 'A Southern Maid' for the Royal Comic Opera Company. The microphone was placed on the stage near the centre of the footlights with a speech amplifier unit being located under the stage and controlled by the Technician.

A few minutes prior to the broadcast of the performance, a peal of chimes produced by tubular bells was transmitted to allow listeners to tune-in their receivers.

Broadcasters were quick to realise the benefits of collecting program material from sources outside the studios. They established permanent program circuits using PMG Department telephone lines, to churches, sports ovals, entertainment areas, town halls, stadiums and other points where regular broadcasts were planned. They could also request the provision of temporary lines where rental for a permanent line could not be justified.

In addition to OB circuits for program purposes, some stations, particularly metropolitan stations had the line and complete OB equipment including microphone permanently set up in the Town Hall or GPO clock tower for broadcast of bell time signals. Broadcast of GPO clock chimes began as early as 1924 in South Australia.

The advent of broadcasting into the realm of sport, the church, dance halls, concert halls etc. was received with enthusiasm by many listeners who followed those activities.

One outside broadcast which employed considerable resources and which was broadcast to listeners in every State through National and Commercial stations, and also to listeners overseas from short wave stations based in Australia and through BBC transmitters in England, took place on 26 January 1938, in Sydney on the occasion of the official opening of Australia's Sesqui-Centenary Celebrations. Principal participants were staff of the Australian Broadcasting Commission and the Postmaster General's Department.

As part of the overall technical facilities provided, a temporary control room was set up on the shore of Farm Cove and a temporary outside studio set up on the beach close to where a party was to land from the ship 'Supply' anchored in Farm Cove. Incoming lines included a submarine cable to the 'Supply' and several lines to microphone points along the beach. Splits were provided to National transmitters throughout Australia, a public address network covering the entire Sydney Gardens, a public address system along the route of the procession, various Commercial stations throughout the Commonwealth, two newsreel camera recording units on the landing beach and ABC recording studios in the city.

In addition to the submarine cable to the 'Supply', a short wave radio link was installed for emergency purposes in case the submarine cable should fail.

One of many OB points was installed in a pylon on the Sydney Harbour Bridge where the Commentator had a good view of the party being rowed ashore from the ship.

The long procession of floats was a highlight of the activities. The floats had been planned as a cavalcade of Australia viz., from the earliest buildings, houses, costumes and characters up to 1938.

The Official Luncheon was held on board the ship 'Ormonde' which was connected to land by a submarine cable to enable broadcast of speeches by the Governor General, State Governors and Cabinet Ministers to be sent to studios.

Throughout the day, 19 microphones were employed from seven separate OB pick-up points.

Although in more recent times, more complex and larger technical set ups have been involved in outside broadcast activities, such as the visit of the Queen during 1954 and others, the 1938 arrangements set the pattern for many others which followed.

Over the years, Technical staff and Commentators have been subjected to some dangerous situations, particularly as a result of crowd movement. One such occasion occurred in Sydney when OB equipment was set up for the ABC to broadcast the arrival of Kingsford Smith on completion of his historic flight in 1933. Ted

Mosely, Foreman Mechanic and H A G Stanford set up the equipment in a position on the landing site which they considered was a good position for the ABC Commentator Charles Moses to cover the landing. The crowd was enormous. When the plane landed the crowd surged forward overrunning the broadcasting position and almost crushing the three men. Fortunately, they were not seriously injured but the equipment was damaged beyond usefulness. Cords were dragged out of the equipment and dragged across the paddock. The microphone was a write-off job. Charles Moses picked himself up and dashed over to Kingsford Smith where he arranged to interview him in his flat that evening.

In another situation, 3DB Melbourne wished to broadcast the Easter Cup event from a country racecourse in 1936. The Chief Engineer Max Hooper could not spare any of his Technical staff as he had many important commitments in Melbourne over the Easter period. He asked Harry Kauper who was Consulting Engineer for the station if he could undertake to handle the broadcast.

Harry visited the site several weeks before the event to arrange for the provision of broadcast line by the local Telephone Mechanic and to arrange for a local Engineering firm to construct a five metre high steel structure with a platform on top to accommodate the OB equipment and himself, plus the race caller.

On the day of the broadcast, Harry hauled all the equipment to the platform and set it to work with connection being established with the 3DB studios.

The first two races went without incident. The Easter Cup was an exciting race. The horses were bunched together as they turned into the home straight. However, when within a few metres of the winning post the favourite and leading horse fell causing two horses behind to also fall.

The Commentator who had invested heavily on the favourite, leapt out of his deck chair and while jumping up and down knocked Harry over in his deck chair causing him to fall off the platform. Harry had his headphones on and dragged the amplifier with him as he fell.

An Ambulance Officer on the course treated Harry for abrasions and shock. Harry had been Chief Engineer at 5CL Adelaide for four years before transferring to Melbourne and had never had an accident in all his time in Adelaide.

SPORTS BROADCASTS

There was no question about the popularity of sporting broadcasts. Broadcasts of Test matches in cricket, football matches and racing descriptions provided spectacular and convincing evidence of this fact. Never in cricket history had Test matches aroused such public interest as they did during the 1930s. Huge crowds jammed the streets outside Radio Shops while they listened to the broadcasts from ovals in Australia or overseas. A shop which displayed a notice outside saying 'Cricket Broadcast by Wireless Here', was sure to attract a large appreciative crowd. Early photographs show hundreds of people standing outside some shops listening to broadcasts. On one occasion in Brisbane, the crowd swelled onto Queen Street, the main street in the city, and brought traffic to a halt.

The administrators of football and racing were not pleased with the apparent inroads that radio was making into their sports. They vigorously opposed broadcasts from within their properties for many years on the grounds that if people could hear the events on their radios they would not attend the grounds and the clubs would thereby lose money.

Experience, however, subsequently showed that the broadcasting of descriptions was a most effective method of stimulating public interest in sport and invariably resulted in greater attendance.

The broadcasters of the 1920s, realising the tremendous interest by the public in sport, did everything to put sporting events on air. Commentators, with binoculars, perched in trees, they hung to ladders and they stood on the roofs of houses in order to give a coverage of the event. At one racecourse, officials placed screens in front of the judge's box, at the starting post and near bookmakers to deter the broadcasters. The football administrators were just as keen to disrupt the work of Commentators. One Commercial station erected a steel platform tower outside the South Melbourne grounds and the officials responded by erection of a huge hessian screen to block the view of the ground.

For one Brisbane football broadcast, a house with a tin roof was selected for the broadcast point. The roof was so steep that the 4QG Technician Bill Rohde had to be tied down by a hemp rope to prevent him and his equipment sliding off. For two hours he lay tied down to the roof with his feet in the guttering and holding the amplifier, battery, portable telephone and an assortment of cords while the Commentator, straddled across the very top of the roof, did his best to describe the match. Icy wind and a heavy downpour added to the discomfort of the two brave men.

The Australian Broadcasting Commission was quick to realise the popularity of sport as a program and during its first year of operation in 1932, broadcast descriptions of horse racing, cricket, football, basketball, tennis, athletics, boxing, wrestling, rowing, cycling, hockey, lacrosse, golf, baseball and polo. Rental of Post Office lines and pick-up costs associated with sporting broadcasts amounted to 2.5% of the Commission's expenditure for the year.

EQUIPMENT DEVELOPMENT

The equipment employed for outside broadcasts in the 1920s was bulky and heavy and the Operator often laboured under the most difficult conditions. Typical equipment comprised a Reisz or WE microphone, a station-made two channel amplifier, a six volt car battery, a B battery, a field telephone, headphones, a roll of cable, a box of cords, plugs and spare valves and a microphone stand.

The technical facilities of 3LO Melbourne were operated and maintained by Amalgamated Wireless (A/Asia) Ltd on behalf of the Broadcasting Company of Australia and OB equipment was manufactured by the company in Sydney. A photograph circa 1928, shows the Technician immaculately dressed in suit, hat and bow tie standing beside his equipment prior to loading it into a chauffeur driven car. The load comprised five wooden boxes each securely locked, an amplifier case and a telescopic microphone stand with heavy base.

In some cases the Technician had to haul it onto the roof of a house, strap it down in a rocking boat, manhandle it up the trunk of a tree, fix it in the boot of a car, strap it to the saddle of a horse, or even carry the whole system in his hands, or strapped to his back, up the side of a steep hill. Outside broadcasts from 4QG Brisbane in the early days are typical. They included broadcasts deep down in mines, under the waters of Moreton Bay and in the caisson of the Grey Street Bridge.

In addition to local outside broadcasts, many programs originated in other towns and frequently interstate and even overseas. In these cases, the program was transmitted over trunk line channels of the Post Office from pick-up point to the studio.

In 1931, outside broadcast equipment used at National stations for broadcast of ABC produced programs comprised combinations of equipment developed by A Class station Technical staff before takeover by the PMG's Department or equipment built by the PMG's Department staff.

In South Australia, as a typical example, microphones used for outside broadcast work were identical with the studio types in service at the time, i.e. STC condenser types with an integral amplifier of one stage. For important broadcasts, up to four microphones would be employed simultaneously.

The line amplifier was mounted in a specially made carrying case. It was a three stage resistance-capitance coupled amplifier with a gain of 60 dB which was ample for OB work. The output stage was either a 4101D valve of 4104D type, the former providing ample undistorted output for the majority of cases, and the latter providing higher undistorted output when required such as for noisy lines. Batteries were carried in another case with a battery plug and jack providing ready means of connecting the batteries to the amplifier.

The amplifier was modified about 1932 and fitted with both faders and volume indicator. The faders were four point type and enabled up to four microphones to be handled smoothly and conveniently from the amplifier. The faders were each made of fixed resistors arranged in logarithmic manner to provide a uniform loss per step. There were ten steps of about 2 dB per step. The faders were used in conjunction with the main gain control of the amplifier to effect a smooth change from one microphone to another. The volume indicator used a Westinghouse copper oxide rectifier unit with a Weston meter. The AC terminals of the rectifier were connected through two series resistors across the output of the amplifier. The meter gave standard mid-scale deflection on the normal output of the amplifier which was minus 8 dB referred to 5.9 milliwatts. The provision of the volume indicator on the amplifier allowed the OB Operator to control the level rather than having the control room Operator perform that function. The control room Operator was remote from the pick-up point and could be caught unawares of some action which might have a serious impact on the signal level being sent to line.

Special portable outside broadcast equipment was developed by the Post Office to cover broadcasts related to the visit of His Royal Highness, the Duke of Gloucester in 1934. The equipment employed four input microphones, each of which was individually controlled and fed into an amplifier. Very effective use was subsequently made of the equipment for the broadcast of operas in Melbourne when one branching channel was fed to a loudspeaker operating in a specially treated room at the outside broadcast point. This was an important innovation in Australia and contributed a great deal to the value of the broadcast, owing to the more effective control of the production and active co-operation with the musical producer.

With the introduction of moving coil microphones for OB pick-up work, a new amplifier design was produced, having sufficient gain to be capable of an output power of 6 mW to line when used with these microphones. As the rated output of microphones in service for this work was of the order of 70 dB below reference volume, the amplifier was designed to produce a gain of 80 to 85 dB to provide a reasonable margin. As four input channels had met the need of 99 per cent of all broadcasts since 1931, this number of input circuits was retained.

The amplifier employed two 6F5 valves and a 6C5 output valve, and was powered by a 6 volt filament battery and 180 volt B battery. Horrie Hyett was Engineer-in-Charge of the project.

The amplifier built in Sydney by Post Office staff was first used for the opening ceremony of station 2NR from the Saraton Theatre, Grafton in July 1936.

In 1937, Murray Stevenson, Chief Engineer of Commercial station 2UE designed and built an OB unit for use by station staff incorporating the latest practices and equipment at the time. The unit was small compared with many others in service at the time and was completely self-contained. The overall size was 250 mm by 300 mm by 175 mm.

The amplifier had an overall gain of 87 dB and employed three Australian-made 1K4 battery pentodes in a three stage amplifier producing 10 milliwatts into a 600 ohm line. Provision was made to mix two input channels with overall response of the amplifier being almost flat over the range 30 Hz to 10 kHz, referenced to 1 kHz.

Batteries to power the unit included two No. 6 dry cells in series with a resistor, for filament supply. Ever Ready K730 three volt bias battery tapped at 1.5V, and an Ever Ready Q21 type specially designed by the company for the amplifier provided the high tension supply. Two Q21 batteries each 45V were employed to cater for the 1.7mA drain. The dimensions of each battery were 94 mm by 84 mm by 56 mm.

Other facilities required for an outside broadcast including two microphones, ringer telephone, cables etc., were housed in another matching case the same dimensions as the amplifier case.

Bill Robinson Assistant Chief Engineer also played a major role in the development of the unit particularly in field trial assessment. Bill joined 2UE in 1934 after having been associated with NBS station 2NC. He became Chief Engineer of 2UE in 1956.

When Gil Miles, Chief Engineer of 7HT Hobart built an outside broadcast unit in 1937, his first concern was for reliability, with size and weight being of secondary consideration. The unit comprised three boxes. The first case measuring 750 mm by 450 mm housed the valve operated amplifier designed to cater for two microphone inputs. The second contained the microphone, the magneto telephone and all necessary cables for setting up the equipment. The third case contained a lead acid accumulator. Although bulky, it gave sterling service and functioned well, even after very rough handling in getting to some difficult broadcast points.

Modern day OB units are very lightweight and high performance models using solid state technology and in combination with lightweight radio links, an OB point can be set up very quickly and be completely independent of external support such as power mains and telephone circuits.

The provision of temporary telephone and program circuits was a time consuming and costly business. Many circuits were telephone pairs with restricted bandwidth and frequently equalisers had to be designed at short notice to make the circuit suitable for broadcast program purposes.

One member of the South Australian PMG's Department who was involved in the early development and construction of OB units was Cliff Moule. Cliff began his career in radio when he commenced work with Amalgamated Wireless (Australasia) Ltd, in Adelaide in 1927. He later worked with Healings Ltd, and Louis Coen Wireless, and in July 1936 joined the Transmission Section of the Postmaster General's Department. Cliff commenced as a Temporary Mechanic but within two years had qualified as Senior Mechanic in both broadcasting and telephony. Work activities included installation, maintenance and developmental projects in long line, broadcast transmitter and studio equipment. Part of the studio work was the development and building of OB units to meet the increasing demand of the ABC for improved outside broadcast activities. Following a period during the War years in which he installed air navigation equipment, and RAAF communication stations, he took up a position at the Adelaide Hindmarsh Studios where he assisted with the installation of two additional studios and a relay switching system. He then moved to the Technicians Training School where he instructed students in radio and electronics. In 1955, he returned to the ABC studios as Shift Supervisor until 1957 when he began a period as acting Engineer on the development of solid state equipment for the Adelaide ABC studios.

One project of particular interest in which Cliff played a leading role, was the development of a solid state OB amplifier to replace equipment which had been designed in 1936 by Engineer Laurie Billin and which was still in service in 1957. By that stage it was outdated technology. The introduction of the transistor appeared to be a good opportunity to take advantage of new technology to produce a new design.

A breadboard amplifier was constructed but it was not up to expectations. The input stage using an OC71 was very noisy and the output stage using two OC72 transistors had insufficient output.

Other types were then trialed with OC45 types being installed in the input stage. After changing base resistors, an optimum collector current of 1.3 Ma gave approximately 10 dB improvement in noise. A change in the output stage using OC26 types gave the required output power without being extravagant with the 9 volt battery consumption.

Ziguras Hermanis, a skilled broadcast Technician was then given the task of packaging the equipment into as small a space as possible. He eventually came up with a superb product. The case was 200 mm high, 150 mm wide and 125 mm deep. It had a sloping panel 150 mm by 150 mm and accommodated a VU meter and two input volume controls. The OB Technicians were delighted and even boasted that the two microphones took up more space in the carrying case than the amplifier.

While the OB amplifier was in its final stage of development, Brian Perkins, Divisional Engineer, was planning for a solid state studio switching system with Cliff assisting in the work. Early experiments on a 10 IN and 5 OUT matrix using OC77 type transistors showed that the idea was workable and it was put into service for three months before Brian presented a paper at the IRE Convention in Melbourne during May 1959. He detailed a scheme for 30 program outlets, selecting from 100 sources by using 20 push buttons for each outlet, arranged in a 'tens' and 'units' selection to control the positive or negative base voltages applied to the two switching transistors per connection. The scheme involved some 6000 transistors for the full matrix and at the time, was an important development in Radio Studio Engineering in Australia.

The only major disadvantage advanced at the time, was the high cost of the system compared with the relay/uniselector systems then in use. However, the cost was eventually justified on the basis of considerably less maintenance and very much improved reliability in the studio switching network.

With the introduction of television, Cliff was appointed Officer-in-Charge of the ABS2 Mt Lofty station where he remained until retirement in 1976.

RECEIVING STATIONS

From the earliest days of broadcasting, the A Class stations in all States made extensive use of overseas short wave stations as a means of obtaining specific program material for rebroadcast by their stations.

Most installations were relatively simple arrangements usually with an aerial wire above the roof of the building where the studio was located and an appropriate short wave receiver.

However some station Engineers installed elaborate facilities. Wally Coxon of 6WF had a well-designed installation for regular reception of 2XAF operated in USA by General Electric Company. The American Announcer advised listeners that the station was on relay to 6WF in Australia and gave a run down of items of interest to Australian listeners, such as wheat prices etc.

Wally experimented with diversity reception and used it to rebroadcast the 1928 Melbourne Cup. Receivers were set up about one mile apart with mixing taking place on the control panel before being fed to the transmitter. Many favourable reports were received from listeners concerning the program quality.

Station 4QG Brisbane rebroadcast the Melbourne Cup using a short wave receiver before the availability of dedicated program lines.

Station 2BL Sydney was also one of the early stations to rebroadcast a program from a station based in USA. On 18 April 1925, Ray Allsop, at the time, Technical Consultant for Broadcasters (Sydney) Ltd operators of 2BL using a three valve short wave receiver he constructed himself comprising detector and two stages of AF amplification using Cossor valves received station KDKA on 63 metres. The program was sent over the telephone line from his residence in Coogee to the 2BL studio using a choke-capacity coupled amplifier and rebroadcast for one hour. Even though the receiver had no RF stage the signal was high quality for most of the time.

In 1932, the Research Section of the Postmaster General's Department designed and built a Radio Receiving Station at McLeod (Mont Park) in Victoria, for the purpose of monitoring and relaying the new BBC Empire Service for the National Broadcasting Service. It consisted of one receiver housed in a portable type corrugated iron garage 3.7 m by 2.8 m and one Rhombic aerial situated on a leased property of approximately 36 hectares. The Mont Park station was subsequently replaced by a new station at High Park near Kilmore in 1959.

One officer who was associated with upgrading and maintenance of the Mont Park facilities, was Jack Carnell, who retired as Telecom's Broadcasting Operations Manager in Victoria on 14 February 1988. Jack joined the Postmaster General's Department in 1942 during the period when the Department was responsible for the installation and operation of the studio technical services. He was advanced as Technician in 1946, and qualified as Senior Technician two years later. His first assignment as Technician was in the ABC Melbourne studio Switchroom followed by periods in the Radio Laboratory, and on upgrading work at the Mont Park Receiving Station. He also carried out inspections of the technical facilities of Commercial broadcasting stations on behalf of the Australian Broadcasting Control Board.

In a career extending over 40 years, Jack was Officer-in-Charge of a number of stations including the Metropolitan Transmitting Centre 3LO/3AR and Yatpool TV station. In 1977, he was appointed Principal Technical Officer in the Victorian Radio Section where he was responsible for Broadcasting and Radiocommunications functions throughout the State, and activities of the Radio Lines Group. With the formation of the Broadcasting Directorate, Jack was appointed Broadcasting Operations Manager in 1984.

Operations commenced at the High Park station on a limited scale on 29 May 1959 with full-scale operations starting on 1 July 1959.

Services provided by the station included:

- Reception of HF transmissions from overseas broadcasting stations. Programs were sent via PMG's Department landline circuits to Melbourne where they were distributed for rebroadcast by NBS and Radio Australia transmitters, and for monitoring by the ABC News and Sporting Sections.
- Regular and special reception reports on established transmissions, with tape recordings of typical reception twice yearly as an additional check on weekly reception reports.
- Band surveys were made to assist in planning Radio Australia operating schedules and for the European Broadcasting Union. Special observations were carried out on request for use by Radio Australia frequency planners and for overseas broadcasters.
- Field strength measurements made on MF and HF transmissions.
- The receiving equipment for the Perth-Melbourne SSB and FSK links and the Wilkes Base Antarctica — Melbourne ISB experimental link were installed and located at the station.

The station building comprised main operating room, observation room, maintenance room, engine room/heavy workshop, garage, line plant area, staff room and OIC office.

Equipment installed at the station included:

- Wideband transformers covering the range 3 to 30 MHz with maximum loss 2 dB and mounted in weatherproof boxes together with protective gas filled arresters.
- Aerial distribution amplifiers providing isolation between receivers operating from the same aerial. They provided four independent 50 ohm outputs from one 50 ohm input with a minimum isolation of 30 dB between outputs.
- Communication receivers for reception of signals for rebroadcast and for observation purposes.
- Measuring equipment such as frequency meter, signal generator, pen recorders and associated logarithmic amplifiers for field strength measurements.
- Tape recorders, VU meters, equalisers and variable high pass and low pass filters.

Aerial systems installed at the site included:

- Simple vertical aerials used for reception reports and recordings for overseas broadcasters as an approximation to domestic receiving aerials.
- Wideband dipoles to augment directional aerials on the most used bearings.
- Directional aerials including two wire two tier general purpose rhombic with gain 11 dB at 15 MHz designed for path lengths

greater than 3000 km, two wire two tier rhombic with gain 10 dB at 10 MHz used as a second rhombic in a diversity pair to work paths of length greater than 3000 km, two wire single rhombic designed specifically for the Perth-Melbourne circuit with gain of 9 dB at 10 MHz and used in conjunction with a two wire two tier rhombic as a diversity pair, and an inclined Vee type directed on the Wilkes Base Antarctica station with a gain of 14 dB at 15 MHz. Keith Ferris Engineer in Victorian Radio Section played a major role in the design and construction of the facilities.

Transmission lines were 200 ohm open wire balanced types terminating on poles about 20 m from the building and fed into the equipment room via 50 ohm coaxial cables.

At the time of establishment of the High Park station most of the equipment had been transferred from Mont Park where it has been in service for a considerable time.

Over the years, new equipment was installed and facilities upgraded. However, the importance of the services provided from the station steadily declined because of the development of alternative communication systems such as the use of satellites and also many of the earlier functions had been discontinued.

The High Park station ceased its broadcasting function on 9 July 1986 and was taken over by the Department of Communications for radio frequency management purposes.

At cessation of Telecom's role in the station, the Officer-in-Charge was Peter Dainton, assisted by Technicians George Weissman, John Robinson and Bill Harder. A number of people who had been associated with the station attended a closing-down ceremony and included Leon Firestone, Ken Johnston, Jack Carnell, Bill Edwards, Chris Rogers, Jack Buckland and Keith Ferres.

Many Commercial broadcasting stations had some form of short wave receiving facilities for reception of overseas broadcasts, particularly during the War when the BBC news was widely rebroadcast. Typical was the short wave listening station established by 5AD Adelaide staff during the War at Northcote near West Lakes. Facilities were provided for reception of BBC and other overseas services for use by local radio stations and the 'Advertiser' newspaper. Stations receiving the broadcasts were 5AD, 5DN and station 5KA after it resumed broadcasting following shut down between 8 January 1941 and 6 December 1943.

One station which relied heavily on off-air program material was 5DR Darwin. The station facilities comprising transmitting and receiving stations, were installed by PMG's Department staff from Adelaide and commissioned for the Australian Army Amenities Service on 11 February 1945 to provide entertainment for troops in the Top End.

The Lieutenant-in-Charge was a former 5DN Adelaide announcer, and programs consisted mostly of USA made 16⅔ RPM records with news and other items of interest being available from BBC and Radio Australia transmissions via receiving station facilities at Leanyah Swamp about 16 km from Darwin. Rack mounted receivers were installed in a corrugated iron shed and connected to reversible Rhombic aerials beamed on London and Shepparton. There were also three centre fed dipoles available. The rack equipment included two Halicrafter, one AWA, one STC and two Kingsley AR7 communications type receivers, a patch panel, aerial switching and program line/receiver switching facilities.

After the War, the station became part of the National Broadcasting Service and although most of the original equipment including transmitter, transmitting aerial and receiving station facilities were reinstalled at other sites closer to Darwin, a more elaborate and up-to-date studio was provided for the ABC program staff. The majority of programs were provided locally but news, current affairs and some sporting segments were rebroadcast from interstate National HF stations VLM and VLQ Brisbane and VLW Perth. With the provision of dedicated program line between Adelaide and Darwin in late 1948, the role of the receiving station declined and was eventually dismantled.

One of the staff members associated with the 5DR (later 8DR) installation and maintenance of studio and transmitter facilities for many years was Brian Woodrow. He commenced with the PMG's Department as Junior Mechanic-in-Training on 5 January 1942, graduating as Technician in 1946. During 1947–48 he was involved with the installation activities at 5DR, later becoming Officer-in-Charge of the station.

In 1956 he became a Trainee Engineer, obtaining a Bachelor of Technology (Electronic Engineering) Degree in 1959. During 1967 to 1972 he was a member of the HF Broadcasting Project team which installed the Radio Australia Cox Peninsula station near Darwin. He retired in 1987 while occupying the position of Network Management Engineer in Darwin.

Although there were receivers built for off-air pick-up from MF stations and located at NBS MF transmitters for use in the event of failure of the normal program circuit, most receivers incorporated the HF bands for pick-up of distant stations transmitting in the short wave bands.

Standard communication type receivers were widely employed with Australian manufactured receivers including STC, AWA, Kingsley, Philips, Stromberg-Carlson and Radio Corporation models. Overseas models included Racal, Collins, Hallicrafter, Hammarlund, National, GEC, RCA and Eddystone.

The Kingsley AR7 receiver was readily available at bargain prices after the War from Disposals sources and many were installed at National and Commercial stations. Those installed at Commercial stations were employed mainly for reception of the BBC News programs.

The receiver designated K/CR/11 by Kingsley, was known as AR7 by the RAAF and Reception Set No. 1 (Aust.) by the Army. It was based on the popular USA receiver National HRO manufactured by National Company Inc., an Engineering and Manufacturing organisation which had been established in 1914.

The AR7 was manufactured by Kingsley Radio Pty Ltd, 308 St Kilda Road, Melbourne with Kingsley Love being Managing Director. They were manufactured in the hundreds and widely employed during the Second World War throughout Australia and the Pacific War Zone. At Madang, the entire station was equipped with AR7 receivers with 27 units being operated around the clock by a team of 76 Wireless Telegraphists.

The receiver covered the range 138 kHz to 25 MHz using plug-in coil boxes. A calibration chart was provided for each coil box when employed with its designated receiver. The main vernier tuning control had an equivalent scale length of some 3.7 metres and was based on the HRO model with a 20:1 ratio.

The design comprised a single conversion superheterodyne circuit with two RF stages; mixer-oscillator; two IF stages; detector, AVC and AF stage; AF stage and rectifier stage. Valves comprised 6U7G, for 1st and 2nd RF, and 1st and 2nd IF stages; 6K8G, mixer-oscillator; 6G8G, 2nd detector, AVC and AF amplifier; 6C8G, BFO and S meter amplifier; 6V6G, output valve and two 6X5GT, half wave rectifiers.

Units were mounted on a bench top rack about one metre high with separate panels being provided for receiver, power supply and loudspeaker.

The equipment was intended to be powered from 230–240 volt AC source or 12 volt DC, with a rotary switch being used to select the appropriate source. A non-synchronous vibrator was employed when operating from the 12 volt DC source.

PORTABLE RADIO LINKS

Many outside broadcasts were difficult to cover with facilities available in the 1920s and early 1930s. These included such events as golf, motor bike and motor car racing on bush tracks, yacht racing and others. The problem was mainly one of setting up circuits at suitable vantage points to cover each event. A self-contained portable radio transmitting unit was the answer and many enterprising staff were developing units in the 1920s employing high frequencies.

One early notable broadcast employing radio was undertaken in 1929 during the search for the 'Kookaburra' aircraft which vanished during the search for the 'Southern Cross' with Charles Kingsford Smith, Charles Ulm and two others on board. A search aircraft the 'Atlanta' was fitted with two way radio by Fred Stevens, Chief Engineer 4QG. From the aircraft, 4QG listeners followed the dramatic events associated with the search.

In 1936, the PMG's Department Research Laboratories developed a rack mounted 'portable' transmitter/receiver unit operating in the 60 MHz band. However, the unit was not widely used. In 1951, units specially made for OB work by STC were obtained for use by the ABC and were extensively used during the 1954 Royal Tour. A Holden car at the Brisbane 4QG/4QR studios was modified to carry the equipment in the boot and the car used in Brisbane and Toowoomba during the tour. The link operated in the 70–85 MHz region and was powered by either 50 Hz mains or a 6V accumulator. Transmitter output of 10 watts was provided by a pair of 5763 beam tetrodes in push-pull.

Although the equipment weighed some 35 kg, excluding the accumulator and was bulky compared with modern solid state hand held units, it was in its time, state-of-the-art equipment and provided a valuable resource for OB work.

OB VANS

Some outside broadcasts such as large outdoor concerts are so complex that outside broadcast vans have been produced to provide a wide range of services on site. Vans are basically mobile studios and have been used by both National and Commercial studios for many years. In April 1939, a mobile van provided for broadcasting for the ABC from remote points was fitted out with most of the facilities provided in a studio including disc cutting equipment, short wave transmitting/receiving equipment and a fully equipped Announcers console.

Some mobile studios in service overseas are as large as TV OB vans and even have closed circuit TV installed so that the producer in the van can closely watch proceedings at those points where microphones are installed.

Since the War, outside broadcasts from many fixed venues such as town halls, show grounds etc., have become elaborate installations, some being almost full-scale studios, allowing for recording, interviewing and program presentation.

The majority of Commercial stations possess an OB van for use as a mobile studio. The van is usually purchased as chassis and shell with the technical facilities being designed and installed by station staff.

Typical of mobile studios in country areas was one constructed by staff of 3SR Shepparton under Chief Engineer Ray Jenks in 1962. At the time, it was considered to be the most modern in country Victoria. Ray left 3SR in 1968 to go into business in Shepparton but in later years moved to USA.

COMMUNICATION CIRCUITS

Until recent times, transmitting stations were staffed and circuits were necessary between studio and the transmitter for staff to communicate on a variety of matters. A means of communication was also necessary between studio and outside broadcast points. Although almost all stations were connected to the telephone network, calls had to be made via a manual exchange and in the country this involved a trunk call which could mean some considerable delay. In order to establish a direct circuit, independent of the Telephone Operator, it was normal practice to establish a cailho circuit over the program line. This allowed communication at any time even when the program line was in operation. The usual means of communication was by use of the Morse Code. This was widely used with National stations and staff were paid a special allowance if they became proficient in the use of Morse Code up to a specified speed.

In 1932, station 5CK Crystal Brook was a typical station with Morse Code facilities provided, but at the metropolitan transmitting station 5CL in Adelaide, not far from the studios, a simple bell arrangement was found to be satisfactory. A single stroke bell was installed in 1928 and by using a prearranged code of signalling, quite a variety of information could be passed between the two points without the need to be proficient in the Morse Code.

With the majority of outside broadcasts, two circuits are provided — one for the program, and one for a portable telephone. However, before the widespread expansion of the telephone network, two circuits were often a luxury at many remote points such as motor bike cross country broadcasts etc. In these cases, a special telephone was often employed. A key box was used to enable either the telephone or the OB amplifier to be connected across the line. When the amplifier was switched in, a pair of high impedance telephone bells was also bridged across the line. The bells had negligible effect on the performance of the line. This allowed the control room Operator to call the OB Operator at any time. The control room Operator would make the necessary switching to isolate the line before calling and speaking, so that nothing of the action went to air. This action would only take place in an emergency, such as failure of the broadcast at the OB point due to amplifier or microphone problem.

WARTIME EMERGENCY STUDIOS

During the Second World War, the ABC in conjunction with the PMG's Department established a number of secure emergency studios at strategic locations throughout Australia in order that National broadcasting services could continue in the event of bombing attacks or invasion of the country. The plan was to re-establish broadcasting in case normal communication circuits should be disrupted and metropolitan transmitters and studios put out of action.

Action by the ABC included the following:

- Arranged for dispersal of studios over metropolitan areas where existing studios were not considered to be safe.
- Selected studios were made more secure.
- Selected staff were required to standby and were trained to operate the emergency studios.
- Provided for regional stations to carry on in the event of any metropolitan system being put out of action.

Emergency studio arrangements included:

- Melbourne.
  A switchroom was installed underground at the ABC block in Lonsdale Street.
- Brisbane.
  A strengthened studio was installed on the third floor of Penny's Building. The main ABC 4QG/4QR studios and office facilities were located on the 6th Floor of the building.
- Adelaide.
  Emergency studios were installed at Prospect, an Adelaide suburb, at Crystal Brook and at the 5CL Brooklyn Park transmitting station.
- Perth.
  An emergency studio was built in a private building in South Perth and another at 6WA Wagin transmitting station.
- Sydney.
  An emergency studio, control booth and self-contained power plant were installed in the air raid shelter in the basement of Broadcast House, Pitt Street until completion of a specially constructed studio in Forbes Street. The Forbes Street facility was hewn out of solid rock. Entry was via two blast proof gas tight doors. Emergency exits were provided through the ventilating tunnel. Seismic disconnection of studios was

attained by floating the complete interior studio structure on cork on separate foundation walls so that exterior shocks were not transmitted to the interiors. A large tank provided water for washing and drinking purposes. Other facilities included mechanical ventilation and standby electric generating plants, disc recording equipment and secure OB lines, telephone lines and program circuits to National transmitters and also Commercial station studios.

Emergency studios were manned 24 hours a day by ABC staff who slept on the premises or nearby.

In New South Wales and Victoria, mobile program units fitted into vehicles were provided to allow programs to be originated from inland centres not adjacent to normal regional facilities. They were more self-contained than the units which were provided to run the regionals. Among their facilities were spring wound turntables and battery operated short wave receivers.

During 1943–45 an organisation known as the Army Broadcasting Control Unit was in operation for the dissemination of information through medium wave and short wave transmitters including Commercial Networks, ABC and 'Australia Calling' outlets.

Broadcasters associated with the Unit included many Army personnel who had previously worked in the radio and newspaper industries. Accredited correspondents and reporters were located throughout the Pacific and Asian war theatres.

Headquarters of the Unit were at 74 Pitt Street, Sydney with broadcasting and recording studios being located in Burwood.

Far left: The most widely used microphone when broadcasting began in Australia was the Western Electric double button carbon microphone developed in USA about 1922. Initially, it was only available with WE transmitters made by the company. It was the first microphone developed specifically for broadcasting purposes. It was a push-pull type with a duralium diaphragm acting on two carbon buttons mounted one on each side of the diaphragm.

Left: This converted pedestal carbon granule telephone instrument was employed as the microphone with experimental station A5AC Adelaide operated by Roy Cook when he broadcast a performance by the Tramways Band from his home in 1923. The loop was part of the modulation arrangement employed with the transmitter.
This type of microphone was widely employed at early low power B Class stations.

Baldwin mica diaphragm headphones developed by Nathaniel Baldwin a Mormon in USA. Baldwin employed new technology using a driving rod to actuate a non ferrous diaphragm of mica or corrugated aluminium. Although dearer than steel diaphragm types the 'Baldies' were popular with crystal set owners because they were much more sensitive.

Early 2BL studio on the roof top of The Daily Guardian Building, Phillip Street, Sydney. The Announcer sat at a table with the Western Electric double button carbon microphone. A similar microphone was mounted on a stand in the far corner of the room. The studio size was 4.3 m by 3.6 m. The station began operation with a 500 watt transmitter on 23 November 1923.

The 3LO control room 1924. Meters, switches and valve amplifiers followed telephone practice at the time. The switchboard used for OB lines was a standard telephone switchboard. By mid 1926, there were 34 OB circuits terminating in the studio control room. The glass window allowed the technical operator to observe activities in the adjacent studio. The two monitoring loudspeakers were Amplion cone type AC12, on switchboard, and Amplion Radiolux Model RS5, on instrument cupboard.

Original equipment and power control racks 3LO control room 1924. The Western Electric line amplifier was a three stage amplifier employing WE type valves. Meters and patch cords enabled anode and filament currents to be measured. Rheostats enabled each filament current to be adjusted to correct value. A and B batteries for filaments and anodes respectively, were located in the battery room but C batteries were located in a grid battery box alongside the amplifier on the rack. A 22 step potentiometer controlled the output level of the amplifier.

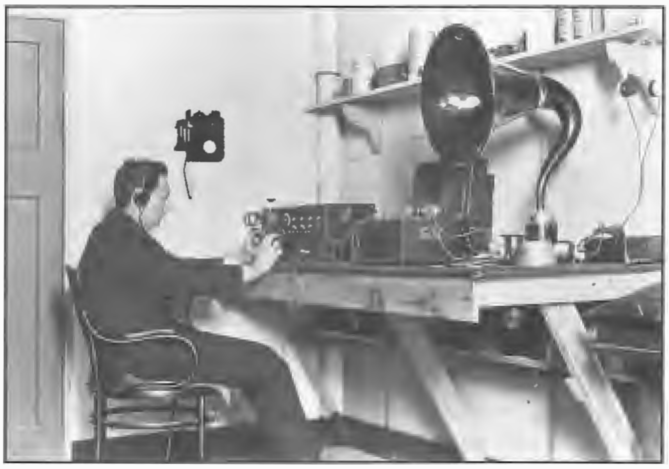
The battery room at 3LO Melbourne 1924. At the time all power requirements of valves was provided by A,B and C type batteries. The A batteries were usually accumulator types. It was not until 1935 that suitable valves became available for operation of filaments using AC.

The original 6WF Perth Studio 1924. The A Class station transmitter and studio operated by Westralian Farmers Ltd were located on the roof of the company building. Facilities included WE microphone, WE control panel, equaliser, patch panels, studio amplifiers and a time signal line from the Perth Observatory for broadcast of time signals, initially at 1 pm and 8 pm.

Program amplifier, control panel and wavemeter, 6WF Perth 1924. The panel, equipment and microphone were manufactured by Western Electric Co., USA who also provided broadcasting station equipment for stations in England and USA. George Sutherland Chief Operator near control panel and Walter Coxon, Chief Engineer and Manager, near microphone behind observation window.

Original studio of 5DN Adelaide 1924. The studio had previously been the Music Room of the home of the owner Mr E J Hume in Park Terrace. Mrs Hume well known in the fields of art, music and literature took charge of live broadcasts. Mrs Hume is standing behind the piano and Mr Hume is seated on far left.

Walter (Walley) Coxon, Chief Engineer and Manager, Westralian Farmers Ltd beside the Magnifier unit of the 6WF 5000 watt AWA transmitter. It operated on 1250 metres (240 kHz). Service began on reduced power on 4 June 1924. Studios, transmitter and aerial were all located on the roof of the company building.



Receiving equipment installed at B Class station 5DN Adelaide 1924. Ern Hume in charge of technical facilities at the controls. Although the transmitter and aerial were located near the studio, program monitoring was carried out off-air. There was no pick-up monitoring point provided on the transmitter.

Typical carbon granule type microphones used during the 1920s. They included the Western Electric double button type, a suspended French made model, a marble cased transverse current type and a solid back type. The transverse current type was also referred to as a Reisz type and many were manufactured by station staff.

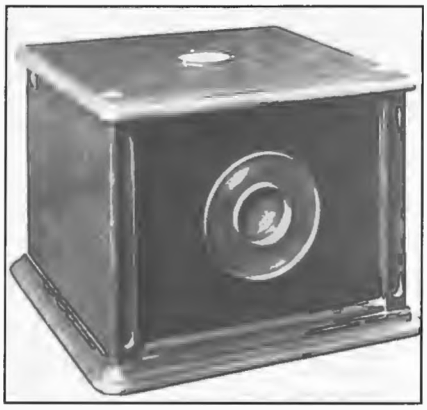
No. 2 studio 3LO Melbourne 1927. At the time, little was known about the need to control reverberation of sound in studios but a great deal of attention was paid to aesthetic considerations such as numerous displays of fresh flowers daily, highly polished floors and window drapes which harmonised with the Royal Blue coloured carpet runners and squares.

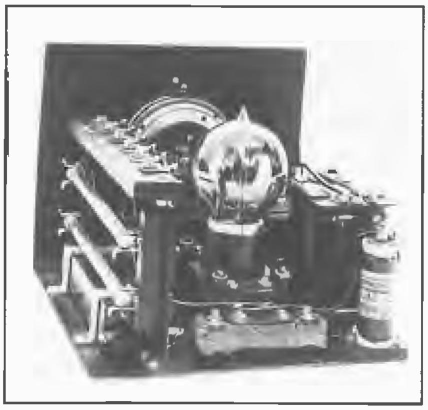
No. 3 studio, the largest studio at 3LO Melbourne 1927 with accommodation for audience participation. There is an instruction board for announcer and artist hanging from the beam above the microphone pedestal. The studio located at Cambridge Building, Collins Street, Melbourne was opened together with other facilities on 13 October 1924.

Studio at 5AD Adelaide. The 21 m by 6 m studio walls and ceiling were lined with Celotex. The station in the city centre, commenced operation with a 300 watt transmitter on 2 August 1930. Harry Kauper formerly Chief Engineer 5CL, designed the technical facilities.

No. 1 studio Hindmarsh Square 5CL Adelaide 1931. Microphones were condenser types. The Hindmarsh Square studios were established by Central Broadcasters Ltd in 1928. When the PMG's Department Transmission Section took control of the studios in 1930, the first Officer-in-Charge was Nelson Stone.

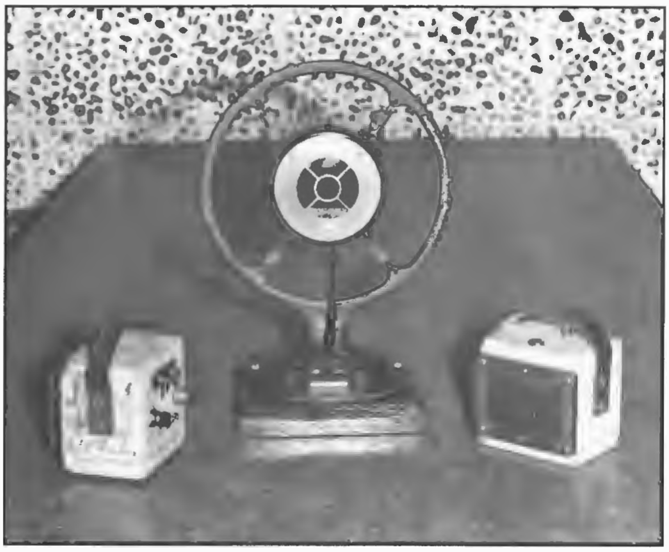
Mr W C (Bill) Rohde, Supervising Engineer Radio PMG's Department Queensland holding one of the condenser microphones used at 4QG Brisbane. Bill was a member of the technical staff which took over responsibility for operation of 4QG from the State Government's Queensland Radio Service in 1930 as part of the Commonwealth Government's plan to establish the National Broadcasting Service.





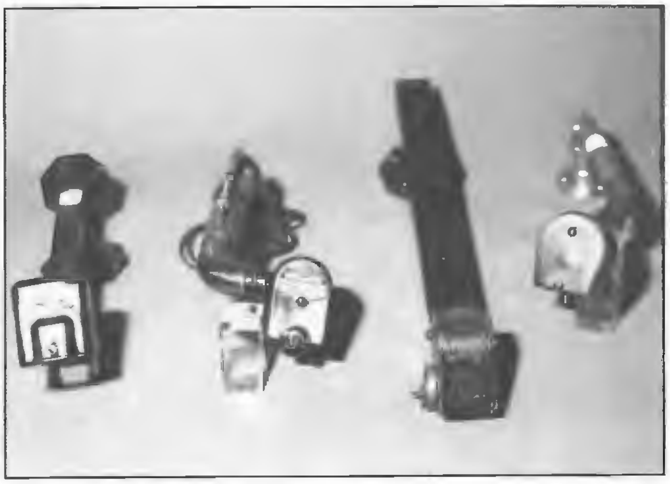
The WE condenser microphone was manufactured by Western Electric Co., USA and by 1928 was widely employed at A Class and B Class stations throughout Australia. It used an amplifier with 4102A type valve and an output transformer for working into a 200 ohm load. Power for the valve was provided by batteries. At some studios this comprised 6 volt accumulators for filament and 130 volt battery system for anode and the microphone polarising voltage.

Many stations with good workshop facilities manufactured their own microphones in the 1930s. This condenser type was manufactured by staff at 5AD Adelaide. The station began operation in August 1930.



Carbon microphones made by 4QG Brisbane station technical staff in the early 1930s. The centre microphone is a double button carbon type while the two with marble blocks are Reisz types one of which has been autographed by artists who made broadcasts using the microphone. The Reisz type was popular for OB work and was widely used for sporting events, particularly by race-course commentors.

Typical microphones used in studios and for outside broadcast work by the ABC in the 1930–1950 period. Many were also used by Commercial stations. They included condenser, ribbon and moving coil types.



Typical pick-ups used in studios from about 1927 to mid 1930s.
L to R: Pacent Phonovox, Bosch Recreator, WE 4A Reproducer and BTH Magnetic pick-up. In the WE unit the moving assembly was surrounded by viscous oil. It was still in use at some transmitting station emergency studios in the mid 1950s.

Frank O'Grady at 5CL studio control panel 1931. Frank later became Director General of the PMG's Department. The studio complex comprised a large production studio and one common control booth/switchroom. All amplifying equipment was battery operated and program level was controlled by a potentiometer in the input circuit of the program amplifier.

The studio A Model Ford van used with mobile station 3YB October 1931 to October 1932. The studio facilities included record cabinet, two turntables and Reisz carbon microphone. The van was painted scarlet with '3YB Mobile Broadcasting Service Pty Ltd 262 metres' in gold lettering on the sides.
L to R: Bert Rennie, Business Representative and power plant operator; Vic Dinneny, Manager and Announcer and Bert Aldridge, Chief Engineer.

Emergency studio at transmitting station 5PI Crystal Book 1934. Facilities included condenser microphone, two turntables, BTH magnetic pick-ups, horizontal control panel, and rack mounted amplifiers employing type 57,58 and 2A3 valves. The telegraph key was used for communications with technical staff at the main station 5AD Adelaide using a cailho circuit over the program line. Advertiser Network Chief Engineer and station designer, Don Gooding.

Emergency studio at transmitting station 3GI Sale, the first Victorian Regional station of the NBS to begin service when it was commissioned on 30 October 1935. Facilities included STC 4017 microphone, two WE4A gramophone reproducers, STC mic/gramophone amplifiers and two receivers. Divisional Engineer Harold Robertson.

Andy Fisher operating the vertical cut disc recording equipment at 5DN Adelaide mid 1930s. Also known as Hill-and-Dale recording, the system was in use at several Commercial stations. Although the technology had a number of advantages, the lateral method eventually outpaced the vertical cut system by the number of records produced. About 1940, the ratio was 10:1 in favour of lateral.

No. 2 studio 7ZL Hobart 1936. Facilities included condenser microphone on pedestal, WE double button carbon microphone and wall-mounted RCA loudspeaker for monitoring. These facilities were somewhat behind the times compared with ABC studios on the mainland during the period.

No. 10 Outside Pick-Up Amplifier built by PMG's Department staff at 5CL Adelaide studio 1936. More commonly known as Outside Broadcast or OB amplifier it used 6C6 valves, Lekmek faders, Meltron and Trimax transformers. A 240 volt power supply unit was housed in a separate case. A hooded lamp over the level meter allowed the unit to be monitored in a darkened area. Unit designed by Laurie Billin.

Mont Park Receiving Station 1938. The station was established in 1932 by PMG's Department Research Laboratories for the purpose of receiving programs off air from the new BBC Empire Service for rebroadcast by the ABC. The station was replaced by a new station at High Park near Kilmore, Victoria in 1959. Jack Carnell who later became Manager Broadcasting Operations Victoria was one of the early operators at Mont Park.

Speech input equipment racks and emergency studio 4RK Rockhampton circa 1936. Pick-ups are Western Electric 4A oil damped gramophone reproducer units employing steel needles. The microphone is a type 633. The station was commissioned in 1931 but equipment shown was provided later.

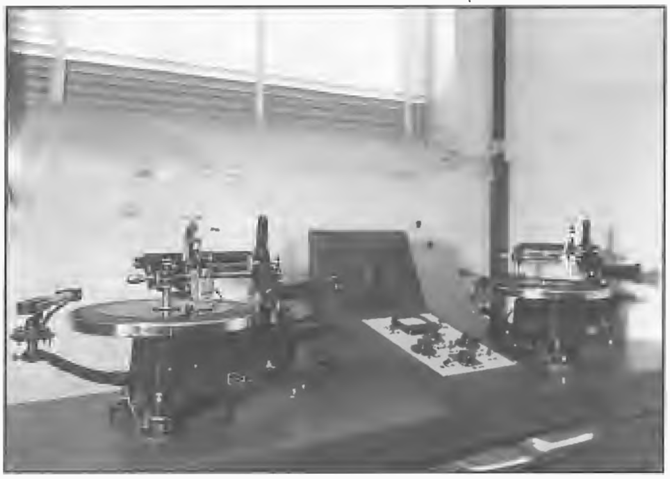
Control room Adelaide Street studios 4BC Brisbane circa 1937 showing AWA control panel, rack equipment and patch panels typical of the period, Station 4BC was the first Commercial station to go to air in Brisbane when it employed a temporary transmitter on the roof of a building at 43 Adelaide Street where the studios were also located. On air date 16 August 1930.

One of the 4BC Brisbane studios in the Wintergarden Theatre, Queen Street, Brisbane circa 1938. The Reisz microphone was typical of those used in other studios. Curtains covered the leadlight windows during a broadcast. Sound absorbent panels were fitted above the windows and on the ceiling.

Outside broadcast equipment had to be placed in some awkward locations for the benefit of the commentator. This shows the set up for broadcast of the Grand Prix Motor Race at Lobethal near Adelaide in 1938. The 5DN staff in the tree were Technician Frank Hill (L) and Commentator Gordon Marsh.

ABC studios Melbourne Show Ground circa 1948. Typical of post War facilities provided at similar Show Ground studios in major capital cities. Facilities included Announcer's console, technical control desk, disc replay desk with twin turntables and dual disc cutting equipment.

Harry Fuller, Chief Engineer 3YB Warrnambool and one of the first wire recorders to be made locally for broadcasting purposes. Harry made the equipment using the station workshop facilities in the 1940s. He became Chief Engineer of 3YB in February 1939.



Two Presto disc recording units and control panel installed at ABC Hindmarsh Square studios Adelaide December 1947. This type of equipment was widely employed by the ABC and Commercial stations with some Commercial stations installing units about 1940. It was manufactured by Presto Corporation USA. Bill Smith was one staff member who spent many years operating the equipment.

3UZ studio 1947, operated by Nilsen's Broadcasting Service Pty Ltd. Facilities included a replay unit to allow Announcer to check a record without using control desk, a standard announcing desk and control panel and an interview desk with time gong.

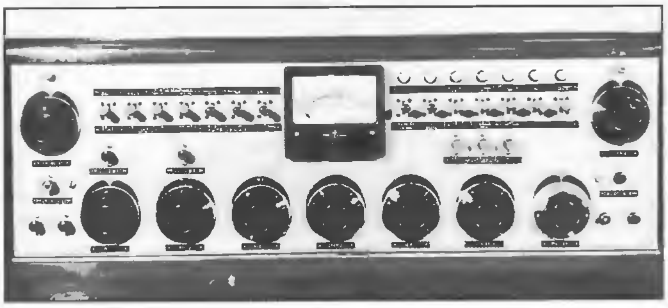
Outside broadcast equipment set up for Royal Hobart Regatta in late 1940s and broadcast over 7ZL. Splits for public address loudspeakers were normally part of such broadcasts. Max Chaplin, operator.

EMI reel-to-reel tape recorders in service at 3AW Melbourne 1956. Announcers Norman Banks and Graham Evans observing the units. These types of recorders were widely employed at ABC and Commercial studios for many years. One of the earliest installations of this static recording equipment was provided at Parliament House, Canberra for use by ABC programmers.

Control panel and microphone 3TR studio in Stawell Street, Sale 1954. The Stawell Street studios were established in 1938 and fed a 1000 watt AWA transmitter. Station 3TR was originally established at Trafalgar in September 1930 but moved to Sale in 1932. Chief Engineer George Nolte.

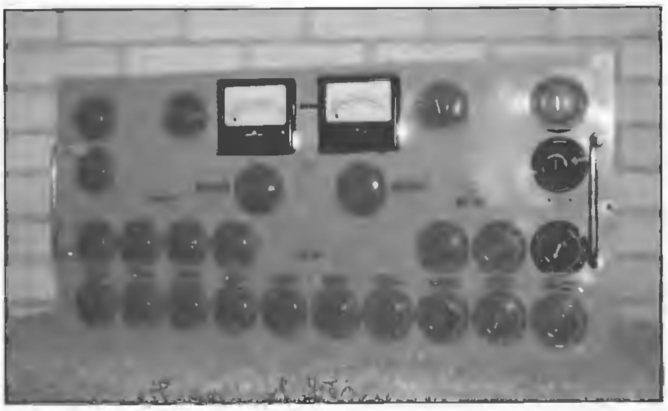
Technical staff dubbing from console tape recorder machine to disc recording unit at 4BC Brisbane studios circa 1955. Console tape recorders were widely employed at Commercial and National studios from about the mid 1950s. They were frequently installed in pairs with a matching control console between the recorders.

Receivers and aerial patching facilities at High Park Receiving station 1959. In the period between its establishment in 1959 and closure in 1986, the station played an important role in reception of programs for rebroadcasting by the ABC.
At time of closure, station Officer-in-Charge was Peter Dainton.



Announcer's control panel at ABC 3WV studio Horsham circa 1960. The 3WV transmitter began operation on 25 February 1937. The control facilities were typical of those provided at other ABC studios at Regional centres throughout Australia.

Enclosed type high quality headphones used by Commercial station announcer in 1960s. Some announcers preferred a single headphone unit as it allowed them to cue up the next record item while still keeping an ear on the program already being broadcast.



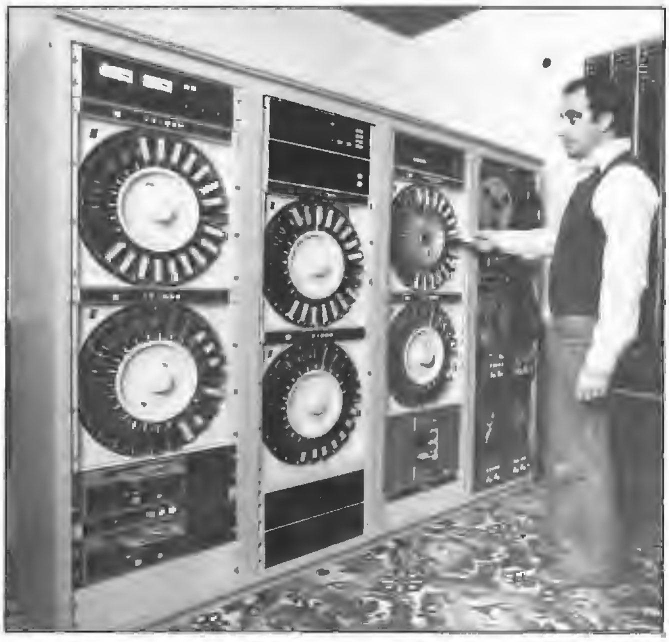
Mixer unit developed to provide AM stereo broadcasts from ABC studios in 1968. Two NBS transmitters were employed with the broadcasts. The all-valve equipment was transferred around the State capitals for use at Metropolitan centres.

Left: Noel Bishop, Chief Engineer, Commonwealth Broadcasting Network. Noel began work at 4GR Toowoomba in 1932 as Technician, transferring to 4BC Brisbane in 1940 as Studio Engineer. He was promoted to Chief Engineer in 1946 and appointed Chief Engineer of the Commonwealth Broadcasting Network in 1967. Noel became an Associate Member of The Institution of Radio Engineers (Australia) in 1938.

Announcer's console 3BA Ballarat, 1970. Announcer Judy-Ann on duty. Chief Engineer Keith Ridgway. Station 3DB was the first Victorian country Commercial station to begin broadcasting when it went to air on 31 July 1930 and also the first to transmit with a power of 5 kW into the aerial. It commissioned a 61 m directional aerial system on 18 August 1976.

ABC FM studio 508 Adelaide. The ABC FM Stereo network commenced in January 1976 with the commissioning of transmitters at Canberra, Sydney, Melbourne and Adelaide with programs originating in the ABC studios in Adelaide where two studios were provided.

In 1986 the two original ABC FM Stereo studios in Adelaide were replaced with new units incorporating updated technology and a third provided so that three studios were available for both network and production operations. Ron Ehrke oversighted the changeover to the new facilities. John Starr Director of Technical Services.



CDC Automation equipment installed at 3UL Warragul 1976. John McPhee checking operation of the equipment which was one of the first such systems installed in Victoria. The station commenced operation on 19 May 1937 and by 1976 there were four studios in service with program going to air from 9 am until closedown being fully automated.

Nagra portable stereo tape recorder Model IV-S used at ABC Collinswood studios circa 1980. Nagra, a firm in Switzerland was a leading manufacturer of high quality portable tape recorders. The Model IV-S was designed for general application for broadcasting purposes.

By the 1970s some studio control desks had become very elaborate with a wide range of functions being available. This desk at the Light Entertainment studio in the ABC Adelaide studios is typical. John Starr Director of Technical Services.

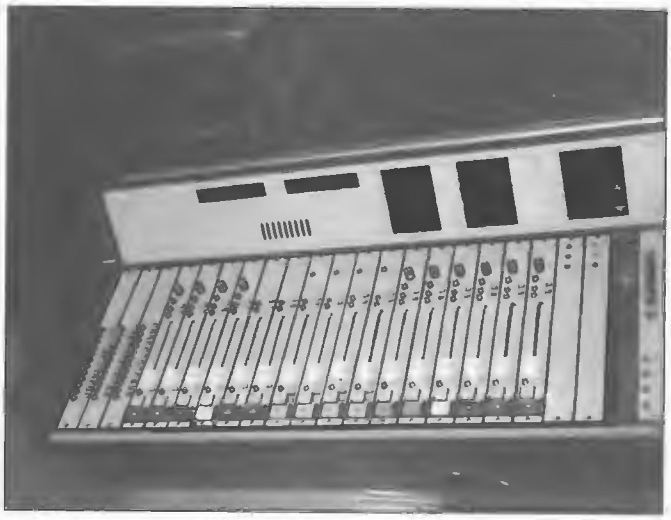
Chief Engineer Brian Perry at 3KZ station control equipment located in the studios. New studios commenced service during July 1981 at Carlton providing two complete production areas and two additional booths. All studios were floated for noise isolation and double lead-lined walls were provided between studios.

Microphone set up at ABC Collinswood studio Adelaide preparatory to orchestral concert broadcast, 1985. Many microphones were needed to obtain a balance between the various instruments of the orchestra. For a general coverage of the orchestra, a high quality microphone with a cardioid pattern was used.

Station 3EON-FM Master control equipment. Transmissions commenced on 11 July 1980 with technical facilities being under control of Technical Director Neil McCrae. Facilities included three production control rooms, two on-air studios and a voice-over booth. The two larger control rooms were each fitted with a Sony fully automated console.

Studio of Central Australian Aboriginal Media Association (CAAMA) at Alice Springs, established 1985. Programs are provided for a network of FM stations and the HF (Bush Radio) Service. Announcer, Agnes Young.

Tom Rowan, Transmission Supervisor in Master control room of the ABC Radio Australia studios Burwood East, Melbourne 1988. At the time, 16 Aussat lines plus terrestrial lines came into the Master control room and 20 lines were available to serve Radio Australia transmitters at Shepparton, Carnarvon, Cox Peninsula and Brandon.



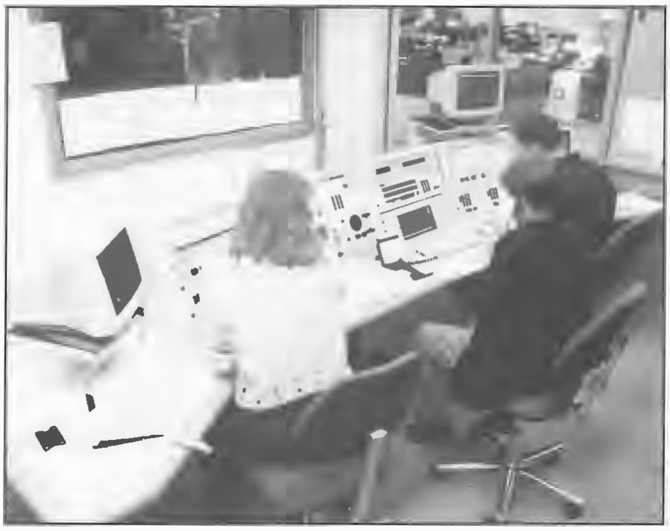
Paul Kirk console at 2HD Newcastle installed 1988. During the 1980s, the studios, and control room were rewired for AM Stereo and a Nautel solid state transmitter installed with a Motorola AM Stereo exciter. All music played is from CD and commercials are played to air via cartridge machines. Chief Engineer Ian Porteous.

Studio facilities Radio for the Print Handicapped (Vic) Co-operative 3RPH, 1989. Volunteer Panel Operator Marilla Cooper at the controls. The service began in 1981 and officially opened in December 1982. In 1994, the service was operating with former 3KZ transmission facilities at Lower Plenty with 5 kW into a 135 m high radiator.

ABC 2NC Newcastle studio announcer's console 1990. The station was commissioned on 19 December 1930 with two studios in Strand Theatre, Newcastle. One was a talks studio and the other used for orchestral and choral programs. Studios were relocated to Newcomen Street in the 1940s and with the addition of the latest studio in 1989, facilities comprised four major studios.

ABC Studio Cairns commissioned 3 May 1991. Judith Langridge at the controls. Prior to establishment of a studio in Cairns in the mid 1950s, programs for 4AT Atherton and 4QY Cairns were prepared in Townsville and inserted in the program line. In 1992, the new studio provided programs for MF transmitters 4AT, 4MS, 4WP and 4TI and FM transmitters at Bellenden Ker and Cooktown. The 4QY Cairns transmitter was shut down in 1992 and program provided via an FM station.

Broadcast studios in the ABC Ultimo Centre, Sydney are adjacent to the presenter/producer work spaces. ABC Radio programs can be made and broadcast from no fewer than seven of the nine building levels. (Courtesy ABC.)



D-Cart developed by ABC Radio's Technology Research and Development Group, is a world first in digital audio edit and storage technology. Introduced in 1991, it replaces conventional tape editing — recording on, and replaying from, a computer hard disc. (Courtesy ABC.)

Master Control is the technological heart of the ABC Ultimo Centre, Sydney. It manages the switching of the same program to a number of ABC Radio stations across Australia; program source selection, whereby a studio in Sydney is linked with another studio for long-distance interviews; quality control with responsibility for ensuring broadcast quality at all times; and network integrity to ensure that each network or station remains on air at all times. (Courtesy ABC.)

Ward Beck console, Sonifex cartridge machines and other facilities at 2NEW FM Newcastle operated by Newcastle FM Pty Ltd. The console was originally installed at studios in Darby Street, Newcastle and transferred to studios in Sandgate with operations at the new site beginning on 5 November 1995. Chief Engineer is Ian Porteous.

Part of the collection of recorders in The Ellison Museum of Magnetic Audio Recording and Playback Equipment owned by Neville Ellison, Malvern, South Australia. The collection covering the period 1940–60s includes two wire recorders, four magnetic disk recorders, eight Australian-made and 39 other reel-to-reel recorders. The Museum also features the Ferry Collection of ten recorders and allied equipment made in South Australia by the late Jack Ferry; dictation machines; cartridge players; an endless echo recorder; cassette recorders and a sync pulse recorder.

Broadcasters at a function to mark the closure of Telecom's High Park Receiving Station 27 June 1986. The station was commissioned in 1959.
L to R: Leon Firestone, Bill Harder, Ken Johnston, Peter Dainton (Officer-in-Charge), George Weissman, Jack Carnell, John Robinson, Bill Edwards, Chris Rogers, Jack Buckland and Keith Ferres.

Chapter Four

Transmitting and Receiving Aerials

Transmitting Aerials

Wireless Telegraphy Aerials

By the turn of the century, many countries were active in the development of aerials for wireless telegraphy purposes. These included Great Britain, France, Russia, Germany and the USA. Designers had produced a range of transmitting aerials such as the fan, grid and the square cone as well as various single wire or cage vertical and horizontal designs.

Prior to the outbreak of the First World War, there were many powerful spark and arc transmitters operating into elaborate aerial systems supported by very tall masts or towers. When the USA Navy commissioned its radio station at Arlington near Washington in 1913, the aerial system was supported by one 600 ft (183 m) and two 450 ft (137 m) steel towers. The aerial was a flat top type, triangular in shape and consisted of two sections 355 ft (108 m) in length and one of 240 ft (73 m). The shorter section contained the down lead at its centre. Transmitting equipment comprised a 100 kW synchronous rotary spark unit and a 35 kW arc transmitter.

Ship's aerials for both civil and naval purposes were of different format for obvious reasons. Designs comprised single and multiple wire T, cage T and inverted L types employing single wire, multiple wire or cage construction. The cage types were also known as squirrel cage types.

In Australia, about the same time, the country had been circled by a network of Coast Radio Stations. The stations at Sydney and Perth employed Telefunken equipment while all the other stations employed a design referred to as Balsillie or Commonwealth design. John Graeme Balsillie was the first 'Engineer for Telegraphy' employed by the Commonwealth.

The type of aerial employed at Sydney and Perth was a design referred to as an umbrella type. It was supported by a lattice steel mast 394 ft (120 m) high. The mast rested on a glass insulator base, the original idea being that the mast would form part of the aerial and would not absorb energy. However, this idea was not put into practice. In addition to the umbrella aerial, there was a smaller inverted L aerial which extended from the mast some distance from the top. It was found that the smaller aerial gave better signal reception during periods of high atmospheric noise.

The aerial employed for the Balsillie design was usually a squirrel cage type. There were a few exceptions. Each cage was made up of 7/18 gauge phosphor bronze wires, separated by five spreaders and hoops of 10 mm copper tubing. There were four cages each 27 m in length, extending from a cross-arm at the top of the mast. The mast was constructed of Oregon pine in 12 m lengths. The height of the standard mast was 50 m and it was 525 mm square. The lengths of pine were bolted together by coach screws and suitable connections for guy ropes were fitted at three positions on the mast. The foundation comprised a concrete block one metre square and 2.5 m deep. The structure, after being assembled on the ground was hauled into position by means of a winch and jury mast. At some stations, two masts were provided with the aerial being centre-fed T configuration. At others, using a single mast, the aerial was an umbrella type.

Prior to the First World War, there were a number of spark wireless telegraphy experimenters in Australia undertaking development work with their station aerial systems.

One was Ern Stanton of Enfield, Adelaide. In 1908, he was employed by Gerard and Goodman an Electrical Engineering business and he took a keen interest in the new science of wireless telegraphy being studied by local enthusiasts. By 1910, he had constructed a workable transmitting and receiving system and applied to the PMG's Department for a licence to operate a station. On 10 February 1913, he was granted a licence to operate a station with 12 watts input power on 250 metre wavelength with callsign XVN.

Ern was an experienced Electrical Mechanic and built the transmitter with a large induction coil some 12 inches (300 mm) in length and 3 inches (75 mm) diameter with 15 wires as an iron core. A rotary gap was made from an eight day French clock with the gap being connected across the inductor secondary winding.

The aerial resonating capacitor was a concentric type made with two copper cylinders. The outer cylinder was 17.5 cm long and 7.5 cm diameter. Due to flash-over problems, the capacitor was changed to a square design using copper plates 10 cm square and spaced with 2 mm thick celluloid.

The first transmissions were conducted using an L type aerial with a single top wire six metres long. He soon realised the arrangement was unsatisfactory for long distance communication and replaced it with two new designs either of which could be selected separately or as a parallel combination by using a triple pole double throw knife switch which he recovered from an old electric power board.

According to notes and a log book which he left, Ern described the first aerial as being made up of five conductors each eight metres in length with two nine metre cross conductors. There were six down leads three metres long and one five metres long. The aerial and down leads were constructed with 14 SWG copper wire and the feeder to the transmitter with 12 SWG wire. The second aerial comprised two conductors 40 metres in length spaced about 70 cm apart with wooden spacers. There were two three metre leads joined to a feeder 14 metres in length. All wires were 14 SWG copper. This aerial was supported by a pole at the transmitter end, and a tree at the other end.

Drawings, design notes, construction details and test result figures indicate at least three other designs were trialed over an 18 month period. Some employed square copper wire, samples of which are in a vintage radio collection in Adelaide today.

Associated log book comments include the following:

- A five wire flat top with conductors spaced 30 inches (750 mm) apart produced higher aerial current than a five wire cage, 30 inches (750 mm) in diameter.
- Connection of the feeder to one end of the aerial (inverted L type) produced a greater transmission range than that produced by a centre fed (T) aerial.
- A greater degree of voltage flash-over occurred at the far end insulators of a centre fed aerial than for an end fed type with maximum input power to the aerial.
- For receiving purposes, no one design trialed was superior to the others.

- There was no apparent change in aerial current if flat top wires were bridged with conductors at points beyond the feed point.
- The insertion of an inductor comprising 30 turns on one inch (25 mm) former in the far end of each conductor, produced increased aerial current and transmission range.
- Aerials erected over the roofs of buildings with tin roofs were not efficient radiators, as the metal roof appeared to absorb a considerable amount of the RF power.

One of the local experimenters who took a keen interest in Ern Stanton's work was Lance Jones, and when he designed the aerial system for 5DN in 1924, he took advantage of what was known about the flat top aerial. The aerial provided for 5DN, the first broadcasting station to be commissioned in South Australia, was an inverted L type 20 metres above a counterpoise system and about 30 metres long with five horizontal wire cages 65 cm in diameters with wires being spaced by cane hoops. Each cage comprised seven strands of 20 SWG copper wire. The owner of the station, Mr Hume designed the support structure along the lines of a ship's mast with a crossarm across each mast.

During 1930–31, flat top aerial systems were employed for 2NC Newcastle and 4RK Rockhampton. The design was still being employed in 1950–60 with NBS stations 2TR, 5WM, 5MG, 8TC, 8KN and 8DR.

PROBLEMS WITH LONG WAVE AERIALS

Although it may seem odd today to erect an MF broadcast transmitting station with an aerial other than a vertical lattice steel radiator and a buried radial or cartwheel earth system, it took many years before this type of construction became the accepted practice.

The early Broadcast Engineers used the technology of long wave (low frequency) aerials and simply modified systems to operate on medium frequencies. This resulted in aerials of low efficiency being used with consequent high percentage power losses. Little was known about earth system design and the benefits which a good design could provide.

Another factor was that whereas in wireless telegraphy point-to-point working, the designers were concerned with microvolts per metre of signal at long distances, the Broadcast Engineer was more interested in the field strength much closer to the transmitting site.

Major factors of concern was rapid attenuation of the ground wave which placed considerable restriction on the service area of the station, and the signal distortion shortly after sunset at areas on the edge of the daytime service area. This distortion resulted from interference between the signal directly radiated in a horizontal direction along the surface of the earth and an indirect signal radiated at high angles to the horizon and reflected back to earth from the ionosphere existing at some distance above the surface of the earth. At the point of reception, the two signal waves added vectorially with the resultant varying in magnitude fairly rapidly, owing to differences in phase because of the different path lengths that the signals traversed. The fading was worst at points where the magnitude of the two signals were equal, resulting in the signal level varying from zero to twice the daylight signal.

However, the phenomenon of fading was not confined to long wave transmission as Broadcast Engineers soon found out when they began to employ aerial systems for transmitting on medium waves. For stations operating in the low power range of 2 kW and below, the primary service area of the station was limited by inadequate field strength whereas for high power stations employing 10 kW and above, the primary service area was limited by the presence of night-time fading.

THE 1920S

The most widely employed types initially for MF broadcasting purposes, were T and inverted L types using single wire, multiple flat wire construction or cage construction. These were supported, in the main, by steel masts or towers and in a few cases by wooden masts, usually fabricated from solid or laminated Oregon pine. Many Engineers were of the opinion that steel support structures absorbed energy from the aerial and also distorted the radiation pattern.

In order to increase the aerial capacitance, the flat top section was usually constructed of several wires spaced horizontally by spreaders or crossarms sometimes fabricated from best quality Oregon, although some designers preferred metal tubing spacers. Wire spacing varied with the particular design, with one to two metres being typical. Experience indicated that moderate spacing was as effective as more wires with smaller spacing, and also reduced the likelihood of damage during high wind gusts.

Some designers, particularly those who had experience with shipboard radio systems preferred cage aerials. These were usually fabricated from four or more copper or phosphor bronze wires equally spaced on metal hoops of diameters as large as 1.8 metres in some installations. The hoops or rings were spaced at frequent intervals giving the aerial the appearance of a long squirrel cage or sausage. This led to them being referred to as squirrel cage, cage or sausage aerials.

The feeder from the transmitter to the aerial was often simply an extension of the horizontal cage although centre fed types were also in common use, with the feeder being of smaller diameter than the aerial.

Although rugged and widely used for MF broadcasting purposes, the cage type system had about 20 to 30% less capacitance than a flat top design with the same number of wires spread out horizontally using spreaders.

Typical of various designs employed at the time of the establishment of broadcasting in Australia in the early 1920s, were those provided at the A Class stations 3AR Melbourne, 3LO Melbourne, 6WF Perth, 5CL Adelaide, 4QG Brisbane, 2FC Sydney and 7ZL Hobart.

Station 3AR began operation initially from the roof top of a building at 51–53 a'Beckett Street Melbourne on 26 January 1924, but a three sided lattice steel structure 67 m high was later erected on a site at North Essendon. The mast was erected in one piece using a 20 m falling jury pole by a team of six workmen. The structure weighed 10 tonne and was guyed at three levels by nine insulated steel guy ropes. One end of the aerial was suspended from an outrigger on the mast and the other end terminated on a steel gantry located alongside the transmitter building with a feeder being taken to the transmitter via a lead through porcelain insulator. The top of the mast carried a pennant with the station callsign '3AR' and was a landmark in the district.

Station 3LO Melbourne employed two stranded copper wire squirrel cage type aerials using a four wire configuration supported by two lattice steel masts 61 m high. One aerial was 50 m in length and was employed with the 5000 watt transmitter operating on a wavelength of 1720 metres and designated the Senior Service while the other much smaller aerial was used with a 500 watt transmitter on 400 metres and designated the Junior Service. The masts were spread 175 m apart and small steel structures installed alongside the transmitter building for terminating the feeder and counterpoise system. Large strain type porcelain insulators and corona rings were attached to each end. The corona rings were provided to minimise loss of energy which might result from brush discharge at the ends, especially during wet weather and hot dusty days.

The 6WF Perth aerial was erected on top of The Westralian Farmers Ltd building housing the transmitter, and comprised an inverted L type using a single cage aerial and cage feeder. The four wire cage aerial component was 1.8 m in diameter and was suspended between two steel tube supports 27 m high and spaced 47 m apart. Each support was guyed at three points with the intermediate sections braced with crosstrees to minimise deflections. The masts were designed and constructed locally, and each weighed about 2.5 tonnes. With the guy ropes correctly tensioned, the downward thrust was nearly 6 tonnes.

The feeder was a 20 cm diameter cage tapered both ends. The building corrugated iron roofing sheets were electrically bonded together and at a single point the roof was strapped to the building lightning conductor. A counterpoise was erected just above the roof and connected to the rod of a conically shaped porcelain lead-through insulator on the roof. The aerial feeder was connected to an identical insulator and the two conductors were taken through a rectangular duct 56 cm by 76 cm to the aerial loading coil in the transmitter room. The conductors were supported in the duct by standoff porcelain insulators.

The original 5CL aerial was a simple three wire flat top type suspended between two wooden masts 20 m high erected on top of the Grosvenor Hotel, Adelaide where the transmitter was also located. When the permanent 5 kW transmitter was installed in 1925 at Brooklyn Park, the aerial comprised a sloping vertical cage type about 1.5 m in diameter and suspended from a 62 m lattice steel mast at one end and a short pole at the other. The original plan was to use a standard T type cage aerial supported by two 62 m masts but the Associated Radio Company who were carrying out the aerial construction work for both 3AR Melbourne and 5CL Adelaide decided on the basis of economics to divert one of the 5CL masts to Melbourne with a result that both 3AR and 5CL had aerial systems supported by a single tower.

The 4QG Brisbane aerial comprised two copper cages fed in parallel at one end to form an inverted L type. The cages were supported by two 30 m high lattice steel self supporting towers with spreader arms keeping the two cages separated at the correct distance. Movement of the spreader arms was contained by drop cables attached to the ends and secured to turnbuckles at the base of the masts. The aerial was erected on top of the State Insurance Building in George Street and was nearly 70 m above street level. The station had commenced operations on 27 July 1925 with temporary facilities at the Executive Building, George Street, pending the installation of the permanent facilities which became available on 22 April 1926. In 1936, the original aerial system was still in service and close-in field strength measurements, gave an RMS value of the product of field strength in mv/m and distance in km, of 340.

Station 2FC Sydney began operation on 5 December 1923. The transmitting station was located at Willoughby (Castlecrag) using two four wire aerial systems suspended between two lattice steel masts 61 m high and spaced 175 m apart. The cage wires were kept in position by brass hoops. One aerial was associated with the 5000 watt transmitter operating on the licensed wavelength of 1100 metres and designated the Senior Service while the other was linked to a 500 watt transmitter on standby mode and licensed for operation on 880 metres. It was designated the Junior Service.

The facilities were provided and operated by AWA. During the erection of one of the masts, an accident occurred resulting in the collapse of the structure. This was the first collapse of a mast at a broadcasting station in Australia. Erection of the structures was undertaken by Morts Docks Engineering Company.

In 1925, the facilities were transferred to the AWA radio station complex at Pennant Hills.

The lattice steel masts at Willoughby were designed by Murray Johnson, an AWA Engineer. While working at Morris Brothers, an engineering firm in Sydney, Murray completed a course leading to a Diploma in Electrical and Mechanical Engineering. In 1910 he joined the Australasian Wireless Company as a Junior Engineer. He worked at Pennant Hills on the installation of the Telefunken spark wireless station and then moved to Western Australia to work on the Coast Radio Station at Applecross. While there he played a major part in improving the reception capabilities of the receiving equipment, using galena crystals from a mine in the State.

When the Royal Australian Navy took over the technical facilities and staff at the Coast Radio Stations shortly after the start of the First World War, Murray was appointed to the Navy with rank of Commissioned Warrant Officer. In 1922, AWA took control of the Coast Radio Station services and Murray joined the AWA engineering staff.

When AWA became involved in the design, manufacture and installation of broadcasting station equipment following Government approval for licensing of broadcasting stations, Murray was a member of the company staff under Chief Engineer Arthur McDonald to handle a number of major projects in the early 1920s.

He later became involved in other company projects including installation of radiocommunication stations at large cattle stations in Northern Territory and north west Queensland, 1925–26; design and installation of radio equipment in aircraft for Kingsford Smith and Ulm, 1928; installation of base radio equipment for the Royal Flying Doctor Service and School of the Air; installation of AWA broadcast transmitters for Commercial broadcasting stations 1929 to early 1930s; design of the technical radio services at Australian terminals when Guglielmo Marconi transmitted a signal from a yacht in the Mediterranean Sea to switch on a large display of lamps in the Sydney Town Hall in 1930; establishment of radio telephone services from Sydney to UK and New Zealand; installation of picturegram service London to Melbourne 1934; installation of Bellini-Tosi DF systems for aircraft navigation 1936; installation of communications and radio navigation systems for DCA 1937. In 1945, he established the AWA Aviation Division, remaining with the Division until retirement in January 1962. Murray died on 27 November 1986, aged 97 years.

In Hobart, 7ZL began service in a building in Macquarie Street, but in 1927 new facilities were erected at Radio Hill on the foot of Mount Wellington. The aerial was a four wire inverted L type, 55 m long supported by two 45 m wooden masts spaced 76 m apart. The length of the feeder was 37 m.

B Class or Commercial stations of the 1920s employed similar type aerials with a few exceptions. Some stations which had earlier been constructed by Amateur station operators continued to employ experimental short wave designs adapted for broadcast band working.

Station 5DN Adelaide, employed an aerial typical of the period. The aerial was supported by two wooden masts each 20 m high and spaced 30 m apart. The masts, made of Oregon pine, were similar to ship's masts with a crossarm and with fittings at the crossarm to allow the top section of the structure to be lowered vertically for aerial maintenance purposes. The masts were designed by the station owner, Mr E J Hume, and fabricated on site by a carpenter to Mr Hume's specification and drawings. Each mast was secured at the base by a stout piece of timber set in the ground in concrete. The top was guyed with three heavy wire cables broken up with egg type porcelain insulators. The aerial was an inverted L configuration about 20 m in length at the top with lead-in feeder also being 20 m in length. The aerial section was made in the form of a five wire cage separated by 65 cm diameter cane hoops. The wires were seven strands of 20 gauge copper. The feeder was a cage of much smaller diameter than the radiator and gradually tapered at the bottom and connected to a brass rod passing through a porcelain lead-in insulator.

Basically, the L type aerial comprised a vertical radiating element which was effectively top loaded by the horizontal section of the system. However, generally, a loading in excess of about 36 degrees resulted in a drop in efficiency and increased fading due to radiation from the top horizontal element. Some designers folded back the top horizontal section so increasing the effective loading.

THE EARLY 1930S

Even until about the mid 1930s, the T, inverted L and folded dipole type aerials, operating at about 1½ times their fundamental frequency, were the dominant types of aerials employed for MF broadcasting purposes. Commercial stations which operated with T type aerials of single wire, multiple wire flat top or multiple wire cage types included 2AD, 2CH, 2DU, 2GF, 2KM, 2PK, 3AK, 3DB, 3HA, 3MA, 3UL, 3WR, 4BH, 4MB, 4ZR, 5MU, 5RM, 6IX, 6ML, 6WB, 7EX, 7HO and 7HT. Those transmitting with inverted L types included 2BH, 2HD, 2UE, 3GL, 4IP, 5KA, 5SE, 6PR, 7BU and 7QT. Station 2LM was one of several Commercial stations employing folded dipole type.

It is unusual for an MF radiator to be installed on a mountain top but 3HA Hamilton commissioned on 24 October 1931 by Western Province Radio Pty Ltd, was one of the first to use such a site. Studios were located in Gray Street, Hamilton and programs fed over PMG's Department line to the transmitting station on Mount Bainbridge which was some 335 metres high. Reports from early listeners indicated a reliable daytime service area extending to 160 km away.

The 300 watt AWA transmitter operating on 1010 kHz fed a variation of the basic Marconi aerial in the form of a quarterwave T type aerial. It was inductively coupled to the tank circuit and resonated by a series variable capacitor with large plates rounded on the edges. A great deal of attention was paid to the installation of the aerial and ground system to ensure a low resistance.

Design and installation of the station facilities was undertaken by Chief Engineer Rupert Fitts who had previously worked at A Class stations 3LO and 3AR Melbourne. He later became General Manager of the Victorian Broadcasting Network comprising 3HA, 3TR and 3SH.

Unlike VHF, operation of an MF radiator from an elevated site does not in itself usually provide a significant advantage in service area coverage. Factors of most importance include frequency of operation, ground conductivity, radiated power, aerial radiation pattern and the useable field strength. The ground wave loses energy due to current being induced into the ground over which the wave passes. The loss increases as the conductivity of the ground decreases.

The 4MB Maryborough aerial which was put into operation on 16 August 1932 is of interest as it was supported by two enormous turpentine poles brought over from Fraser Island. The studio and transmitter were located in the same building and when the poles were transported along the streets of Maryborough using four pole jinkers in tandem they created much interest. One pole was 122 feet (37 m) in length and the other 116 feet (35 m) in length. The poles supported a wire aerial 95 feet (29 m) high.

One of the few Commercial stations employing umbrella types during the period was 3SH Swan Hill. The station commenced operation on 29 September 1930 with a 50 watt transmitter feeding the six wire umbrella aerial which was supported by a 100 foot (30 m) Oregon mast. Listeners reported good daytime signal levels at 120 km from the station.

At many of the early installations, the T type aerial straddled the transmitter building with, in some cases, the down lead conductor being connected to a lead-through insulator inserted in the roof. In other arrangements, a stepped lead-through porcelain insulator was mounted on the wall and the down lead attached either directly to the brass rod which passed through the insulator or the down lead was tied to a vertical rod insulator with a lead-off being taken to the lead-through insulator rod. To allow for movement of wires due to the wind, the rod insulator was usually attached to a suspended weight which was free to move in a pipe or frame guide.

Where the aerial was mounted some distance away from the building a coaxial cable or wire transmission line was employed to connect transmitter to the aerial.

Many Commercial T type aerials were supported by tall lattice steel structures. Typical was 2CH Sydney with the aerial being supported by a pair of 100 m high masts spaced 180 m apart at its Dundas site in 1932. Operating wavelength was 252 metres (1210 kHz) and power 1000 watts.

When 7LA Launceston went to air on 13 December 1930 as the second Tasmanian Commercial station, the aerial system was supported by two steel masts each 160 ft (48 m) high. The masts comprised six steel tubular sections ranging in diameter from 210 mm at the base to 100 mm at the top. The support structures were separated by a distance of 600 ft (183 m). This spacing was selected to provide the minimum absorption of the RF signal propagated from the aerial. The stranded copper wire aerial was a flat top type 100 ft (30 m) in length and the system was erected on a site 260 m above the Tamar River. The operating frequency was 1100 kHz, and the transmitter input power to the aerial, 300 watts.

When a new station was established for 5PI at Huddleston in 1934, the first aerial provided was a conventional quarter wavelength T type erected over a buried earth mat comprising some 3 km in total length of copper wire buried about75 mm below the surface. The measured aerial resistance at the operating frequency of 1040 kHz was 12 ohms.

With an aerial current approaching 13 amperes from the 2 kW transmitter, the Chief Engineer Don Gooding, designed a new aerial system to reduce the loss at the coupling hut by reducing the aerial current. The original aerial was replaced by two quarter wavelength radiators joined in the shape of an inverted U and the earth mat doubled in size.

Aerial resistance was 31 ohms resulting in an aerial current of 8 amperes. Two Oregon wooden masts 135 ft (41 m) high supported the radiating system. It resulted in an increase in signal strength over the whole of the Mid North district service area.

One of several Commercial stations to employ folded dipole aerial systems was 3LK Lubeck.

A licence had been granted to Wimmera Broadcasting Company on 29 June 1932 for establishment of a station in Horsham. The station was commissioned on 11 September 1933 with callsign 3HS and a 50 watt transmitter operating on 1370 kHz. The licence was subsequently transferred to 3DB Broadcasting Co., Pty Ltd effective from 16 May 1936 and the company asked its Technical Consultant Harry Kauper to find a site for a new station. A suitable site was located in the Lubeck area and about 2 hectares purchased for the station to comprise a station building and a residence for the Officer-in-Charge.

The station was established on the site with a 2 kW AWA transmitter employing low level modulation mode and operating on 1090 kHz. The new facilities were officially opened on 2 January 1937.

The folded dipole aerial designed by Kauper comprised three stranded copper conductors each half wavelength in length at the operating frequency and producing one third of the input current in each conductor. This provided an input impedance of approximately 600 ohms or nine times that obtainable with a single half wave conductor. This arrangement enabled the employment of an open wire copper transmission line from the transmitter building to the aerial input point at the centre of the middle conductor. The three conductors were separated by porcelain rod type insulators and joined at the end points.

Chief Engineer at the station was N Buzacott. Programs were relayed from 3DB Melbourne.

In later years, a two tower directional system was provided at another site employing 5 kW Continental and AWA transmitters with a further change in callsign having been made, when it became 3WM in 1977.

When the first 2 kW National Broadcasting Service Regional stations 2NC Newcastle and 4RK Rockhampton were commissioned in 1930 and 1931 respectively, they employed similar T type aerials with flat tops, and cage type feeders about 100 mm in diameter. The flat top section was about 20 m overall length and consisted of four parallel wires spaced just under 2 m apart. The two self supporting lattice steel structures were about 40 m high and spaced 64 m apart. Each of the four legs of the towers was bolted to a concrete anchor block 1.8 m cube in dimensions. The base of the structures were 3.6 m square tapering at the top to 38 cm square. A 2.4 m tower containing a concrete weight insulated from the feeder served to keep the aerial taut. A windlass was provided near the base of each tower to allow the aerial to be dropped to ground for maintenance purposes.

The towers were manufactured to a design by STC England and were assembled on the ground and hauled into their vertical positions.

The 4RK aerial was still in operation in 1997 as a standby unit, but some changes had been made by Doug Sanderson and staff to enable the aerial to operate at 10 kW. At the station operating frequency of 837 kHz, the input impedance was 10–j150 ohms which would have resulted in high coupling equipment loss at 10 kW. The flat top was extended in length resulting in an input impedance of 13–j54 ohms. The original insulators on the flat top were more than adequate to handle the increased power.

Even as late as the 1960s, single wire T types and multiwire flat top types were still being installed as main radiators at some low power National stations. Stations employing single wire types included 5WM (1953) and 5MG (1955) while multiwire flat top types were provided at 8TC (1960), 8KN (1960), 2TR (1948) and others.

One of the main disadvantages of the T type aerial was the existence of high RF voltages at the ends of the flat top, particularly when transmitter input powers of 2 kW and above were employed. This required the use of high quality insulators of appropriate radio ratings and in some cases fitted with corona rings.

THE MULTIPLE TUNED AERIAL

With the installation of high power transmitters for the NBS Regional services in the 1930s, a new type of flat top aerial was employed to improve efficiency. These were installed at 2CO Corowa, 6WF Perth and 5CK Crystal Brook. They were multiple tuned types developed originally for low frequency working by E F W Alexanderson of the General Electric Company, USA and referred to as the 'Alexanderson' aerials. A major disadvantage of the standard flat top aerial was that the effective total resistance was low, particularly for the low frequency end of the MF band, resulting in the radiation efficiency being generally low.

The effective total resistance of an aerial is made up of components referred to as the radiation resistance and the loss resistance. It is desirable that the radiation resistance be as large as possible and the total loss resistance be as low as possible. Many factors contribute to the total loss resistance. These include loss in inferior dielectics, corona losses, I^2R losses in the aerial and earth circuits, leakage loss across insulator surfaces, loss in the ground connection and loss by eddy currents in support towers and other neighbouring conductors.

In the 2CO, 6WF and 5CK systems, the aerial comprised a flat top with three individually tuned down leads. The aerial current was considered to be divided equally among the down leads. Power into the aerial was fed through the centre down lead.

Multiple tuning increased the ratio of the radiation resistance to total resistance. The radiation resistance was increased approximately N^2 times where N was the number of multiple tuning down leads.

In addition to improvement in radiation efficiency, the multiple tuning arrangement provided a more easily matched input impedance at the feed point. In the case of 5CK, the resistive component was 67.5 ohms resulting in an aerial current of 10 amperes at a frequency of 635 kHz.

The aerials provided at 5CK, 2CO and 6WF were basically the same. The 5CK and 2CO systems were supplied by STC, together with the transmitters, with the equipment being manufactured in England. The 6WF aerial and transmitter were made in Australia, with the aerial design being based on the English 5CK and 2CO designs.

The following details of the 5CK installation is representative of the other two installations:

Two lattice steel self supporting towers each 55 m high were used to support the three down lead aerial system. The towers were spaced 110 m apart with the aerial being strung between them. The aerial was attached to steel cables which passed over pulleys at the top of each tower and secured to winches anchored behind each tower. The top portion of the aerial comprised six 7/16 phosphor bronze conductors attached to three 6 metre spreaders, one at each end and one in the centre. The spreaders were made from Norwegian Spruce made up like ships spars. They were hollow to reduce weight, tapered from the middle to each end and had a dome shape plug glued into each end. Very heavy cylindrical tension type porcelain insulators were used at each end of each wire. The three down leads each comprised six 7/16 phosphor bronze cables attached symmetrically around rings of copper tubing, forming a hollow vertical cage.

The two outer leads were attached at the bottom ends to insulators cemented into the flat top of small concrete tuning huts. Inside each hut, a copper tube tuning inductance was installed with an RF ammeter to read the down lead current.

The centre down lead was attached at the lower end to a cylindrical porcelain insulator, the bottom of which was connected to a steel cable passing through a bushed guide hole in the top of a small anchor tower. The steel cable supported a weight which was chosen to allow free but damped movement of the aerial due to temperature and wind changes.

The down lead was connected to the lead-in insulator which passed through the glass of one of the windows of the transmitter room. Inside the room, the lead-in was connected to a lightning gap and a safety earthing switch and then to the transmitter.

The masts were manufactured in Melbourne by Johns and Waygood and erected piece-by-piece on site. Concrete footings approximately 2.4 m cube were provided to anchor each leg of the four sided structure.

Erection of the 5CK towers was undertaken by Messrs Gibb and Miller of Port Adelaide.

The mechanical aids, equipment and tools available today for the erection of masts, towers and earth mats were not available at the time 5CK was commissioned. Excavation for the two tower foundations including rock removal was carried out with hand tools, all tower steelwork members were either bolted or riveted together and holes drilled tediously by hand, all excavation for the fishbone earth mat was carried out using picks and shovels and all soldering performed with large solid copper soldering irons heated by kerosene blow lamps. Even if some electrically powered tools were available, the electric power was not connected to the site until late in the installation stage of the work.

About 1940, the 5CK aerial was damaged during a storm with two of the original spreaders being broken when they fell to the ground. All three spreaders were replaced by selected Oregon spreaders of uniform hexagonal cross-section made up in the PMG's Department, Carpenters Workshop, Adelaide.

Some years later, further damage was done during a fierce storm. The aerial elements were replaced but the spreaders were undamaged. During re-erection of the aerial, a mishap resulted in the original very large and heavy tension type insulators in the flat top section being pulled apart in mid-air. They were replaced by sets of compression types arranged in series. Ted McGrath who was in the team involved in the original construction of the station during 1931–32 was involved in both these aerial repair works.

In 1997, the 2CO original aerial was still being used as the main aerial while the 5CK and 6WF aerials were used as standby for tall vertical radiators.

OTHER WIRE AERIALS

Other wire types were employed at both National and Commercial stations at various stages of development in aerial technology. These included umbrella or cone type, folded back types, delta type and others.

The umbrella or cone type aerial has taken many forms over the years and is still widely used today as part of vertical radiator systems.

With the establishment of stations 7NT Kelso in August, 1935; 3GI Sale in October, 1935; and 4QN Townsville in November, 1936; an umbrella type was used for the first time in the National service. The type had earlier been used successfully at BBC stations in Great Britain. The system consisted of a single lattice steel mast about 152 m high, from the top of which were suspended three stranded copper wires terminating on short poles equi-spaced around the base and some distance out from it. The wires were fed by horizontal wires erected about 3 m above the ground and commoned near the base of the mast for connection to the aerial coupling unit. The lengths of each horizontal and uplead wires were so proportioned that a current node existed near the base of the uplead. This resulted in the distance from the current node to the feed point being slightly less than one quarter wavelength and the upleads a half wavelength at the station operating frequency.

Subsequent vertical radiation pattern measurements using an aircraft showed that the characteristics of this type of radiator to be slightly worse than that of a vertical radiator of the same electrical length.

In more recent designs such as 8DR, 8HA/8AL, 4HT, 4WP, 4TI and others, the umbrella wires were used as loading in order to increase the electrical length of the vertical radiator.

A typical umbrella installation employed eight wires or cables at about 45 degrees to the vertical with formats including wires being kept separate, wires being joined by horizontal wires to form a skirt or wires arranged in a folded configuration.

The skirt arrangement provided a greater degree of loading than the others. The optimum dimensions of the umbrella configuration were somewhat critical and varied both with the height of the vertical radiating element and the operational frequency. A well-designed system would provide a reduction in base voltage of several times and an increase in radiation resistance of about two times that of the structure if unloaded.

At one National station with a 22 m high umbrella loaded radiator used for standby purposes and fitted with 12 m umbrella wires and installed over an earth mat comprising 60 radials 100 degrees in length, the measured field strength at 1000 kHz indicated 165 mV/m at one mile for 1 kW transmitter input. For insulator design purposes, the top voltage was calculated to be 4.5 kV RMS for 2 kW input at the base.

Various forms of folded back aerials were popular in the 1930s at a number of Commercial stations. The aerial was basically a folded dipole with the total aerial current being divided between two or three conductors. They were parallel at current node point with power being fed into one leg only. The advantage of the technique was that it gave an increase in resistance at the feed point. Records indicate that stations employing folded back versions in the mid 1930s included 2GZ, 2KA, 4SB and 2LM. Station 3LK had a three wire system.

The cage wire delta aerial was provided at a number of National stations as standby aerials. A major disadvantage with this type was the low input resistance resulting in considerable power loss in matching equipment. Typical was the 27 m delta provided at 4QL Longreach in 1954 for use with the 10 kW transmitter and standby for the 198 m main radiator. The base resistance of the delta at the station operating frequency was 2.8 ohms resulting in an input current of nearly 60 amps.

The delta aerial was basically two L type aerials in parallel support by three masts. The two down leads at each end sloped away from the support structures to meet at the feed point midway between the two mast bases.

Although delta had a lower impedance than a T type it was less heavily loaded and possessed greater bandwidth at frequencies below resonance.

For an operating nominal frequency of 1000 kHz with a delta system supported by three 22 m masts and provided with 60 radials 100 degrees long the top voltage was about 2 kV RMS when operating with 2 kW input rising to about 5 kV RMS for 10 kW input at the feed point.

The aerial used at 3AR Melbourne until the late 1930s was also of the wire variety. It consisted of an approximately vertical cage supported by a 61 m earthed mast and connected at the top to two horizontal cages mutually at right angles. It was operated with a counterpoise system. Vertical radiation measurements of the aerial made with instruments in an aircraft showed that the radiation characteristic was in rough agreement with the cosine curve except at high angles where considerable high angle radiation appeared.

The aerial used at 5CL Adelaide into the 1930s was also of the vertical cage type. The aerial was made up of six 7/16 hard drawn copper wires attached to copper rings, forming a large diameter hollow cage aerial. The lower end was attached to an insulator fixed to a small steel anchor outside the lead-in point of the building. The top end of the aerial was slung from a porcelain insulator with corona rings attached to a steel cable which passed over a single lattice steel mast and anchored in a winch at one end and a counterweight system at the other end. The steel cable passed over the roof of the transmitter building. The vertical height of the aerial was about 46 m. The mast was 61 m high and was guyed at three levels. The steel strain pole was 13 m high.

In the early 1930s, a change was made to the feed-in arrangement. A cast glass tile replaced one of the transmitter building terracotta tiles and the down-lead was connected to the transmitter via the glass tile drilled to take a brass lead-through rod.

During 1936, an attempt was made to use the guyed support mast as a shunt fed aerial but the project was abandoned as the height of the mast was too small.

In 1944, the mast was raised and a three arm steel section spider fitted to the bottom of the structure. The spider sat on three insulators and the mast was used as a radiator. It was fed by a six wire 200 ohm impedance line with an aerial coupling unit being mounted in a hut erected near the mast base. Frank O'Grady and Ted McGrath were two people associated with the project.

A major problem with these early aerial systems was that a significant proportion of the radiated power was directed at an appreciable angle above the earth. This so called 'sky wave propagation' not only degraded the station's ground wave signal but caused interference to other services, particularly during the period following sunset.

Although many broadcasters were proud to announce that reception reports had been received from listeners hundreds or even thousands of kilometres away, it meant that local listeners were being deprived of a better signal level from the available transmitter power.

During daytime, the sky wave signal is absorbed by the D layer of the ionosphere some 70 km above the earth surface but soon after sunset, in the absence of the D layer, the signals are reflected back to earth by the E layer about 100 km above the earth. The reflected sky wave signal is subject to considerable rapid fluctuations in both amplitude and phase in the listening zone on the ground at which sky wave and ground wave signals are of the same order of magnitude but out of phase. The combined signal in the zone leads to very poor reception of the station program. For high power stations, this may mean that the night-time coverage zone of the service is reduced by the fading problem.

Because the sky wave signal can travel great distances from the source it may also cause interference with signals of other stations in their designated service ares. It has potential to interfere with stations operating on the same frequency (co-channel services) or sometimes to services operating in adjacent channels.

During 1937-38, records indicate that Radio Inspectors investigated a number of interference complaints concerning stations operating on co-channels. Two of the investigations included:

* Listeners to 5SE Mt Gambier, South Australia who experienced interference from 6GE Geraldton, Western Australia which employed a 500 watt transmitter feeding a 45 m high T type aerial supported by two lattice steel towers. Both stations operated on 1370 kHz.
* Listeners to 4CA Cairns, North Queensland who experienced interference from 4GR Toowoomba, South Queensland which employed a 500 watt transmitter feeding a quarter wavelength vertical tubular radiator. Operating frequencies were 1000 kHz.

Another interference problem of interest investigated by the Inspectors concerned interference to receivers operated in Melbourne tuned to 3XY on 1420 kHz. Interference was experienced from transmissions by 7NT Kelso in Northern Tasmania which operated on 710 kHz. As a result of a faulty capacitor in the output circuit the 7NT second harmonic (1420 kHz) was outside of limits and of sufficient level to be received by some listeners in Melbourne with sensitive receivers.

VERTICAL RADIATORS

Tall steel vertical radiators had been used for wireless telegraphy transmission nearly 20 years before broadcasting as an entertainment medium appeared on the scene. The Broadcast Engineers did not make use of the technology, instead they employed wire T and inverted L types. It was to be another 10 years before they changed over to steel mast and tower radiators.

One of the first Engineers to use a tall vertical steel radiator was Reginald Fessenden. In 1905, he erected one at Brant Rock in the USA and another at Machrihanish on the Scottish coast for the purpose of conducting wireless experiments across the Atlantic. Fessenden reasoned that tall smoke stacks had stood the test of time and used the same design principles for his aerial. It comprised a 122 m high cylindrical steel tube with a 30 m diameter capacity hat on the top. It rested on a ball and socket joint which was mounted on an insulated base. It was maintained in the vertical position by four sets of guy ropes broken up with insulators. The structure was 1.5 m in diameter and contained an internal ladder to the top.

Fessenden had the Massachusetts Institute of Technology undertake considerable work on the design of the base insulator to be capable of handling a load up to about 28 tonnes, and a working potential of 500 kV. Safety gaps were fitted to bypass any potential above this level.

Unfortunately, on 5 December 1906, the mast in Scotland fell to the ground during a violent storm in the area. Due to bad worksmanship, five guy wire terminations pulled out of their zinc filled sockets.

One of the first Australian wireless telegraphy experimenters to employ a locally designed, insulated and top loaded vertical radiator was Ingram Banyer of Malvern, Adelaide. He operated station XVQ before the First World War.

The vertical element comprised a 3 inch (75 mm) diameter iron pipe about 66 ft (20 m) high and held vertically by three levels of steel wire guy ropes spaced at 120 degrees. The guy ropes were broken up with 6 inch (150 mm) sections of well-seasoned pine rod about 1½ inch (37 mm) diameter. The pine spacers which had holes drilled at both ends had been placed in a vat of boiling beeswax for about 20 minutes to drive out any moisture from the wood and to provide a waterproof surface. The base rested on a slab of Swedish granite supplied by a local stonemason. The granite block about 12 inch (30 cm) cube had a recessed hole in the top to keep the vertical pole in position. The top loading consisted of a sulky wheel mounted on the top with eight uniformly spaced wires hanging down from the circumference of the wheel. Each wire was about 10 ft (3 m) long and had a lead sinker attached to the bottom to maintain verticality. The tops of the wires were tied to the pole.

In notes found in the records of Ern Stanton, another local experimenter of the period, figures showed that the aerial current into the vertical radiator was 0.5 ampere greater than for a single wire 10 m high T type system.

The station log book recorded contacts being established with stations XVK Mt Gambier, XQF Brisbane, XNY Melbourne and XLH Sydney during one weekend using the vertical aerial.

Although Broadcast Engineers were able to design efficient transmitters for the early stations, very little was known about aerials, particularly vertical types, and earth systems. They therefore followed aerial practices of low frequency wireless telegraphy stations, adapting them for shorter wavelengths. Radiation resistance was low, usually 5 to 20 ohms and the advantages of a good earth system were not appreciated.

It was not until 1924 when Stuart Ballantine in the USA published two papers on vertical radiators that the modern broadcast aerial was developed. However, it was some 10 years before they became the standard for broadcast working. From the mid 1930s, the FCC in USA included data on vertical radiators only, in its rules and regulations.

Ballantine showed that the radiation resistance rose to a high value as the height of the structure approached one half wavelength. He also showed that there was an optimum height of a vertical radiator for obtaining maximum ground wave field strength.

A major disadvantage of the T and inverted L types of aerials was that they produced a wave that was horizontally polarised. The presence of a conducting ground obstructs the propagation of a horizontally polarised ground wave owing to cancellation effects between the electrical vector parallel to the ground and the currents induced in the earth. This effect is of little consequence where horizontally polarised waves are used for short wave broadcasting purposes, as the ground wave adds nothing to the signal at the distant reception point. However, with medium wave broadcasting, the ground wave is the one which is of importance. With vertical polarisation resulting from the employment of a vertical radiator, the earth induced currents strengthen the surface wave so that for a flat highly conductive earth, the field strength at short distances is very much enhanced, compared with propagation in free space. However, the ground wave attenuates rapidly with distance from the source.

About 1933, when the PMG's Department began to develop plans for expansion of the National Broadcasting Service following a slow down during the Depression years, their Research Laboratories staff began a study into the most appropriate designs of radiators for the service.

The wire umbrella types supported by lattice steel structures provided for 7NT, 3GI and 4QN during 1935–36 were considered appropriate for those particular stations but not for others being planned.

Designs which followed, used the steel structure as the radiator and not as a support structure for wire aerials.

Advantages of this approach were that the aerial system was cheaper to construct and it overcame the problem of high induced currents from the nearby aerial elements and also distortion of the radiation pattern.

Investigations undertaken by Alec McKenzie and others of the PMG's Department Research Laboratories and overseas organisations showed that maximum ground wave field gain and the best antifading characteristics could not be obtained with the same aerial height. Best field strength was obtained with a radiator 225 degrees (0.625λ) in height but the best antifading performance over land was provided by a radiator about 190 degrees (0.56λ) in height. A radiator of height 225 degrees produced a secondary lobe of high angle radiation resulting in severe fading characteristics at the edge of the primary service area.

In the late 1980s, a low profile radiator in the form of a toroidal helix was proposed by designers at a NAB Engineering Conference in USA as an alternative to tall structures to provide antifading characteristics. No MF aerial to this design has been erected in Australia to date.

Tall structures particularly those required for operation at the low frequency end of the band are expensive to erect, they result in antifading problems for one of the frequencies where dual frequency operation is required and they can cause an operational problem should the transmitter frequency later be shifted significantly. Typical of the dual frequency problem was the case of 2FC/2BL where 2FC operated at 0.46 wavelength and 2BL at 0.55 wavelength when they were both linked into the common radiator.

The Research Laboratories Engineers, after studying a number of alternatives, undertook the development of a guyed structure surmounted by a horizontal armature. Electrically, the armature was insulated from the vertical section and fed via a loading inductance. The armature and coil combination acted as a termination equivalent to many metres of mast height. The loading allowed the optimum radiation characteristic in the vertical plane to be achieved with reduced height and over a range of frequencies in the ratio of about 1 to 1.5 without impairment of radiation performance.

The first of these radiators was installed at 2NR, the Northern Rivers station of the NBS at Lawrence in 1936. The radiator was 152 m high but had the same antifading characteristic as a non-loaded radiator 213 m high. Similar designs but of slightly different heights were subsequently installed at 6WA Wagin (200 m) in 1936; 3WV Dooen (201 m) in 1937 and 2CR Cumnock (198 m) also in 1937.

In early 1998, the 18.3 m diameter armature of 2NR was replaced by Telstra riggers due to severe corrosion of some of the steel members. The radiator had been in service since 1951 following the collapse of the original 1936 radiator during a storm.

Measurements of the Figure of Merit of these radiators were carried out soon after commissioning of the stations by Alec McKenzie who had played a major role in the design of the radiators. The following results in terms of millivolts per metre at 1 km for 1 kW input were obtained:

- 6WA–390.
- 3WV–400.
- 2CR–403.

In the case of 6WA, the inductance at the top of the radiator was adjusted for a current node located 0.1 wavelength above earth. The base impedance was 35.3 –j189 ohms at 560 kHz. At 3WV, the current node was 0.102 wavelength above earth and the measured base resistance using the added resistance method was 38.4 ohms at 580 kHz. The 2CR radiator was adjusted for a current node 0.1 wavelength above earth resulting in a base resistance of 39.2 ohms at 550 kHz.

One person who made an important contribution to the mechanical design of these structures and also the design of the porcelain insulators was Reg Turner. He had been involved in 1932 in the design of the new 6WF Perth station which employed for the first time in Australian broadcasting, a coaxial feeder to an Alexanderson type aerial system. Reg was the author of an article 'Northern Rivers Regional Station Grafton NSW — Some Aspects of Design, Construction and Erection', published in the 'Telecommunications Journal of Australia', Volume 1, Number 3, 1936. In addition to the 2NR station described in the article, he was also involved in the design of similar structures for 6WA Wagin, 3WV Dooen and 2CR Cumnock. These stations were erected during 1936–37.

In an article 'Strength of Porcelain Insulators and Cement Joints', published in the 'Telecommunications Journal of Australia', Volume 2, Number 5, he described design aspects of the insulators employed with these radiators.

Another important paper was 'Concrete Foundations for Radio Masts', published by the Postal Electrical Society of which he was a member. At the time of his death in 1940, Mr Turner was the Department's Chief Draftsman in the Chief Engineer's Branch, Victoria.

In 1948, a 198 m radiator was erected for dual frequency operation at 4QG/4QR followed in 1953 by a 180 m radiator for 6WF/6WN. Some slight changes were made to the original construction of the armature making it lighter and using push-pull type insulators instead of tubular tapered types. The electrical network of the dual frequency radiators was also different. It employed a capacitance network across the inductance to allow optimum adjustment to achieve antifading characteristics for both operating frequencies. The current distribution in the mast was measured by means of a travelling pick-up coil and detector. Although hand-held lightweight models later became available the models used up until at least the late 1950s were heavy and bulky and had to be hauled up and down the outside of one leg of the structure by a rope.

Because of complex structural arrangements associated with the armature, the overall cost of these structures was not much different from the less complex taller simple structure without top loading.

In 1938, tall unloaded types were installed at 2FC/2BL (225 m) and 3LO/3AR (215 m) and in 1939 at 4QS (219 m).

The question of the relative advantages of loaded radiators compared with tall unloaded types is largely an economic one. However, vertical radiation pattern measurements using aircraft, showed that in the case of the top loaded types similar to 2NR, the loaded type is suitable for a wider range of frequencies. Whereas the optimum antifading condition exists at only one frequency for the non-loaded vertical type, it exists over a range of frequencies for the loaded type. For the 2NR radiator, this covered the range 700 to 1100 kHz.

A slightly different form of top loading using a sectionalised mast was introduced in the 1950s. It involved the insertion of an inductor a little way down from the top and a simple adjustable capacity hat provided with some structures. These were installed at a number of stations including 4RK (128 m), 4QN (198 m), 5CK (183 m), 5CL/5AN (168 m) and 2NC (91 m). The 4RK mast installed in 1954 is typical of this type. The section point and the inductor were located at the 98 m level.

The top loading armature had a diameter of 9 m, giving an electrical height of 0.56 wavelength. The base impedance of the radiator was 86 ohms. Engineers associated with commissioning the radiator were Mick Hall, Frank Sharp and Jack Ross.

One Engineer of the PMG's Department who made a significant contribution to the development of top loaded radiators, particularly to matching network design in the late 1950s, was Leon Sebire who later became General Manager of Telecom Broadcasting.

Leon began work in the radio manufacturing industry in 1947, and joined the Department in 1956. He was attached to the Broadcasting Stations Installation Division at Headquarters Radio Section where he remained until 1962. During that period, he was responsible for the implementation of the Joint Australian Broadcasting Control Board/PMG's Department Plan for improvement of the National Broadcasting Service with some of the major projects being the establishment of MF stations at Armidale, Wollongong, Mt Isa, Tennant Creek, Katherine and Rabaul. Another important engineering involvement was the increase in power of 12 existing National stations to 50 kilowatts.

He then moved into the radiocommunications area and among other system activities, was responsible for the Darwin-Nhulunby tropospheric scatter system. He returned to broadcasting to develop the major Phase 7 Television Extension Plan for Remote Areas.

Leon was a long-time proponent for recognition of the broadcasting function within Telecom, and was the architect of the proposal which led to the eventual formation of the Broadcasting Directorate in 1983. He was the first Director and later became General Manager Broadcasting with the change of name of the group to the Broadcasting Division. A further name change took place in 1992 with Leon becoming General Manager of Telecom Broadcasting.

Leon represented Australia at many International forums including attendance at ABU and CBA General Assembly where his contributions were invaluable to world broadcasters. He presented numerous papers at these Conferences, many of which have been published world wide.

In 1992, he was made a Member of the Order of Australia 'for service to communications, particularly broadcasting'.

Leon retired from Telecom in early 1994.

Not many Commercial station broadcasters invested in anti-fading radiators. Since about 1936, they tended to employ radiators about 0.25 wavelength high, although 3CV was one station which commissioned a half wavelength radiator.

Station 5DN Adelaide was one of the few Commercial operators provided with an anti-fading radiator when a 141 m high sectionalised lattice steel radiator without capacity hat was put into service in 1958.

Decision to invest in the aerial was made to increase the service area of the station. At the time, it was the only station in Adelaide without country relay stations and management considered that an increased service area would increase the stations advertising base.

Chief Engineer responsible for establishment of the facility was George Barber. George had worked with the Chrysler Corporation electrical maintenance group from 1933 until 1939 before moving to 5DN in 1939. He took up a position with 5RM during 1940–42 but returned to 5DN as Chief Engineer in 1942. He adopted a policy of designing and constructing all transmitting and studio facilities which could be made by the local station technical staff. Included were three transmitters including a 2 kW standby unit, remote control equipment replacement and upgrading of studio equipment and facilities. George was an active member of The Institution of Radio Engineers (Australia) joining as an Associate Member in 1943 and becoming a Member the following year.

Another example of increase in service area by replacement of a radiator with a more efficient one was at ABC Regional Radio station 5MV Berri near the Murray River.

The station was commissioned on 31 July 1957 on a frequency of 1590 kHz with main and standby Philips 2 kW transmitters feeding a 38 m lattice steel radiator via an open wire 200 ohm transmission line. Divisional Engineer-in-Charge of the installation was Jack Truss. Operating frequency was later changed to 1305 kHz.

In 1996, the radiator was replaced with a 100 m high structure resulting in the daytime service area being extended approximately 30 km in the north/south directions and about 20 km in the east/west directions. The new radiator provided an 0.43 wavelength radiator compared with 0.16 wavelength for the original structure at the operating frequency.

At the same time, an ABC Radio National service on 1062 kHz was provided. Programs were received via satellite for the Radio National transmitter and over land line via the Renmark ABC studios for the Regional Radio transmitter 5MV.

A radiator modified in an unusual manner to provide anti-fading characteristics was provided at 2HD Newcastle. In 1983, a 134 m high lattice steel structure was erected to replace a bore casing type. The new radiator fed by a 2 kW transmitter operating on 1143 kHz was manufactured by Good Engineering in South Australia and was approximately one half wavelength at the operating frequency. It was modified by the addition of a one eighth wavelength earth stub inside the lower portion of the mast making the structure electrically equivalent to a five eighth wavelength mast.

The present day slender lattice steel radiator has varied little since its introduction in the late 1930s and has fitted well into modern Broadcast Engineering requirements for the widespread employment of dual frequency radiators and directional aerial systems so necessary to meet the challenge of spectrum congestion in the medium frequency broadcasting band.

The first station to be equipped for dual frequency working of the radiator was 3LO/3AR. The network comprised HF coupling unit, HF selective unit, LF coupling unit, LF selective unit and aerial tuning unit. The same principle with some minor changes is still used today for dual frequency working. National stations at Brisbane, Sydney, Melbourne, Hobart, Canberra, Adelaide, Perth and Newcastle employ dual frequency radiators. A number of Commercial stations employ similar types today with 8HA/8AL Alice Springs using a common radiator for Commercial and National transmitters.

An unusual application of multiple use of a radiator occurred at Thursday Island. When National station 4TI Thursday Island went to air on 18 June 1979, transmitting on a frequency of 1062 kHz with a 2 kW transmitter, it employed a temporary 32 m Hills Industries lattice steel radiator. The plan was to share a 46 m radiator owned by the Overseas Telecommunications Commission which operated the Coast Radio Station on the island. Engineers developed a network to enable four frequencies to be fed to the radiator. They were 1062 kHz for 4TI and 488.5, 500 and 512 kHz for the Coast Radio service. During 1992, OTC closed down its station which had been in service since 1913, leaving the radiator transmitting only the 4TI service.

Although directional aerials had been in service in the USA since the mid 1930s in order to deal with the problem of spectrum congestion, the first directional aerial system using vertical radiators was not installed in Australia for MF working until 1957. It was designed and installed at 4BH Brisbane by AWA Engineers. The station had been transferred to a site near the mouth of the Brisbane River and in order to minimise the transmission of signal out to sea, a two mast system was installed to improve the signal strength in the heavily populated areas of the city and adjacent areas.

The first directional aerial system designed to prevent interference with signals of another station on the same operational frequency was installed by STC for 2MG Mudgee in 1960 with 33 m high radiators. This was followed the following year by a system installed at 5AU Nectar Brook near Port Augusta in South Australia. It employed two 50 m high lattice steel structures and was fed by an STC 2 kW transmitter.

Today, there are many stations employing directional radiators mainly employing two radiators. Installations designed with three radiators were used at 2WS Sydney, 2GO Gosford and 4KZ Innisfail. Station 4KZ operates with 5 kW power and 121 m high aerial system on 531 kHz, the lowest frequency in the MF broadcast band. At 1996, it shared the frequency with 2MC, 3GG, 5UV and 6DL.

One directional aerial of particular interest is the four element system commissioned for 3EE on 3 July 1992. Station 3EE operated by AWA Media Pty Ltd was a new station erected in the Werribee area to replace 3XY which since 1991 had been operating on 2000 watts with a temporary aerial from a site at Altona. AWA Media had purchased the licence and hardware of 3XY Pty Ltd in 1991 on the basis that the company be allowed to close the station down for a period and relaunch it on one of the last available low frequency channels — 693 kHz — on the MF band for Melbourne.

A problem for the station designers was to adequately cover the Melbourne service area; to provide protection for 4KQ, 5SY and a group of stations planned for New Zealand all on the same frequency; to provide adjacent channel protection for 2BL and to limit the field strength in Geelong.

David Morris of AWA Defence designed a four element array to achieve the required results. Hardware was installed and commissioned by contractors including Bill Hardinge of Radio Masts Australia and Alex Kennedy of Radio Transmission Engineering. The facilities included four 90 m masts and 70 km of earth mat conductors. Chief Engineer was Paul Taylor and Operations Director was Joe Oost.

Unfortunately, 3EE did not remain on air long as a self-supporting business enterprise. On 27 May 1993, it was acquired by the owners of Melbourne based station 3MP and a plan implemented to simulcast the 3EE and 3MP programs to provide a wide and effective coverage of the large metropolitan area.

In 1997, directional aerial installations in Australia included 89 Commercial, Community and National broadcasting stations. The tallest system at that stage was 207 m high located at 4QW St George in Queensland.

Directional aerial systems employing horizontal systems had been in operation long before the appearance of vertical systems in Australia. One early system was at 2GF Grafton which began service in December 1933 with a 200 watt transmitter on 1210 kHz. It employed a multiwire cage T type aerial supported by 49 m high twin telescopic steel masts with a reflector behind the radiating element to concentrate the signal inland.

Frank Miller who designed and built the 50 watt station 5MU Murray Bridge in 1934, erected a Marconi quarter wave flat top aerial with the top wire being spaced by a six metre spreader. The flat top was suspended between two wooden masts 30 metres high made in three spliced sections by Ted Faehrmann a local carpenter. In order to provide a good signal into Adelaide some 65 km away, Frank installed a parasitic reflector element on one of the wooden masts with the element protruding above the flat top by about five metres with an extension pole. The element was kept clear of the wooden pole by a series of porcelain cleat type insulators. There are no records of measurements having been made to assess the effectiveness of the arrangement but large numbers of letters from listeners asking for request records indicate he had a large following in the city even though some of his programs were rebroadcasts from one of the Adelaide stations.

About nine months after the station went on air the extension pole fell to the ground during a storm and was not replaced. In later years the aerial was replaced by a tubular guyed radiator.

Although the majority of vertical radiators today are of lattice steel construction, the tubular steel construction was popular many years ago, particularly with Commercial stations operating in the high frequency end of the band. They were cheap to construct and required little maintenance. However, some stations had trouble with corrosion where the sections were screwed together. The steel tubing used was often bore casing material. This was a thin walled pipe of good quality steel used for casing artesian and sub-artesian bores. The casing was supplied in lengths of about 6 metres, threaded both ends.

At one coastal broadcasting station in Queensland during 1947, the corrosion was so severe that RF currents across a join were so effected as to upset the normal current distribution pattern of the radiator. The base input impedance fluctuated, causing problems with transmitter loading and radiated field strength. It also resulted in the production of spurious radiation because the oxide acted as a metal rectifier to form a random frequency generator or mixer.

Commercial stations which employed tubular aerials in 1930–40s included 5AU–58 m, 5MU–50 m, 2HD–65 m, 3CV–82 m and 4GR–70 m. Many others used tubular masts to support T or inverted L aerial systems. Station 2GF Grafton was a typical installation with two 49 m tubular masts supporting a multiwire flat top aerial system.

One aerial of unusual design was that erected at 4AT Atherton. It was a quarter wavelength tubular type using four crosstrees to stabilise the top section. From ground level to a height of 80 metres, it was fabricated from 200 mm diameter steel tubing and for a further 30 metres, 150 mm tubing was used. At the junction of the tubes, four horizontal members were extended with guy ropes linking the extremities of the horizontal members to points above and below, on the vertical section. There were seven sets of guy ropes below the crosstrees in four directions. The 4AT station was owned by Atherton Tablelands Broadcasters Pty Ltd, when it began service on 15 February 1939 but during the War years it was taken over by the Government and operated as part of the National Broadcasting Service as from 27 January 1941. The original mast was felled in June, 1961 and replaced by a 61 m high screwed pipe mast. First Chief Engineer was Ambrose Armistead followed by Alf Walker of PMG's Department in 1941.

Some National stations were also commissioned with tubular radiators. One of special interest was the 80 m high structure erected as a quarter wavelength radiator for 4QR in 1942 at Bald Hills near Brisbane. In the design, 150 mm bore casing was utilised from the masthead downwards to a point where the factor of safety approached 4 at maximum wind loading and from that point to the base, the casing diameter was increased to 200 mm. A ball and socket was fitted at the base and the structure placed on a porcelain insulator. The base insulator was mounted on a frame 2.5 m above ground to allow for flood conditions. Four sets of guys broken up with egg type insulators were attached at six points on the structure.

The mast was fully assembled on ground and erected by the falling jury method. Vern Kenna, Divisional Engineer and Alf Howard, Draftsman were associated with this project.

With the commissioning of a 198 m dual frequency lattice steel radiator on site in 1948, 4QR shared the new radiator with 4QG and the bore casing structure remained as a standby. It was felled on 8 May 1987 to make way for a replacement standby aerial. Janis Ozolins was associated with the project.

Many vertical radiators have been installed in low lying flood prone areas to take advantage of the high conductivity of the soil but in several cases, this caused problems for the Design Engineer to ensure that the radiator remained operational during flooding of the site. This meant raising the transmission line, the aerial coupling box and the base insulator to a height to ensure they would remain clear for a predetermined rise of water.

Flood water levels of 2 metres are not unusual, and arrangements such as concrete blocks or metal frames are typical for mounting the base insulator. For tall radiators such as those above about 150 metres in height, a very substantial base structure framework is necessary if this method is employed.

The 198 m radiator at 4QN is typical of a station with a steel support base, while 4QG/4QR also with a 198 m radiator, employs a raised concrete block. Another station with a raised base is 2KP Kempsey where the insulator is mounted about 2.5 metres above ground level. The station is close to the Macleay River reputedly the fastest flowing river in the Southern Hemisphere when in flood. During the 1963 flood, the water level at the base of the 169 m radiator reached above 2 metres but did not interrupt station transmissions.

Great care is necessary in the design and provision of the earthing arrangement with radiators employing elevated structures for the base insulators and raised aerial coupling units. Many early installations experienced considerable signal instability trouble due to incorrect practices. The lesson learned was that no metal work should be installed near a radiator without making provision to either insulate or earth it. Experience at a number of sites indicated that it was not sufficient to just connect the aerial coupling unit box with a low reactance strap to the busbar at the base of the radiator where the radial earth mat wires were terminated. Where the ACU support frame was simply cemented in the ground, arcing frequently developed between steel footings and the nearest radial copper wire. At one station, the arcing occurred during the wet season and disappeared during the dry months. The arcing resulted in instability in the radiated signal. Solution of the problem encountered at various stations included insulating the ACU steelwork in the ground by using plastic tubing, brazing the radial wires to the steelwork or insulating the nearby radial wires. Also, when earthing the base insulator frame Engineers found that care had to be taken not to introduce coupled loop circuits. This problem did not occur with a copper covered concrete block.

Guys associated with insulated mast radiators are a critical component of the structure and station Engineers have found it necessary to provide regular inspection and maintenance, particularly at those sites with an aggressive environment such as locations near the sea.

Guy replacement is an expensive exercise. Where guys have had to be replaced, the main reasons have included:

- Damaged insulators resulting from electrical and mechanical factors.
- Corrosion of the steel wire strands.
- Increased operating voltage due to increase in transmitter power.

During 1992–93 Telecom Broadcasting undertook a major works program to replace guys at NBS stations 2BL/2RN Liverpool, 3LO/3RN Sydenham, 5AN/5RN Pimpala, 5CK Crystal Brook, 5SY Streaky Bay and 6WA Wagin. The structures had been in service for periods ranging from 30 to 56 years.

The procedure for changing the guys was basically the same for each structure. For sectionalised masts, the section point bracing steelwork was installed with the upper part of the mast resting on the sectionalising insulator. The bracing steelwork prevented any shear forces being transferred to the insulator. With the steelwork in place, all guy tensions were reduced to the pre-defined temporary or construction tensions.

A temporary guy was then installed parallel to the guy that was to be removed and while the tension in the temporary guy was increased, the tension in the guy which was being replaced was released. The insulated guy was then removed, and the replacement was simply the reverse procedure. During the changeover process, the mast deflection was measured from two directions as a check on the tensions which were being applied.

Nearly all vertical radiators in service today are insulated at the base and series fed, but an alternative is to earth the base and shunt feed it. This latter arrangement had its supporters during the late 1930s, as it was seen to provide better protection against equipment damage during a lightning stroke.

The radiator performance is about the same for both feed methods. However, much care has to be taken with the shunt feed arrangement to minimise ground or current return losses between the radiator base and the earthed point of the coaxial feeder where the inner conductor inclines up to the contact point of the structure where the resistance component of the system impedance is the same as the characteristic impedance of the coaxial feeder.

In the late 1930s, 2UE Sydney was one installation successfully using a shunt fed self-supporting tower with the base insulators shorted to ground. Murray Stevenson was Chief Engineer controlling the work.

Attempts by some Engineers to use the technique were not successful because the structures were not high enough in terms of wavelength. The structure had to be a minimum of 0.2 wavelength for the attachment of the inclined feeder to be reasonably close to the ground. At 5CL Brooklyn Park near Adelaide, the original aerial comprised a sloping cage aerial supported at one end by a 62 m high lattice steel tower. Decision was made to dismantle the sloping cage aerial and to use the support structure as a shunt fed radiator. However, the electrical height was too small to allow this arrangement, so the structure was raised, insulated at the base and series fed via a matching network.

One of the best known applications of an earthed structure is the folded unipole with skirt where power is applied to the skirt. It finds application where the structure has to cater for FM and TV services as well as the AM service.

Designers who prepared plans for the installation of transmitting equipment in the centre of cities were faced with the problem of providing an adequate aerial system. The practice started in the early days of broadcasting when A Class stations 4QG Brisbane and 6WF Perth installed their permanent aerial systems on the roof tops of city buildings. However, the towers in the case of 4QG and masts in the case of 6WF were not employed as the radiators. They supported wire aerial systems. Many Commercial stations followed a similar practice.

The use of a single lattice steel tower insulated at the base by specially designed porcelain insulators and mountings at the base, with structure being used as a radiator, received some support from designers during the 1930s.

The obvious advantage of a single tower used as a radiator compared with two to support an aerial was that it required less space. However, the roof top construction had to be capable of supporting the weight of the tower plus handle the reaction of wind induced forces on the structure. Depending on the design, the area required to mount the structure was between 8 and 20 % of the overall height of the structure. Consideration had also to be given to the logistics of getting the individual steel members to the roof top to enable the erection to proceed.

Typical examples of roof top radiators included National stations 5AN Adelaide commissioned on 15 October 1937 with a 500 watt transmitter feeding a 62 m tower on a building in Post Office Place alongside the Adelaide GPO; 4QR Brisbane commissioned on 7 January 1938 with a 500 watt transmitter feeding a 55 m tower on the Central Automatic Exchange building in Elizabeth Street; 6WN Perth which went to air on 12 October 1938 with a 500 watt transmitter feeding a 60 m tower on the roof of the Perth GPO; Commercial station 5AD Adelaide employing a 50 m tower on a building at 11 Waymouth Street, Adelaide and others.

Another Adelaide station, 5KA, also employed a lattice steel tower as radiator in the city centre but it was installed on foundations in the ground rather than on top of a building. The station had been closed down during 1941 by order of the Government when National Security Regulations were invoked while operating from Richards Building, Currie Street, Adelaide with an end fed flat top aerial supported by two wooden masts on top of the building. When the station reopened under new owners in 1943, equipment was relocated to the Central Methodist Mission Building, Franklin Street with the aerial initially comprising a single copper wire strung from the church steeple. Twelve months later, a 62 m high lattice steel self-supporting base insulated tower was erected as a radiator. Foundations were installed in the ground using a five metre square layout. The structure tapered to one metre square at the top where aircraft warning lights were installed. The total weight of steel in the structure was 20 tonnes and the porcelain base insulators were subjected to test loads of 90 tonnes each prior to installation.

One country Commercial station which employed an insulated four leg tower was 2CK Cessnock commissioned on 9 January 1939 by Coalfields Broadcasting Co., Pty Ltd. The radiator was of lattice steel design 170 ft (52 m) high and approximately one quarter wavelength of the station's carrier wavelength of 205 metres. The weight of steel employed was 4.5 tonnes, with the four concrete leg foundations using concrete of total weight 34 tonnes. The earth mat comprised 360 copper radials each 167 ft (51 m) long radiating from a copper sheet at the base of the structure about 28 ft (8.5 m) diameter. The far end of each radial was terminated on a 4 ft (1.2 m) galvanised stake driven full length into the ground. The total length of wire laid with the earth mat was 11 miles (17.6 km) and weighed 0.85 tonne. Aircraft warning lights were fitted to the top of the tower.

The radiator was located at Neath with an AWA 2 kW transmitter while the three studios were located in Vincent Street, Cessnock. Station Chief Engineer was Tom Taylor.

A major problem encountered in the design of a roof top tower radiator was the provision of an acceptable earth mat system for the radiator. Some installations had radial wires extended to adjacent buildings with the entire mat being insulated and acting as a counterpoise. Compared with a similar radiator at ground level with a buried radial earth mat, most roof top systems were classified as 'poor' in a rating scale of 'poor', 'medium' and 'good'. For a 52 m radiator operating at say 1000 kHz, typical measured field strength figure was 140 mV/m at one mile for 1 kW input compared with about 180 mV/m for a similar radiator at ground level on an earth mat of 120 radials of 150 degrees in length.

For a power input of 2 kW at the base, the base voltage for both radiators was about 1 kV RMS at 1000 kHz.

MF vertical radiators are sometimes used for other purposes in addition to their broadcast role. A typical example is for support of one or more TV aerial systems. A number of techniques are available for using an insulated structure as a combined MF radiator and support for TV aerials. However, the most popular involve the use of lumped components or a transmission line section.

In the lumped component method, the TV coaxial cable is formed into a coil between ground and the insulated mast base with the inductor being tuned to resonance at the MF band frequency with a parallel capacitor. The high impedance in the resonance condition results in only small change to the tuning of the MF aerial. However, this arrangement requires that the transmitter be located close to the base of the mast, particularly for UHF transmissions.

For the transmission line method, the coaxial TV cables are connected to the bottom of the mast each a distance of a quarter wavelength from the mast, then earthing the cable at that point. This shorted quarter wave line then represents a high impedance at the mast with minimal effect on the aerial tuning.

At NBS station 6DL Dalwallinu, operating on a frequency of 531 kHz, the transmission line method was employed to cater for a UHF translator installed during early 1985.

The receiving installation consisted of a twin Yagi phased array at a height of 75 m connected by 22 mm coaxial cable to the translator in the 6DL building 200 metres from the mast. For transmission, a 75 mm coaxial cable fed a UHF Bogner slot aerial 150 m above ground.

The quarter wavelength coaxial cables were attached to a catenary wire with the catenary wire and coaxial cable outers connected to the mast at one end and earthed 140 m from the mast. The catenary wire was suspended from steel poles by insulators. The poles were approximately 3 metres high so that the cable was well out of reach of staff who may have been in the area. A copper bus bar was run from the earth at the base of the mast back to the quarter wave earth point to provide a positive return path. The quarter wave earth point was also connected to two earth radials on either side.

After installation, only minor retuning of the MF aerial tuning unit was required. This was ascribed to stray effects associated with the catenary such as the capacitance of the support insulators.

Since the employment of lattice steel or bore casing masts and lattice steel towers as broadcast radiators, or as supports for wire aerial systems, many firms have been engaged in the design, manufacture and erection of the structures. Although a number of structures were acquired from overseas sources from time to time and erected by local contractors, the majority were manufactured in Australia.

Major suppliers include:

- Deeco Steel Construction Co., 4GM, 36 m; 6CA, 31 m; 6BS, 45 m; 6DB, 31 m; 6ED, 31 m; 6GF, 31 m; 6PH, 31 m; 6WN, 31 m; 6WH, 31 m; 6MN, 33 m; 6TP, 37 m; 6PU, 37 m; 6PN, 37 m; 6BR, 46 m; and others.
- Electric Power Transmission Pty Ltd, 4QO, 137 m; 4QW, 207 m; 6BS, 183 m; 6MJ, 99 m; 5CL/5AN, 167 m; 5CK, 182 m; and others.
- Johns and Waygood Ltd, 5CL (original) 62 m; 4RK, 128 m; 4QN (original) 152 m; 4QN, 198 m; 4QS, 216 m; 4QL, 198 m; 4QB, 76 m; 4QY, 41 m; 4QA, 41 m; 4QG/4QR, 201 m; 6DL, 213 m; 6GF, 123 m; 6GN, 61 m; 6WA, 200 m; 6WF/6WN, 180 m; 5CK (original) 56 m.
- Metters Ltd, 5AD, 86 m; 5WM, 21 m; 5MG, 21 m; 8KN, 21 m; 8TC, 21 m.
- Skilfast, 4MS, 61 m; 6AL, 88 m; 6BE, 31 m; 6DB, 40 m; 6DL, 86 m; 6ED, 62 m; 6NM, 86 m; 6PH, 41 m; 5PA, 130 m; and others.
- Andrew Antennas, 4CH, 90 m; and others.
- Ascom Pty Ltd, 4JK, 195 m; and others.
- Colton, Palmer and Preston Ltd, 5AU, 58 m bore casing.
- Good Engineering Pty Ltd, 4AT, 138 m; 2HD, 134 m.

Other firms engaged in the design, supply or construction of broadcast masts and towers included, A G Miers Pty Ltd, G P Wallace, Hardinge, Hills Industries Ltd, Hilo Mast Ltd, James Watt Engineering Pty Ltd, Jennis and Le Blanc Communications Pty Ltd, Prince Engineering, Radio Masts (Aust.) Pty Ltd, Transfield Pty Ltd, ARFC Pty Ltd and Austpower.

At a number of locations where multiple aerials were in operation in close proximity, undesirable coupling between transmitters operating on different frequencies was a common problem. To overcome the problem at some metropolitan centres, it was necessary to install band-pass and band-stop RF filters. STC and AWA designed, manufactured and commissioned equipment at a number of stations where trouble had been experienced.

Aerial Impedance Measuring Equipment

One of the important properties of an aerial is the impedance that it offers to the applied voltage from the transmitter at the operating frequency. A range of different impedance measuring devices have been employed over the years. Considerable experience was necessary in using many of the instruments as it was not always a simple matter to determine the true impedance. Aerial coupling huts or boxes were frequently mounted some distance from the base of the radiator feed point, some were elevated well above the ground level and so were many base insulators.

The impedance of the aerial depends upon a number of factors including the point of the aerial at which the measurement is made, the presence of nearby metal objects such as steel frames of aerial coupling units, steel posts and wire surrounding the base of the radiator, transmission line terminating towers, lighting transformers, lightning horn gaps etc.

The widespread practice of 24 hour operation of broadcasting stations in recent times has made the work of measurements on aerial systems extremely difficult, particularly at night-time when most of this type of work is carried out.

In the 1920s and early 1930s, the resistance component of an aerial was measured by either of two methods. They were known as the resistance variation and resistance substitution methods. The majority of Engineers favoured the substitution method as it was faster and did not require the preparation of a graph. The measurements could be made using components. Station owners could seldom afford the luxury of an expensive impedance instrument which had so little use.

One Engineer who had experience of aerial measurement work extending over some 40 years was Doug Sanderson. Since 1947, instruments he had used included Aerial Impedance Meter designed by PMG's Department Research Laboratories, General Radio Series Reading Bridge, Muirhead and Wayne Kerr Parallel Bridges, Type 1606 GR Bridge, 01B Delta In-line Bridge, Delta RG4 and Hewlett Packard 8753 Network Analyser.

Doug Sanderson began his career in the Postmaster General's Department in Brisbane as a Technician-in-Training in January 1941. He progressively advanced through the ranks of Technician, Supervising Technician, Trainee Engineer and Engineer spending almost his entire 48 years of service with the Department and later Telecom, in radiocommunications and broadcasting areas.

He worked at many centres throughout Queensland on broadcasting activities including periods at the Brisbane Metropolitan ABC Studios in the days when the Department was responsible for the technical facilities; transmitter installations at 4QL Longreach, 4QN Townsville and others; selection of broadcast transmitting station sites throughout Queensland and Papua New Guinea; field strength measurements of NBS stations and Commercial stations for the ABCB; and maintenance of MF, HF and FM stations of the NBS throughout Queensland.

In 1988, just prior to his retirement from Telecom, Doug completed an extensive document 'On Air', outlining the history of the National Broadcasting Service throughout Queensland and Papua New Guinea together with technological developments of MF, HF and FM stations in the State.

Figure of Merit

For many years aerial designers assessed the relative merits of broadcast radiators by calculating or measuring the field intensity at a distance of one mile (or one kilometre) for 1 kW radiated. The figure was known as the Figure of Merit and in more recent times as Cymomotive Force (CMF) in accordance with CCIR Recommendation 561–1. The figure is formed by multiplying the electric field strength by the distance point from the radiator. The distance must be sufficient for reactive efforts to be negligible. The finite conductivity of the ground is taken to have no effect on propagation.

The following selected Figure of Merits of some National stations aerial systems in New South Wales operational in the 1970s are representative:

Station	Frequency kHz	Radiator Height m	Type	Base Z	Figure of Merit
2FC	610	224	lattice steel	90–j175	240
2BL	740	224	lattice steel	495–j310	268
2CY	850	191	lattice steel	77–j144	234
2CO	670	55	multiple tuned	81–j103	165
2BA	810	142	sectionalised/hat	58–j190	252
2CR	550	198	lattice steel/hat	88–j291	261
2WN	1580	26	steel tubular	7.7–j88	181
2NA	1510	91	lattice steel/hat	115–j205	226
2NC	1230	91	lattice steel/hat	159–j262	231
2ML	560	52	lattice steel/hat	16.5–j131	153
2KP	680	170	sectionalised/hat	52–j228	259
2NR	700	155	lattice steel/hat	145–j165	254
2NU	650	171	lattice steel/hat	113–j260	225
2GL	820	142	sectionalised/hat	66–j266	264
2AN	720	24	wooden pole/ umbrella	5–j68	162
2CP	1570	26	modified Winchamatic	13.5–j200	159

EARTH SYSTEMS

THE COUNTERPOISE

Prior to the development of tall steel vertical radiators, the ground was not considered to be of any great importance in the electromagnetic transmitting chain. Earth system design was considered to be a 'black art' and text books of the period devoted very little space to design aspects.

Some academics however, had firm ideas on the role of the earth in radiocommunication. Professor Pupin of Columbia University, an admirer of Marconi, said in 1912 at the time of the Titanic disaster:

'When he (Marconi) grounded the transmitter and then the receiver, and let the spark go, then the world had wireless, and no one had done that before.'

He had more to say about the earth in his autobiography in 1922:

'Every now and then we are told that wireless signals might be sent some day to the planet Mars. These suggestions are unscientific for the simple reason that we cannot get a ground on the planet Mars and therefore cannot take it into close partnership with our Hertzian oscillations. Without that partnership there is no prospect of covering great distances.'

One of the earliest radio earth systems used, was a buried cylinder. It is known to have been used in the USA and in Germany prior to 1910. It consisted of a cylinder 5 m in diameter made of sheets of galvanised iron. Radial wires were soldered to the iron, and at the centre point, a wire was taken to the transmitter ground terminal. Some illustrations show the cylinder being buried in the ground while others show the cylinder as being kept free of the earth by mounting it on wooden planks.

The next development was the counterpoise or capacity ground. Design guidelines issued in 1923 by the PMG's Department Chief Inspector (Wireless) included the following comments:

'The shape is not important but it should be placed as nearly under the aerial as possible and should extend out well beyond the aerial's projection on the earth. The number of wires should be as large as possible and bound together with cross wires.

The height of the counterpoise is governed by several considerations including separation of the wires, evenness of the ground and its conducting qualities. A height of 8 to 10 ft (2.5 to 3 m) is a good safety compromise.

The counterpoise is a condenser and should be treated with respect.

Wires should be terminated at both ends with good quality porcelain insulators.

In no circumstances should the counterpoise be directly grounded at one or two points, for this will defeat its whole purpose.'

When 4QG Brisbane was installed on the roof of the Queensland State Insurance Building, a counterpoise was erected to cover most of the roof area. The wires were supported by steel poles.

In the case of 6WF Perth, where the aerial was supported by masts on top of the building containing the transmitter, the counterpoise consisted of eight parallel stranded copper wires spaced 1.9 m apart and running the full length of the building at a height of 2 m above the corrugated iron roof. With 3LO Melbourne and 2FC Sydney, using aerials which employed support masts on the ground, the counterpoise was supported by steel poles 4.5 m high and a terminating tower near the building. The wires were insulated from the support structures by large porcelain insulators.

There appears to be no record of a counterpoise being used with the original 5CL Brooklyn Park installation, but in the early 1930s after the station had been taken over by the Postmaster General's Department, an experimental counterpoise system was constructed. However, it was no better than the buried ground system and was dismantled. It was arranged about 2.5 m above ground and ends terminated on steel poles erected on three sides of the main building. The buried ground system at the time comprised two backbone leads of 4 mm diameter copper wires, with cross wires of 2 mm diameter wires attached every 600 mm with network being buried 300 mm deep and extending over the whole of the site.

Many Commercial station aerials of the same period also employed counterpoise systems. Station 5DN is typical. Immediately beneath the 65 cm diameter cage aerial was a five wire counterpoise. At the transmitter end of the inverted L aerial where the feeder was attached, the counterpoise system wires were evenly spaced across a two metre spreader located two metres above the ground. The other end of the counterpoise was spaced across a three metre wide spreader. One end of aerial tuning network was connected to the aerial while the other end was tied directly to the counterpoise. The inductor's neutral point was tied to an earth plate buried in the ground.

Although counterpoise systems were gradually replaced by buried earth systems, a number were still in existence in the late 1930s. They also found application with vertical self-supporting radiators mounted on building rooftops. The second NBS metropolitan station in Adelaide, 5AN, installed in 1937 operated into a self-supporting insulated tower 62 m high located on top of a 24 m high building located at the back of the GPO. The counterpoise consisted of some 25 radial wires varying in length from 10 m to 90 m extending to adjacent buildings. The wires terminating under the tower base were 2 m above the rooftop.

Commercial stations with aerials erected on buildings and employing counterpoise earth systems included 3UZ with a T type aerial in Bourke Street, Melbourne; 4BK with a vertical steel radiator in Queen Street, Brisbane; 5KA with an inverted L aerial in Currie Street, Adelaide; 5DN with a cage T aerial on Savory's Building, Rundle Street, Adelaide and later at CML Building, King William Street, Adelaide; 7HO Hobart provided with a Marconi T type suspended by two 46 m masts, the vertical portion of which was equivalent to one eighth wavelength; and 2UW with a tapered tower on the State Theatre Building, Market Street, Sydney.

Counterpoise installations were also provided at some sites of restricted size where it was not practicable to install a conventional earth system. The establishment of 4QL Longreach in 1947 in the local Post Office yard was a typical example. A counterpoise comprising 16 poles about 5.5 m high with a copper wire from each pole converging to an insulated attachment fixed to the 22 m high steel pole radiator was installed. The counterpoise was earthed at the aerial coupling unit located on the wall of the transmitter building.

Ken Bytheway was Officer-in-Charge when the station was commissioned. Engineers associated with the project included Arthur Clark, Acting Engineer; Vern Kenna, Divisional Engineer; and Sam Ross, Supervising Engineer.

BURIED EARTH SYSTEMS

One of the first buried radial systems was designed and installed by Lee de Forest in the USA as early as 1904 when he installed wireless telegraphy stations at Cleveland and Buffalo. The aerial systems comprised fan types supported by a pair of 210 ft (64 m) masts. The copper earth wires were laid in hand dug trenches radiating from the transmitter shack located beneath the aerial.

At the time, the stations 180 miles (296 km) apart, created a world record for wireless communications over land and ice.

Another early USA installation was designed by Reginald Fessenden in 1909 for use with 122 m steel tubular radiators he erected in USA and Scotland for transatlantic trials.

Fessenden called his system a 'wave chute'. Although of radial format, the wires were not buried but laid on the surface of the soil. The amount of wire employed totalled 160 km with the system covering an area of 2.4 hectares.

With the employment of tall radiators in Australia in the 1930s for MF broadcasting purposes, it soon became evident that the ground played an important role in efficient propagation.

In a vertical broadcast radiator a displacement current extends from the tip of the radiator through the surrounding space to ground. On entering the earth, the current returns to the base of the radiator and becomes portion of the aerial current. In practice, normal earth is an imperfect dielectric so that there would be high return current losses unless a system with high conductivity properties was provided in the ground to minimise the losses.

Earth currents return to the base of the radiator along radial lines so that an earth mat in a radial format is the preferred type for a vertical radiator.

In selecting a site for a radiator requiring a buried earth mat the site condition should be of primary consideration. Some Engineers have selected sites because they gave good elevation but in doing so paid the price of excessively high cost in putting down an efficient earth mat because the sites were devoid of adequate soil cover over basic rock. At Rosny Hill where Commercial station 7HT Hobart's aerial and earth mat were installed in 1937, there was so much loose rock on the site that workers used it to build a 1.2 m high stone wall around the entire property boundary. Obtaining a low resistance earth for the transmitter also caused a major problem for the installation Engineer.

In order to provide a suitable earth system for the aerial, aerial coupling unit and the transmitter, a thick copper plate about one metre square was buried in the centre of the site under the aerial system and copper radial wires fanned out at six degrees spacing. The aerial was supported by two 40 m high guyed wooden poles and fed by a balanced open wire transmission line supported by 3 m high wooden poles. Gil Miles formerly of 3AW Melbourne was Chief Engineer of the project.

Radials consisting of buried solid copper conductors are seldom taken out to a distance beyond about 0.5 wavelength from the radiator base because returning ground currents are very low beyond this distance. In practice, most designs use radial lengths between 0.25 and 0.4 wavelength in length. Usually, radials are laid 200 to 300 mm deep and spaced about 3 degrees apart. With most of the tall radiators erected for the NBS in the 1930s, a radial spacing of 2½ degrees was employed.

An efficient earth system is important for antifading type radiators. A surface near the radiator of high reflectivity for those electromagnetic fields which produce cancellation of high angle radiation is essential.

Where buried earth systems were provided with the T or inverted L type aerials they were usually of a fishbone pattern, a grid pattern or a combination of grid and radial.

The system provided for the 5CK multiple tuned aerial was typical of fishbone pattern installations. It comprised a large backbone copper conductor directly beneath the aerial and extending past the towers at each end. Leads were taken from the backbone conductor to each tuning hut and to the transmitter. Cross wires at right angles to the backbone were spaced 600 mm apart, buried about 225 mm and extended to the boundary of the property. Staff associated with this project included Frank O'Grady, Laurie Billin, Bill Whisson and Ted McGrath.

The 6WF installation commissioned in 1932 at Wanneroo Road, North Perth also employed a multiple tuned flat top aerial system and used a similar earth system of 2 mm diameter copper wires spaced at 600 mm intervals and connected to a centre backbone conductor which ran through the line of the towers and the tuning huts. Altogether, there were about 35 km of copper wire laid for the earth system.

The 7ZL Hobart four wire inverted L flat top aerial installed in 1927, had a slightly different format. Between the two support masts and directly beneath the aerial, the earth mat comprised a rectangular grid 76 m by 40 m brazed at cross points to form 1.5 m square grids. At each end was a semicircular radial system 20 m in diameter, with the radials at the circumference being 1.5 m apart.

The 3AR earth mat installed at North Essendon in mid 1924 was also a grid pattern design. It comprised some 5.6 m of copper wire buried 300 mm below the surface in 3 m grid squares. Wires at the crossover points were soldered to ensure good contact and to improve the effectiveness of the earth system. The system was designed by Donald MacDonald Consulting Engineer for the company and followed practices employed at some Coast Radio Stations many years earlier when MacDonald worked on the installation of these stations.

When the owners of 3CV decided to relocate their station from Charlton to Maryborough in Victoria during 1943, they invested considerable capital in the installation of a comprehensive earth mat in order to provide maximum signal strength throughout the service area. The 500 watt Transmission Equipment transmitter fed an 82 metre high tubular steel radiator and it was not easy to locate sufficient 100 pound per mile copper wire for the earth mat during the War years. The earth system laid in a radial form with vertical stakes at the far end of each radial wire covered an area of some 4.5 hectares. In 1945, Chief Engineer and District Manager was Ken Parker.

With the 2NC and 4RK flat top aerials installed in 1930 and 1931 respectively, the earth system comprised about 95 copper wires running at right angles to the line of the masts and provided a mat of area approximately 91.5 metres by 55 metres. The wires spaced about 90 cm apart were buried in trenches 15 cm deep and commoned up by a main backbone conductor running immediately beneath the aerial. From the centre of the backbone conductor a lead was taken to the RF earth terminal of the transmitter. Altogether, 11 km of solid copper conductor was buried. The aerial resistance was about 20 ohms for 2NC on 1244.8 kHz and 12 ohms at 910 kHz in the case of station 4RK.

When a new transmitting facility was erected for Commercial station 2UE at Lilli Pilli, Port Hacking, 13 km south of Sydney GPO in 1930, the signal strength was considerably below what had been expected from the new water cooled transmitter operating on 1025 kHz and feeding 1000 watts into the T type cage aerial supported by two 55 m high towers. The problem was traced to the poor conductivity characteristics of the site. To reduce earth current losses on the site, Chief Engineer Murray Stevenson installed a system comprising an earthed wire mesh supported a few inches (about 75 mm) above the ground and located immediately beneath the aerial.

Ground mats have not been employed in Australia at short wave stations using horizontally polarised aerial systems, but they were employed with the Radio Australia Cox Peninsula transmitting station where vertically polarised dipoles in a dual plane log-periodic aerial system were used. Five systems were installed and beneath each, a ground screen of copper wire which fanned out in the direction of propagation was provided. In the immediate vicinity of the aerial the screen was in the form of a rectangular grid with longitudinal and cross wires ploughed in at different depths using a multiple mole plough arrangement. Beyond the aerial element the wires were laid in a longitudinal direction only, in a fan pattern. Overall length of each ground mat was about 310 metres. The aerial systems were destroyed in 1974 by Cyclone Tracy, and the ground mat was left in situ after erection of the horizontally polarised curtain systems in 1984.

Designer of the ground screen system was CO-EL, Milan, Italy with the work being carried out by RCA (Australia) Pty Ltd. People associated with the project included Ross Burbidge, Don Rodoni, Ralph Gurner, Jim Finch, Don Beames, Lionel Parker, Bill Beard, Jack Ross, Bill Shapley, Frank Mullins and others.

Ross Burbidge RCA Project Manager had previously worked in the Australian Post Office when he joined as Engineer Grade 1 in 1956. He worked in the Victorian Radio Section in a number of areas including upgrading of the Radio Australia Shepparton facilities. He left to join RCA and during the period 1965 to 1972 was Project Manager responsible for the installation of external plant and radio link equipment at the transmitting and receiving stations.

Where standby or emergency aerials were provided, cost of provision of the radiator and associated earth mat were important considerations. However, a standby aerial at a 50 kW station where a tall antifading radiator often served as the main aerial, a greater capital cost would be justified for a standby system compared with a lower power station eg 2 kW output.

Since the installation of solid state transmitters up to 50 kW output and their high degree of redundancy, there has not been the same level of support for standby aerial systems except as a need to provide for instances when the main radiator has to be taken off air for routine maintenance purposes. In past years, a 50 kW station was provided with a 10 kW standby transmitter and when it became necessary to make use of the 10 kW transmitter, normal practice was to feed it to a standby radiator. A typical vertical standby radiator was fitted with an earth mat comprising 120 radials, 150 degrees in length. Frequently, advantage could be taken of the earth mat associated with the main radiator to minimise costs by erecting the standby just outside the outer guy anchor block area.

Two Engineers who made a significant contribution to standardisation of aerial systems without special antifading properties, were Frank Brownless and Frank Dwyer. Both were members of the Postmaster General's Department, Radio Section. During 1950–51 they undertook a detailed investigation into types of aerials suitable for application as MF radiators in the National Broadcasting Service, presenting calculated performances of a wide range of suitable types and earth systems.

FM AERIALS

Frequency modulation services operate in the 88–108 MHz band and aerials are designed to meet the specific requirements of each station. They vary in design from very simple omnidirectional models to high power models frequently with specified vertical and horizontal patterns. Polarisation may be horizontal, vertical or mixed.

The aerials used in Adelaide for transmission of ABC programs from 1947–48 are typical of types available at the time when experimental transmissions were being carried out. The original aerial was a halo type of four elements. In 1951, the halo unit was replaced by a 17 m high pylon type comprising slotted line sections. Although the mono service ceased on 30 June 1961, and recommenced as a stereo service on 24 January 1976, the pylon aerial, for some time, served as a standby unit at the Mt Lofty transmitting station. Engineers associated with the design and development of the pylon aerial were Frank Norman and Frank Brownless of the PMG's Department Head Office Radio Section.

The main aerial for the new stereo service comprised a four corner reflector type located on the television tower at the 100 m level and placed to give an approximate omnidirectional radiation pattern. Early in 1990, it was replaced by a two level RFS type CP903 system designed and manufactured by Radio Frequency Systems.

In Sydney, an experimental FM service was put to air at the PMG's Department Radio Communications Laboratory during 1952 with an aerial of unknown type on an existing 30 m tower. The rig caught fire some time during 1958, and the service discontinued until new equipment assembled from parts of the earlier facility and locally built units by Brian Eagle, Charlie Youngston and R Broad was put to air during 1959 at Gore Hill. Output was fed via a 6 inch rigid copper feeder to a series of vertical dipoles mounted on a 27 m steel pole on top of the television tower. The service was shut down during 1960 and sold to the North Sydney Technical College for training purposes.

When the ABC FM stereo service came into operation on 26 January 1976, the 6 inch rigid feeder on the tower was linked to a new aerial system.

With the commissioning of 2JJJ FM on 1 August 1980, a corner reflector aerial located immediately below the TV Channel 2 dipoles was installed.

In Queensland, an FM service was established on 6 October 1953 using the ABC 4QR program. The station was installed at Mirrimbul with a folded dipole halo type aerial erected on a 30 m high self-supporting wooden tower fabricated by the PMG's Department Brisbane Workshops. Polarisation was horizontal and the aerial feeder comprised an armoured coaxial cable of 100 ohms impedance. Adjustment operations were carried out by Doug Sanderson and Ted Dennis of the Department's Radio laboratory.

The original service was closed down on 30 June 1961, and when the ABC FM stereo service commenced operation in 1980, a Co-EL type CO-7FM aerial producing a horizontally polarised signal was installed on the Mirrimbul TV tower, at the 100 m level.

A wide variety of aerial types have been, or are in service at National, Commercial and Public stations. They include cloverleaf, ring, dipole panels, slot, coniquad, Shively, Yagi, RFS broadband sideband aerials and others.

The cloverleaf aerial derives its name from the shape of the radiating elements. Its chief characteristics are its rugged construction, omnidirectional radiation pattern, ability to handle high power and simple construction. No insulators are required which gives it good protection from lightning strokes. Individual units are stacked at half wavelength spacing to increase the power gain.

The ring aerial is basically a half wave dipole bent in a ring form with capacitor plates attached to the ends. Any number of rings may be stacked to provide flexibility in power gain to meet any particular design situation requiring an omnidirectional pattern.

The radiator used with the dipole panel system is a full wave dipole permitting broadband matching, and through an appropriate choice of ratio between dipole length and dipole diameter it permits the adjustment of input impedance within relatively wide limits. Panels can be combined in groups on a common support structure to produce a wide variety of overall radiation patterns, beam tilt and null fill options. They may be either vertically or horizontally polarised. The panel array feed system consists of a balun mounted behind the reflector screen through which is connected a balanced feeder system which feeds all dipoles in phase.

The slot aerial is based on the principle of a simple half wave dipole where the slot may be considered to comprise an infinite number of dipoles in parallel stacked one on top of each other. Although the slot is vertical, the aerial radiates horizontally polarised waves. The only known aerial of this type in Australia was in Adelaide earlier used as a standby for the ABC FM stereo service.

The coniquad is a circularly polarised broadband panel intended for the construction of high power, multi element arrays of various configurations. With a wide horizontal radiation pattern of 120 degrees it is particularly suited for omnidirectional use on a triangular supporting tower.

The Shively system has a number of models. The model 6810 is a circularly polarised aerial which radiates equal energy in the horizontal and vertical planes. It features sectionalised construction and can be created with as many sections as are required for a given application.

The Yagi aerial is popular to produce a high field strength in the direction of scattered isolated populated areas. The most widely used are three and six element types and are available for all three types of polarisation.

At National stations where more than one FM transmitter may be operational, aerial systems are typically designed to operate with up to eight omnidirectional, circularly polarised services with an average effective radiated power of 50 kW for each service and transmitter powers of 20 kW. It is usual for the system to be divided into two half sections, an upper stack and a lower stack, often with each stack being capable of handling the full output power of all transmitters. The aerial is generally fed by twin 127 mm (5 inch) main feeders some of which may even be up to 180 m in length.

At stations which accommodate both TV and FM services, it is often practice to use a common aerial for the TV and FM transmitters with a combiner unit. A typical installation is that provided in 1990 at Mt Stuart near Townsville. The aerial consisted of six levels of FM panels mounted in a square configuration. It was a Radio Frequency Systems design Model 904CP FM and had four dipoles mounted off a reflective screen to allow the aerial system to broadcast a combined horizontally polarised TV signal and circularly polarised FM. The broadband aerial covered from Channel 3 (86–93 MHz) to the top of the FM band (108 MHz) with a VSWR of less than 1.05:1. The power rating of the aerial was designed to allow full power of the combined signal (one 20 kW TV service and up to eight 20 kW FM services) to be fed into either half of the aerial if required. The FM-FM combiner comprised two constant impedance combiner modules. Three pole aperture coupled bandpass filters were used in each module which ensured that physical size was minimised while maintaining power rating and isolation between transmitters.

When 2KO Newcastle transferred operations to the FM band on 12 October 1992, it employed a Jampro aerial system and Andrew Australia coaxial feeder installed and commissioned by Comsyst Pty Ltd. The facilities were installed on the NBN TV tower at Mt Sugarloaf. The tower had been upgraded by reinforcement of the footings to accommodate the main and standby FM aerials for 2KOFM. The main aerial was a 4-bay Jampro side mount type and the standby, a 2-bay Jampro type.

The NBN tower also carried FM aerials for other services including 2NUR-FM 4-bay Phelps Dodge main and standby aerials and 2NEW-FM 6-bay Shively main and 3-bay Shively standby.

The Mt Dandenong site near Melbourne where five FM Commercial transmitters are combined into a single aerial, is also an installation of interest. Combined input power into the aerial is 30 kW.

Stations using the aerial system at 1993 included 3FOX on 101.9 MHz, 3TTT on 101.1 MHz, 3RRR on 102.7 MHz, 3KKZ on 104.3 MHz and 3MMM on 105.1 MHz.

The aerial system which weighs 2.5 tonnes was mounted on top of one of the television station's 150 m tower. It was a 24 x 24 element array of dipoles, half horizontal and half vertical to produce a right hand circularly polarised signal. It was broadbanded to cover the 88–108 MHz FM broadcast band.

The pressurised coaxial feeder cable which carried the combined powers was 4½ inch (112 mm) diameter and had a handling capability of 70 kW.

Many people were involved in the establishment of the transmitting facility and included Steve Adler, Brian Perry, Graham Davey, Alan Wighton, Vic Duffy, Bob Rosenthal, Frank Wilcox, Alan Liddelow, Des Deacon, Larry O'Toole and others.

One of the last combined TV/FM aerial systems in 1995 provided for the National service, was put into operation at the NTA Mt Barker station which serves the southern agricultural area of Western Australia. The station had been operational since 6 June 1966 and extensive upgrading work was undertaken during 1995. Services from the station included ABC-TV, and three ABC radio services in the FM band — Classic FM, Radio National and Triple J. The Radio National and Triple J services were new facilities provided as part of the upgrading work. The Radio National transmitter was the 223rd to be installed by NTA around Australia.

A major part of the upgrading work was the provision of a combined or interlaced aerial for transmitting both the TV and FM services. It replaced the separate TV aerial AWA type 4Y60856 in service since 1966, and the Classic FM aerial in service since July 1984. A benefit from the new common aerial was an improvement in FM radio signal coverage due to a higher and better location on the 167 m tower.

The transmitting aerial combined with the transmitter plays a major role in providing a satisfactory signal level in the designated service area. Recommendations of the International Telecommunications Union require that the median field strengths for an FM service at least meet values of 48 dBuV/m for rural mono or 54 dBuV/m for rural stereo; 60 dBuV/m for suburban mono or 66 dBuV/m for suburban stereo; 70 dBuV/m for urban mono or 74 dBuV/m for urban stereo services. The same ITU recommendation indicates the difference in field strengths required when both wanted and unwanted signal are present at the reception point.

To guide FM planners, the ABA has produced a set of Technical Planning Guidelines which indicate the maximum field strength permitted within a licence area and beyond the licence area. This is necessary to ensure a service does not impinge on the licence area of another or cause interference to surrounding services.

Automated prediction models are employed by the ABA to estimate field strengths from HP1000 and RADCOM computer systems. A digital terrain database is used to construct path profiles from proposed transmitter site to reception points.

In a paper delivered at the ABA Planning Seminar in Canberra February 1997, Julie Spencer of the ABA Planning Branch discussed five models, representative of a number of theoretical and statistical models available, for predicting the field strength of a signal at a given receiver point.

The major Australian designer and manufacturer of FM aerials for transmitting purposes is Radio Frequency Systems Pty Ltd. They include Band II Panel Arrays 904 Series designed as a building block for broadband high power FM arrays for broadcasting in the FM band; Band II Panel Arrays 903CP Series, a circularly polarised aerial system designed for triangular cross section masts; FM Sidemount Antenna 828 Series designed for applications which require circular/mixed polarisation and low wind loads; Low Power FM Yagi Antennas 902CP Series intended for applications which require circular or elliptical polarisation and low wind load; Sidemount FM Dipoles SL1-818 Series providing vertically polarised aerials for use where low wind loadings are required and for sidemounting on a tower leg or a pole; Sidemount FM Antennas 760 Series, horizontally polarised antennas for use where low wind loadings are required and designed to be sidemounted on a tower; Log-periodic Antennas LPDR FM Series, a wideband system with low VSWR and without lateral lobes; Ground Plane Antennas GPLB FM Series omnidirectional antennas with vertical polarisation designed for Band II radio broadcasting; Sidemount FM Antennas Shively 6800 Series featuring sectionalised construction which can be supplied from single bay up to 16 bay format; and others.

SHORT WAVE AERIALS

AWA SERVICE

When Amalgamated Wireless (A/Asia) Ltd, operated its experimental worldwide short wave broadcasting service with stations at Melbourne, Sydney and Perth, the aerial system employed at VK3ME at Braybrook, west of Melbourne in 1927 was a half wave vertical type designed for low angle uniform radiation fed by a conventional feeder 76 m in length. The beam angle measured on the VK2ME Sydney aerial was approximately 45 degrees.

LYNDHURST

The Postmaster General's Department Research Laboratories had established an experimental short wave station at Lyndhurst in 1928, and in 1934, when the station was placed into regular broadcasting service with programs provided for the National transmitters by the ABC, the aerial system consisted of a horizontal half wave doublet providing substantially non-directional transmission on 9580 kHz.

Following favourable listener response to the service, the facilities were completely redesigned with the new facilities being brought into operation on 10 October 1938. The aerials comprised a vertical half wave omnidirectional radiator designed for operation on 9580 kHz, a rhombic system directed on Great Britain with switching facilities to enable transmission over the long or the short path and capable of operation on 6140 kHz, 9580 kHz and 11880 kHz, plus three tuned horizontal arrays for operation on the same frequencies. The 6140 kHz array consisted of a single half wave radiating element with reflector, each being three quarter wavelength above ground. The 9580 kHz and 11880 kHz arrays comprised two half wave radiating elements located respectively one half wavelength and one full wavelength above ground. Each radiating element had a half wavelength reflector element one quarter wavelength behind it.

SHEPPARTON

When the Radio Australia, Shepparton station was designed and constructed during the years of the Second World War, Radio Engineers embarked on a project of very large magnitude and under extreme difficulties with shortage of materials and skilled staff. The Research Laboratories of the Postmaster General's Department were given overall responsibility for designing, constructing and commissioning the project which brought together a large team of people from a wide range of organisations with an even wider range of technical specialities and skills who combined to undertake such an unusual and complicated task.

In brief, the station external plant facilities comprised 19 aerials in a semicircle around the main station buildings, in four directions and supported on 14 masts. Included in the massive amount of materials were 1700 poles supporting 20 km of four wire 4.8 mm diameter copper wire transmission lines and 20 km of underground cable. A lot of people were associated with the aerial transmission lines and other external plant facilities and included Sid Witt, Bruce Mair, Alec McKenzie, West Hatfield, Jim Wilkinson, Jack Kyne, Bill Waterworth, John Champion, Jack Laydon, Roy Spratt and many others.

The 14 guyed lattice steel masts used to support the directional arrays were each 64 m high and were manufactured and erected by Sidney Williams & Co., Pty Ltd, of Sydney. Postmaster General's Department staff carried out all work associated with the construction, erection and commissioning of the aerials, transmission lines and the transmitter and aerial switching systems. Electrical equipment for the 151 transmitter — aerial switches was manufactured by Australian General Electric Co., Ltd, of Melbourne and installed by Departmental staff.

Each of the 19 arrays consisted of a radiating curtain comprising a number of half wavelength elements, together with a reflecting curtain containing the same number of half wave elements properly phased, and excited from the radiating curtain. In each curtain, the number of half wave elements end-on in the horizontal plane was four, while the number of tiers in the vertical plane varied from a maximum of four to a minimum of two.

The aerials were designed to give a horizontal beam width of ± 18 degrees wherein the boundary level of field strength was 6dB below the beam maximum level. The vertical beam width varied with the number of radiating elements employed and with the height above ground of the bottom radiating element. It varied between 9 degrees for the highest frequency to 18 degrees for the lowest.

Switching systems allowed direction of transmission to be reversed for some aerials and also for some to be slewed in the horizontal direction 8 to 13 degrees. The facilities allowed transmissions to be carried out in the range 6 to 22 MHz in the designated short wave broadcasting bands.

A number of changes have taken place within the aerial farm over the years, however, in basic form as at 1992, the aerial systems had not altered very much. The Japanese group remained much as it was, although 17 and 21 MHz curtains replaced the old 7 MHz array. The American/African group retained all the old aerials plus some new ones — mainly 6 MHz. The European group was physically moved in the early 1960s to provide transmission bearings of 308–312 degrees. The alternative Japanese aerials were relocated to a bearing of 320 degrees in the 1950s and became the South East Asian arrays. Rhombic aerials JR and AR were relocated and rebuilt using lattice masts in 1978, however the old ER was left as a reminder of the early days.

In late 1993, major upgrading of the aerial system was carried out. The work comprised:

- The installation of five new multiband aerial systems complete with support structures.
- The installation of five new transmission line systems complete with steel supporting poles to feed the new aerials.
- The installation of slewing facilities on the J Group of aerials.
- The removal of all aerial systems no longer required.

A contract was placed with Technology for Communications International Pty Ltd (TCI) for the supply of the five multiband aerials comprising:

- PX1 — type HR2/3/0.4 for operating band 9–14 MHz.
- PX2— type HR2/3/0.4 for operating band 6–12 MHz.
- PX3 — type HRS4/4/0.5 for operating band 9–18 MHz.
- PX4 — type HRS4/4/0.5 for operating band 6–12 MHz.
- PX5 — type HRS4/4/0.5 for operating band 11–22 MHz.

Of the thirty-six single band aerials that were available in 1961, only six J Group aerials were still being used in 1993. The others were replaced by the five new multiband aerials.

The project work began in November 1992 with clearing of facilities from the South Paddock followed by survey work to fix the locations of masts, guy anchor footings, aerial tie-down ropes and transmission line pole positions.

This was followed by the installation of concrete footings by a local Shepparton contractor. In all, over ninety truck loads of concrete were required to complete the work.

The six masts and transmission lines were erected under contract by Electric Power Transmission Pty Ltd. Two of the masts were ex-Radio Australia Cox Peninsula and were upgraded by replacement of bolts and repainting. The other four were new structures purchased for the project.

Control cabling and power cables were laid out to the slew switches by station technical staff.

Two Telecom Broadcasting crews were employed in erection of the aerials. One crew from Victoria was led by Dave McCormack while the other was from Western Australia and led by Alan

Johnson. The station Engineering Services group also provided assistance in the work. Mark Stevens was site Project Engineer.

The facilities came into operation with the transmission schedule change on 28 September 1993.

COX PENINSULA

The Radio Australia Cox Peninsula complex near Darwin comprised a transmitting station feeding basically into South East Asian, Chinese and Japanese target areas and a receiving station which picked up transmissions from Radio Australia Shepparton for rebroadcast. The station was originally referred to locally as a 'Booster Station'. The station began transmissions during December 1969.

During the planning stage a number of aerial systems were considered for possible employment at the transmitting and receiving stations. Transmitting aerials examined included single frequency curtains, wideband curtains, rhombics, log-periodic and a system of vertical elements at ground level with an earth mat. Receiving aerials taken into consideration included wideband dipoles, rhombics, V aerials, fishbones and log-periodic types.

The Tender accepted for the project provided for log-periodic type aerials for both transmitting and receiving stations. The employment of log-periodic aerials for the transmitting station was a novel approach as this type of aerial had not at the time been used anywhere in the world for HF powers of 250 kW.

The aerials were designed and manufactured by Complementi Elettronici S.p.a. of Italy and installed by R.C.A. (Australia) Pty Ltd.

Project Manager Ross Burbidge, PMG's Department Inspecting Officer Jim Finch, Resident Engineer Ralph Gurner and Divisional Engineer Jack Ross were associated with on-site work.

Five identical transmitting aerials were provided each being capable of operating at any frequency within the range 5.95 MHz to 26.1 MHz. Each aerial comprised a stacked pair of vertically polarised log-periodic dipoles in a dual plane arrangement with each plane containing 30 dipoles. Each array was supported by a catenary attached to a 50 m high lattice mast at one end, with the other end passing over a pulley at ground level and attached to a concrete counterweight located below ground level in a concrete chamber. The catenary was broken up by a large number of heavy porcelain egg-shaped insulators. The design of the aerial systems and associated ground screen was arranged to give near optimum vertical and horizontal radiation patterns to best cover the target areas which were located at distances of 1800 and 8000 km from the station.

At the receiving station, two dual plane log-periodic aerials located for space diversity reception and beamed on Shepparton were installed. Insulated wire was used for the dipoles to minimise static electricity noise problems. They were coupled to receivers through wideband baluns developed for the purpose, and via buried coaxial cables.

In 1967, the PMG's Department established a camp site for the Radio Lines Party near the Charles Point Lighthouse adjacent to the transmitting site, to undertake preliminary site work activities and to oversight work undertaken by Contractors. Members of the Radio Lines Party comprised Don Brown, Peter Carlsson, Jim Finch (Officer-in-Charge), Laurie Lindfield, Brian Maden, Joe Mangion, Stan McMahon, Jack Neal, Ray Nurton and Wally Short. The Party later shifted to a motel at Mandorah not far from the Receiving Station.

Others who had joined the group prior to Cyclone Tracy in 1974 included Dave Armstrong, Robbie Astell, Sam Brogan, Phil Farrell, Rees Gore, John Hoole, Damien Jackson, Ian Jordon, Tony Martin, Atha Muir, Jack Murray, Dick Norton, Les O'Dwyer, George Pearce, Bob Saunders, Gordon Smith and Alfie Towell.

After Cyclone Tracy, the Radio Lines group undertook other responsibilities in the Northern Territory with the maintenance of Radio Australia facilities being only part of their overall responsibilities.

It is of interest that during the design and commissioning of the high power transmitting aerials for the station, NBS Engineers employed for the first time in Australia, a computer model to establish the design parameters for a modified form of log-periodic aerial system proposed by the aerial Contractor. It was an important landmark in high power HF aerial design. PMG's Department Engineers involved in the design project included Bill Beard, Don Rodoni and Lionel Parker of the Department's Central Office in Melbourne.

All transmitting and receiving aerials were severely damaged as a result of Cyclone Tracy in 1974, and when the station was rehabilitated 10 years later, curtain type aerials were provided at the transmitting station but the receiving station ceased to be of use for Radio Australia purposes as in the intervening period, the Telecom radiocommunication broadband network had been extended to Darwin allowing programs to be fed to the station direct from the ABC Radio Australia Studios in Melbourne.

The Cox Peninsula transmitting aerials in operation after 1984, comprised seven arrays supported by masts 47, 67 and 97 m high. They were Model 611 types designed and manufactured by Technology for Communications International (TCI) and were wideband, slewable, folded dipole curtain types. There were four bays and four rows of dipoles in each aerial. Frequency range of each aerial was 2:1 eg 13.6 to 26.1 MHz. Power rating was 250 kW plus 100% modulation. Gain was 23dB over isotropic aerial and front/back ratio better than 23dB. Slew capability was ± 30 degrees horizontally from centre bore sight. All aerial conductors were of alumoweld wire material. This had a steel inner with aluminium exterior and gave high strength, good conductivity, resistance to corrosion and lightweight compared with solid copper. People associated with the installation included Volka Lange, Graham Hooper, Jim Finch, Graham Shaw and Ron Falkenberg.

CARNARVON

The aerial system provided at Radio Australia Carnarvon in 1975 comprised four aerials each employing broadband folded half wave dipoles. They were supported by self-supporting towers and designed and installed by the Brown Boveri Co., with Giff Hatfield being responsible for oversighting the work on behalf of Telecom Australia. Local Engineer Terry Sellner carried out the aerial matching work.

Each aerial consisted of an active curtain of 16 folded half wave dipoles arranged in four bays and four stacks. The horizontal sections of the dipoles were constructed in the form of multiple-wire cages. A passive non-resonant reflecting screen was provided a quarter of a wavelength at the geometric mean frequency behind the dipoles.

The aerials covered the bands 6, 7, 9 MHz; 7, 9, 11 MHz; 11, 15, 17 MHz; and 15, 17, 21 MHz.

All four aerials were supported by counterweighted catenary ropes which were wound onto electric winches forming part of the counterweights. The winches allowed the aerials to be lowered to the ground for maintenance or to minimise damage during cyclonic winds.

Maintenance of the aerials was needed mainly as a result of the action of the wind. Wind caused movement in the aerial web and this movement caused fatigue which ultimately resulted in breakages, particularly of wire elements. Wind from the Indian Ocean carried with it moisture which condensed on the wires, ropes and insulators leading to corrosion, and in the case of insulators, loss of insulating properties, build up of temperature and overheating.

At maintenance time, each aerial was lowered and the winch rope treated with special penetrating lubricant to permeate the very core of the rope. This was to allow movement between the rope strands as tension was applied and released, minimising friction, heating and damage to individual elements in the rope as it moved. As the rope was wound back on its drum during raising of the aerial after maintenance, it was coated with specially formulated grease to seal out the blown sand and salt of the coastal environment, trapping the lubricant for the period between overhauls.

As the aerial was caused to move by action of the wind, the floating supports became active and the support ropes moved with the sheaves at the top of the towers. The portion of the rope passing over the pulleys was in constant movement over a small arc, continually flexing. Before fatigue set in the section of rope in the vicinity of the pulley had to be moved to a new non-flexing position. This was achieved by cropping the end of the winch rope at the point of attachment to the aerial structure. This was done by hand splicing because of the unavailability of tools suitable for field application.

To warn staff and visitors of impending dangers associated with the high RF powers when transmission was about to commence, each aerial was fitted with flashing warning beacons and a siren to attract attention.

During August 1993, the aerials were lowered to the ground for extensive maintenance and Les Chidgey, Construction Manager of Telecom Broadcasting Western Australia staff, played a major role in oversighting the activities.

The station ceased operation as a Radio Australia outlet on 31 July 1996.

Although designed as a temporary station with installation fast tracked to take over the transmission schedule previously carried out by the Cox Peninsula facility, the Carnarvon station remained operational for more than 20 years. The life expectancy of the four aerial systems was calculated as about 10 years but they were kept in good operational condition by frequent maintenance.

After cessation of Radio Australia transmissions, the NTA called tenders for removal of all plant except one tower which was retained for domestic ABC and Commercial TV services and the ABC Radio National service.

NORTHERN TERRITORY INLAND SERVICE

The aerials installed at the short wave stations at Katherine, Tennant Creek and Alice Springs in the Northern Territory during 1986, were unusual in that they provided for vertical radiation of the signal. The vertical incidence transmissions, locally called 'shower broadcasting' enabled a service area of 450 km radius from each station to be covered by arranging for a narrow beam to be reflected back downwards from the ionosphere. The aerials were basically log-periodic curtain types providing horizontally polarised transmission, wideband characteristics and power handling capability of 100 kW plus 100% sinusoidal modulation.

Because of their relatively short range characteristics, they were referred to as Short Range Broadcast aerials. The aerials were manufactured jointly by Andrew Antennas, Victoria and Technology for Communications International (TCI), California.

Dipole elements were fabricated from alumoweld, and so positioned from a support catenary that the active elements were always a quarter wavelength above the ground.

The stations operated in the 120 metre band (2.3 to 2.5 MHz) during night and morning, and in the 60 metre band (4.8 to 5.0 MHz) during daytime.

State Telecom Broadcasting staff involved in the project included Graham Shaw, Bruce McGowan, Wayne Croft, Len Som de Cerff, Trevor Gower, Jim Finch, Janis Ozolins and Jack Ross.

BALD HILLS

The planning for a high frequency broadcasting service to cover remote areas of Queensland not covered by MF stations began in 1941, when a site was acquired at Bald Hills, near Brisbane.

A contract for a 10 kW water cooled HF transmitter was placed with STC, Sydney and designs prepared for an aerial system. Four sawn Oregon wooden poles were erected to support half wave dipoles with reflectors oriented to radiate on 310 degrees to provide coverage of inland Queensland. The aerial conductors were cut for frequencies 3, 7 and 9 MHz. Supporting pole heights were 13.5 20 and 33.5 m high.

The transmitter output impedance was 80 ohms, and an LC network was provided to input to the 600 ohm open wire transmission line. The service went to air on 17 February 1943 using callsign VLQ. Project Divisional Engineer was Vern Kenna, and installation supervisor was Arthur Clark who was Acting Engineer at the time.

Transmissions were carried out on three frequencies, 7215 kHz, 9660 kHz and 7240 kHz to cover daily transmissions, but from 1947, only 9660 kHz was used for the entire transmission period.

A new 10 kW service using callsign VLM began operation on 4900 kHz in September 1949 using a delta matched dipole.

In December 1973, a rhombic aerial was installed to provide a Radio Australia service to Papua New Guinea. The service continued until 1976.

As at 1993, VLQ was operating on 9660 kHz while VLM transmitted on 4920 kHz. Both services were closed down on 17 December 1993.

BRANDON

At the Radio Australia Brandon station, commissioned during 1989, two types of aerials were employed. One was a rotatable horizontally polarised log periodic type previously in service at Lyndhurst and the other a group of two curtain types.

The rotatable type placed in service on 7 May 1989 on a frequency of 6020 kHz beamed to Papua New Guinea was designed to cover the range 4.2 to 30 Mhz and had a gain of about 8dB reference to an isotropic aerial. Elements were constructed from aluminium-magnesium-silicon alloy tubing and the system had a nominal input impedance of 120 ohms. The height of the support tower was 31.7 metres and the complete system was manufactured by Standard Telephones & Cables, Sydney. The company developed the rotatable logarithmically periodic aerial in the 1960s.

The curtain aerials were manufactured by Technology for Communications International, USA for Andrew Antennas, Australia who supplied the systems. Masts for the aerials were 58 m high and were recovered from Radio Australia Cox Peninsula where they had supported the log-periodic aerials destroyed by Cyclone Tracy.

Each aerial covered frequency bands 6/7/9 and 11 MHz, and had a power rating of 250 kW carrier plus 100% sinusoidal amplitude modulation. Input impedance was 300 ohms balanced. They consisted of four folded dipoles arranged in two columns of two dipoles. The lowest row of dipoles was 0.4 wavelength above ground for one aerial and 0.6 wavelength for the other. Each dipole was a flat cage of eight wires slightly less than 0.5 wavelength tip-to-tip. Broadband impedance compensation of the dipoles was achieved by placing shorting wires near the ends of the dipoles. There were 42 horizontal screen wires spaced 0.25 wavelength behind the dipoles.

Both aerials were brought into operation towards the end of 1989. One aerial was beamed on Papua New Guinea while the other was beamed on the Coral Sea region.

Engineers involved in the project included Janis Ozolins, Doug Sanderson and Richard Womack.

The service was still operational as at mid 1998.

HAMERSLEY

When VLW was commissioned on 1 December 1939 to provide a high frequency service to remote areas of Western Australia, it operated on frequencies 9560 kHz and 11830 kHz and fed into an aerial system comprising single wire dipoles and reflectors suspended between wooden masts constructed of high quality Oregon.

In the early 1960s, the original 2 kW transmitter facilities were replaced by 10 kW and 50 kW units. New aerials were installed and comprised two for the 6 and 9 MHz bands for 10 kW transmissions and two for the 9 and 15 MHz bands for 50 kW operation. Each aerial consisted of one or two dipoles with curtain reflectors suspended between 40 m guyed masts.

The service known as VLW6, VLW9 and VLW15 operated with frequencies 6140, 9610 and 15425 kHz respectively. The service was closed down on 22 January 1994.

FEEDERS AND TRANSMISSION LINES

FEEDERS

Most of the early MF broadcasting stations employed flat top or cage type aerials supported by two self-supporting towers or guyed masts. Usual practice was for the two support structures to straddle the building housing the transmitter so that only a simple feeder wire or small diameter sausage feeder or cage was required to carry the transmitter output carrier to the aerial. The same practice was adopted for installations provided on the roof tops of buildings.

There were a number of disadvantages in following this practice. These included:

- High circulating currents, and losses from these currents in metal structural components of the building, due to the close proximity of the radiated field.
- Introduced instability in parts of the transmitter as a result of feedback into poorly shielded stages.
- The effective height of the aerial was reduced due to the proximity of earthed building roof and other structural metallic components.
- High voltages were introduced into metal fixtures often creating hazardous situations for operating staff.
- Falling components from a damaged aerial during high wind were a hazard.

TRANSMISSION LINES

With the tendency for designers in later years to locate the aerial system away from the transmitter building, there existed a requirement for a transmission line and an aerial matching unit at the base of the radiator to match the transmission line impedance to the aerial impedance.

In 1932, when the PMG's Department Research Laboratories team of Roy Badenach, Bruce Mair, Ted Stewart, Hec Adam, Alec McKenzie and Reg Turner undertook the first major design work for a new station to replace the 6WF facilities taken over for the National Broadcasting Service, they decided to employ a coaxial line of 100 ohms characteristic impedance.

The line consisted of two concentric copper tubes. The ⅜ inch (9 mm) inner tube was separated from the 2 inch (50 mm) outer tube by porcelain star shaped insulators. The inner tube was joined by internal sleeving and the outer tube by compression joints, the ends of which were soldered to prevent the entry of water. The total length of the line was 183 m. It was the first time a coaxial line was employed for the NBS.

The temperatures of rigid coaxial line conductors varies with the transmitter power passing through the line, and with the ambient temperature surrounding the line. Of the two conductors, the inner conductor operates at substantially higher temperature because it is smaller and heat liberated is contained within the tube until it passes through the wall of the outer tube. As a consequence, the inner conductor will expand and contract at a different rate to the outer. This variation in lengths between the conductors is accommodated by allowing both to move independently, using sliding telescopic or bellow type joints.

The heat problem is aggravated where the line is exposed to the sun, so some Engineers preferred to put the line underground. However, several stations of the NBS were provided with above ground lines during the 1930s.

Station 4QS Dalby was one such station provided with an above ground system. The line with a characteristic impedance of 80 ohms was manufactured by staff of the Department's Brisbane Workshops and installed in 1939 by Bill Stoddart. The inner conductor was a ⅞ inch (22 mm) copper tube centrally supported by star shaped ceramic insulators. The outer copper conductor was a 3¼ inch (81 mm) diameter tube. The overall length of the line from the transmitter building to the aerial was about 275 metres. Support for the line was provided by concrete posts about 600 mm high. To allow for expansion and contraction of both inner and outer conductors, sliding joints were provided at regular intervals.

Unfortunately, the decision to mount the line on posts was not a good engineering decision. The characteristics of the black soil on the Darling Downs is such that considerable movement is likely to take place with structures mounted in the soil, due to the physical state of the soil as it changes from a water saturated to a dried out condition. Large cracks which became evident in station buildings in later years bear witness to the problem.

Attending to movements of the concrete support posts was an ongoing maintenance commitment, and in 1966 a temporary 11 wire transmission line using wooden poles standing in sand was installed to replace the coaxial line. Conditions had become so bad that sections of the line had become deformed resulting in breakage of the separating insulators and allowing the inner conductor to contact the outer. Doug Sanderson oversighted the installation of the temporary line. In 1968, a standard 200 ohm six wire open coaxial line was installed to replace the temporary 11 wire facility.

One station staff member who was with the original installation team at 4QS and who remained at the station for 31 years was Eric Nissen. Some years after his retirement in 1970, Eric recalled his days at the station:

> 'The installation of the 4QS transmitter commenced in May 1939, and while Engineers Vern Kenna and Sam Ross were on a visit to Dalby, I applied for a job at the station.
>
> They referred me to Arthur Clark for an interview and examination. Arthur showed me around the transmitter and apparently being satisfied with my answers to the many technical questions, I was taken on the staff.
>
> A week later, I found myself in company with two new recruits from Brisbane, Jack Wheller and Toby Marcus, bashing and drilling holes in the concrete floor and channelling for installation of the transmitter. I remember the kindness and help of Senior Mechanic Tom Knott, of Fred Emmerson from 4RK, Bernie Duggan from Brisbane and Bill Stoddart from Workshops. Bill did an expert job assembling the pipes for the water cooling system and the solid coaxial line to the 711 ft (217 m) radiator. He was assisted by Bert Williamson.
>
> In the initial stages, Vern Kenna was Engineer-in-Charge of the installation but was called to some other job and Mick Hall completed the commissioning. Engineer Roy Hutchinson was also involved, particularly with matching of the transmission line to the aerial.
>
> The STC transmitter was an interesting one with its low level modulation of the grid bias type on the 500 watt driver unit, the two 5 kW linear amplifiers with common output tank circuit

and the four water cooled triodes which obtained their anode supply from a 12 kV rectifier system using mercury vapour valves.

The station went to air in October 1939, and Foreman Mechanic Harry Conway arrived from Rockhampton. Arthur Clark returned to the Brisbane studios.

The operating staff at 4QS comprised Harry Conway, Bernie Duggan, Fred Emmerson and myself.

During the War years, the station OIC was issued with a 0.45 revolver which the man on night duty was instructed to carry when venturing out of doors to inspect the pumps and water cooling radiator. Harry Conway was not happy about this business as Fred Emmerson, while a likeable bloke was inclined to have a "shoot first and ask afterwards" disposition. At times, we had visits from innocent, although unauthorised motorists who had lost their way and required direction. I would be very surprised if at least one or two did not get an awful shock when Fred opened the door with his revolver at the ready.

We also had less welcome visitors — like snakes. Many a time we could hear OIC Les Macdonald blasting away with a shotgun down in the coupling hut. One day, Don Brownlie had a narrow escape when an enormous black snake came out of the chase in the Control Room.

Nowadays, when I listen to programs from Interstate, my mind goes back to those nights when the ABC took programs of classical recordings from Sydney or Melbourne. Terrible quality, static on line all summer, carrier systems going out of sync, interchannel crosstalk etc. — Ugh! Listeners today should be given a flashback to those days so they might better appreciate the advances made in broadcasting technology.'

Impedances of various rigid coaxial lines varied from about 80 ohms to 200 ohms, with the 200 ohm line versions being used inside buildings linking the transmitter to the outside line, usually an open wire coaxial type. Matching networks for these enclosed coaxial lines were typically T, pi or L networks. These types of networks were provided at 6WA, 3WV, 2CR, 2FC, 3LO/3AR and 4QS. In the case of 4QS where the 80 ohm line fed a 78 ohm aerial the network comprised a simple series inductor and small air spaced capacitor.

An alternative transmission line used at National and Commercial stations during the 1930s was the two wire balanced open wire line of 600 ohm impedance. It was based on telephone practice at the time. This type was employed at National stations 3GI, 7NT, 4QN and 2NR. Matching networks were either balanced pi circuits or mutual inductance coupled circuits.

At Commercial station 4AT erected in 1938, a two wire 600 ohm line fed a 110 m vertical radiator. The balanced-to-unbalanced transition was achieved by an RF transformer made up of two flat conductor spiral coils separated by a Faraday screen made up of parallel vertical copper wires. Station 7HT Hobart was another Commercial station which employed an open wire line. Balanced open wire transmission lines are now rarely used at MF broadcasting stations. Even at receiving stations, open wire lines of two wire (600 ohms) and four wire (200 ohms) configurations are now rarely employed.

In 1942, a six wire open wire unbalanced line was installed at 2BL Sydney, and many transmission lines, particularly at National stations subsequently followed this pattern. The first line to this design provided in Queensland was at 4QY Cairns, installed in 1949.

These open wire lines had a characteristic impedance of 190 to 200 ohms, depending upon the spacing and diameter of the wire.

A typical line consisted of four earthed conductors, one at each corner of a 280 mm square and two bridged central conductors forming the inner of the coaxial line supported about 38 mm apart on a glazed porcelain insulator. The outer wires were supported by a galvanised steel frame attached to a steel pipe or structure sufficiently high to allow safe passage of grass cutting equipment etc. beneath the line. In the case of 50 kW transmitters employed at National stations, conductors were usually 7/14 gauge hard drawn copper. An extensive parallel wire earth mat was laid beneath the line at some stations. In recent times, many of these lines were replaced by underground coaxial types.

An unusual design of unbalanced open wire line was provided to feed the 52 m radiator at NBS station 4QY Mackay in 1957. The line using telephone practice technology employed nine 200 pound per mile (2.8 mm diameter) copper conductors mounted on standard trunk line insulators mounted on wooden cross arms. The wires were bridged to provide 4 active and 5 earthed wires. Measured characteristic impedance of the line was 103 ohms which was very close to the 100 ohm output impedance of the 2 kW transmitter. Commissioning Engineer was Brian Robinson with subsequent aerial radiation pattern measurements being undertaken by Maurie Palmer, Ralph Bongers and Doug Sanderson. A line using the same technology was installed as a temporary measure at 4QS Dalby during 1966.

The trunk long skirt insulators used with these transmission lines had a rating of 6 kV peak (2.1 kV RMS carrier). It had been developed by the Post Office Research Laboratories staff during 1936 to improve the performance of long trunk lines.

A number of National stations in New South Wales were also commissioned with 100 ohm nine wire transmission lines. They included 2BA Bega with a 152 m line feeding the main 142 m sectionalised radiator of base impedance 58–j190 ohms and a 122 m long line feeding a 27 m umbrella standby aerial of base impedance 9–j104 ohms; 2NC Newcastle with a 126 m line feeding an inverted L aerial of input impedance 17–j89 ohms; 2KP Kempsey feeding the main sectionalised 170 m radiator of base impedance 52–j228 ohms and a 27 m umbrella standby aerial of base impedance 4–j123 ohms; 2GL Glen Innes feeding a 142 m sectionalised radiator with base impedance 66–j266 ohms and a 27 m umbrella standby aerial of base impedance 8.7–j74 ohms. At 2NA Newcastle, a 13 wire line 180 m in length and of characteristic impedance 90 ohms was provided to feed an inverted L standby aerial with input impedance 18–j24 ohms.

A wide range of flexible coaxial cables in air dielectric and foam formats were available, so giving designers considerable flexibility in selecting a transmission line to handle any power level and to meet any site constraints.

During May 1993, the twin open wire coaxial transmission lines at the NBS station 5AN/5RN Pimpala were replaced by type HJ8-50 Heliax 75 mm diameter cables laid in buried boxed concrete culverts. The principal reason for the change was for public safety reasons. The station operated with two 50 kW transmitters 24 hours daily, and since it was established in 1961 the site had been surrounded by houses and it was deemed advisable to replace the overhead exposed conductors which were about 3 m above ground with buried cables.

Staff associated with the work included Wayne Croft, Tom Pascoe, Jim Finch, Mick Elliot and others.

At the time upgrading work was being undertaken at 2CR Cumnock in late 1993/early 1994 when a pair of Nautel AMPHET ND25 solid state transmitters replaced a 50 kW AWA BTM50 which had been in operation since 1963, 200 ohm open wire coaxial transmission lines to the main and standby radiators were replaced. The main 198 m radiator was provided with a 2¼ inch diameter Andrew cable and the standby with a ⅞ inch diameter Kabelmetal cable. The standby aerial was intended to carry only 10 kW power. The cables were buried directly in the ground at a depth of 500 mm in a bedding of sand. It is of interest that the original feeder installed at the station in 1937 was an underground rigid coaxial line. Engineer-in-Charge of the upgrading project was Chris Scott.

One of the longest flexible coaxial cables installed at a low power MF station was provided at NBS station 2LG Lithgow when the station went to air on 3 October 1949. A 36 m high Deeco lattice steel radiator was installed on a hill about 213 m from the building housing a pair of AWA 200 watt transmitters. The cable, type UR67 of nominal characteristic impedance 50 ohms and voltage rating 3.5 kV was laid inside a pipe. The cable was still in service in 1993. On one occasion vandals entered the property and severed the cable with an axe putting the station off air for some time. One member of the station installation team in 1949 was Frank Reid. Subsequent maintenance staff included Alan McInante and Dave Spillett.

It is of interest that 2LG was the only broadcasting station commissioned in Australia during 1949. No Commercial stations were built. The installation of 2LG brought the number of National stations to 37 compared with 102 Commercial stations at the time. On 1 December 1993, a Nautel solid state type T400 transmitter was installed at the station.

For FM aerials, rigid lines or flexible coaxial cables are mostly employed. Present day feeders are available to handle a wide range of powers with minimum loss. Impedances are typically 50 or 75 ohms.

The aerial coupling unit (ACU) required to match the transmission line to an MF aerial can be a significant proportion of the cost of establishing the aerial system, particularly for a 50 kW dual frequency system. Highly efficient simple networks are essential to minimise loss of RF power in the networks and provide adequate bandwidth.

Important early design work in the application of dual frequency ACU's was undertaken by Alec McKenzie of the PMG's Department Research Laboratories during 1938–39 when 3AR on 620 kHz and 3LO on 770 kHz fed into a single 705 ft (215 m) high lattice steel radiator. The design parameters called for the aerial to be adjusted to provide a mode of operation of 0.55 wavelength or 198° for 3LO, and 0.44 wavelength or 158° for 3AR. Output from each transmitter was fed via separate coaxial transmission lines to the coupling hut at the base of the mast.

Aerial impedance measurements carried out using a GR 516C bridge indicated 420–j300 ohms at 620 kHz and 66–j165 ohms at 770 kHz.

The coupling system employed five units:

- Two pi coupling units provided for matching the characteristic impedance of each transmission line to the resistance of the aerial at the appropriate frequency.
- Two three element selective networks each designed to be resonant to the frequency of its corresponding coupling unit and anti resonant to the other frequency provided in series with the output of each coupling unit.
- An aerial tuning unit in which power from the transmitters was combined, providing reactance elements which tuned out the aerial reactance at each frequency.

The three element selective networks comprised two capacitors and one inductor for the low frequency case and two inductors and one capacitor in the high frequency case.

The aerial tuning unit was provided with three coils and one capacitor bank to permit tuning an aerial having negative reactance at one frequency and positive reactance at the other frequency.

Although many dual frequency coupling units have been installed at National and Commercial stations since that early development work by Alec McKenzie, the basic design principles have remained the same.

Important work in the practical design of ACU's was carried out by Alan Fowler and Jim Kemp, Engineers of the PMG's Department Victorian Medium Frequency Transmitters Division, during the early 1960s. Their approach to design and construction was the subject of a paper presented at the Institution of Radio and Electronics Engineers Australia Convention in Melbourne during May 1963. The work added considerably to the technology, particularly in relation to losses in coupling networks such as skin effect losses, proximity effect loss, losses in capacitors, losses in coils, coil connectors, connection between components, stand-off insulators and losses in associated equipment.

Where the aerial is below resonance, the major loss in the ACU occurs in the series resonating coil. In some installations it was assessed as being 80% of the total loss. For standby aerial purposes resonating coils of Q = 100 were typical with many station designs, but for a main aerial, coils of Q = 300 were generally specified by the design Engineer.

In order to reduce the level of EMR fields below the non-occupational limit for operational staff, it is practice in modern installations to enclose aerial coupling units in cabinets fabricated with sheet aluminium or copper. These cabinets in conjunction with screened ACU buildings provide a safe environment, even though the facility may be adjacent to the energised mast base. The dual frequency installation at Dalwallinu in Western Australia with NBS transmitters 6DL and 6RN installed in late 1994 employed this approach.

The problems faced by today's designers of AM broadcasting station aerial systems was highlighted by John Innes of Innes Corporation Pty Ltd in a paper 'Innovations in AM Transmitting Antennas' he presented at the ABA Planning Seminar on 24 February 1997 in Canberra:

> 'The planning process should be tuned to permit the best possible final outcome to ensue. Every AM antenna installation is different, whether because of frequency, permissible mast height, available land, directional pattern, power, coverage area or budget. No rigid prescription or code of design rules can anticipate the combination of needs and resources that will apply in all possible cases. Innovation is precluded if past practices must be rigidly adhered to. The best design will result if the planner sets the requirements for the result to be achieved and leaves the greatest possible freedom of choice to a competent designer. You cannot build a new and better highway system by following the old road map. Let us innovate, please!'

LINES AT SHORT WAVE STATIONS

Although rigid high power coaxial lines are employed at some overseas short wave broadcasting stations, they have found no application in Australia. Nearly all transmission lines are of the open wire balanced configuration with lines employing two, four or six conductors.

The conductors range from solid conductors about 3 mm diameter for low power transmitters to 12 mm solid or stranded cables for powers up to 300 kW. Conductors are typically copper, cadmium copper or alumoweld.

A range of configurations are available for short wave systems and include a six wire balanced open wire line of 300 ohms impedance employing 12 mm solid copper conductors and equipotential clamps; a 300 ohm balanced line comprising four conductors with a 12 mm stranded cable on top supporting a 12 mm tube; a 330 ohm feeder consisting of two sausage lines each six wire, 12 gauge on 35 mm PCD; and other configurations.

At Lyndhurst, the site of the first regular short wave broadcasts for the National service from 1934, transmission lines comprised two solid copper wires 300 lb per mile (3.4 m) spaced to give 600 ohms impedance and supported by low capacity type porcelain insulators.

The 50/100 kW Radio Australia Shepparton transmitters erected in the 1940s were connected to the aerial system by four 600 lb per mile (4.8 mm) solid copper wires spaced at the corners of a 12 inch (30 cm) square having two wires on the same side of the square of the same polarity. The lines were still in operation in 1993. The characteristic impedance was about 310 ohms. Similar lines were provided for the HF inland service station at Perth where they were stub matched to the aerials, all of which were single frequency operation. In addition to the four wire lines at Shepparton, two conductor balanced shielded lines connected the transmitters to the outside lines and short two wire lines joined the four wire lines to the aerial panels. The balanced shielded lines had a diameter of 500 mm and employed polystyrene support rods.

Following a major upgrade of facilities in late 1993 in which five new transmission lines were provided, the new lines comprised four wire alumoweld conductors of 300 ohms impedance. The lines used cylindrical steel support poles. Wooden poles which had been previously employed at the station were subject to attack by termites and also resulted in changes in VSWR during periods of rain.

At the Radio Australia Cox Peninsula station which employed 250 kW transmitters when it began transmissions at the end of 1969, the transmission lines were balanced lines of 300 ohms characteristic impedance. Each leg comprised three solid copper 12 mm conductors mounted vertically and separated at 75 mm centres by cast bronze equipotential clamps. The lines were designed to handle 500 kW carrier power plus 100% modulation. The lines were designed and manufactured by Complementi Elettronici S.p.a. of Italy and installed by staff of R.C.A. (Australia) Pty Ltd.

The transmission lines together with the aerial systems were severely damaged during Cyclone Tracy in December, 1974. When the station was rehabilitated ten years later, new 300 ohm transmission lines were assembled using two 18 mm diameter stranded aluminium conductors spaced 120 mm in the vertical plane and 400 mm in the horizontal plane.

Prior to the construction of the Cox Peninsula station, considerable investigation and development work was undertaken in the 1960s into high power transmission lines at Brooklyn Park near Adelaide, the site of the early 5CL/5AN transmitters. At the time, very little was known of high frequency line technology above 100 kW power at short waves. Included in many projects were designs of strain insulators with low capacity end caps, open wire transmission lines of various configurations to handle 500 kW transmitter output powers, contacts for high power line switching systems, transmission line support poles and anchor frames, resonant problems with steel poles and anchor frames, lead-through techniques for connecting internal transmission lines to outside lines, line isolation switches, fibreglass materials for insulators, optimum pole spacing for long lines, corona problems associated with hardware design, absorption losses in steel structures and poles, impedance matching techniques and many others. Staff employed on this work included Bill Gold, Don Beames, Graham Shaw, Les Pridham, Frank Mullins, Brian Woodrow, John Robertson, Ralph Gurner and Frank Wilkinson. Project Engineer was Jack Ross.

At the Radio Australia Carnarvon station employing 100, 250 and 300 kW transmitters, two wire balanced transmission lines were used. Each wire or leg comprised a cage of six wires. Impedance matching at line direction-change poles was achieved by varying the diameter of the cage. The station began transmission in December, 1975.

At the Radio Australia Brandon station, the most recent of the short wave broadcasting stations to be constructed, different types of transmission lines were provided for the log-periodic and curtain aerials.

The log-periodic aerial had a nominal input impedance of 120 ohm and to match into this from the 300 ohm transmitter output impedance, a tapered open wire line 122 m in length was used. The line was supported by 3.8 m high galvanised iron pipes 76 mm in diameter. The first six spans of the line, were of 2.8 mm diameter copper wire using four wires in square formation of 300 ohm impedance. The line then tapered using stranded copper wire 7/1.2 mm. The final section within the mast framework was formed of 20 mm diameter copper tubing.

The input impedance of the curtain aerials was 300 ohms and four wire 300 ohm lines were used from the transmitter. Inside the building, transmission lines from the transmitters to the outside lines comprised 300 ohm types balanced two conductors enclosed within a metal tube and known as boxed lines.

Each column of two dipoles of the aerial system had its own vertical feed arrangement. The vertical feeds were interconnected by a horizontal feed system placed a few metres above ground. A three section balanced Chebyshev transformer converted the 150 ohm parallel impedance of the two columns to the transmission line 300 ohm impedance.

Transmission lines installed at the NBS vertical incidence high frequency stations at Alice Springs, Tennant Creek and Katherine in the Northern Territory, were four wire 300 ohm balanced lines using alumoweld wire supported by steel poles providing a clearance above ground of about 3.5 m. Equipotential clamps were fitted at regular intervals to tune out distributed inductance, and impedance compensators fitted to the lines at the building entry point to accommodate the effects of distributed capacitance at that point. To cater for the aerial input impedance of about 360 ohms, the 300 ohm line was tapered prior to attachment to the aerial feed point.

Transmission line sections were used for feeding power to the aerial dipole elements as these line sections were much more prone to damage than the main lines supported by poles a few metres above the ground. The sections in the aerial array were subjected to frequent movement by the action of wind and at coastal sites such as Radio Australia Carnarvon the environment played a major factor. Wires oxidised, lost body and with vibration became brittle. Broken wires were replaced by splicing-in replacement modules. These modules were made up in readiness for replacement purposes. The new sections were jointed in place with precisely machined crimping machines and care taken to ensure the replacement module exactly matched the one it replaced to maintain structural integrity.

DISSIPATIVE LINES

Dissipative transmission lines were frequently used to provide resistive loads for rhombic transmitting aerials and also in at least one instance, as a transmitter dummy load.

The resistive loads are basically transmission lines built to have high attenuation per unit length and of sufficient length to provide the desired overall attenuation. Rhombic aerials in service at Shepparton for many years employed this type of termination using combinations of tapered stainless steel tubing and iron wire as the dissipative element. A dissipative line with an overall attenuation of 20 dB is virtually a transmission line of infinite length as far as the rhombic aerial is concerned. Jim Wilkinson was one of the Engineers involved with the design of the lines at Shepparton.

The original transmitter dummy load provided at Radio Australia Cox Peninsula was a 500 kW dissipative line. The line of 300 ohm impedance was constructed of 50 mm diameter stainless tubing of line length totalling 306 metres. It was constructed in the form of a U so that the termination point which was earthed, looped back to be supported by the same pole that supported the input point. The line started with a conductor spacing of 240 mm and tapered to 120 mm at the termination. The line was cooled by deionised water circulating throughout the entire length. A forced air cooled radiator located in the input pole area cooled the circulating water. The facility designed by Complementi Elettronici S.p.a. of Italy and installed by R.C.A. (Australia) Pty Ltd, was provided with over temperature and water flow alarms interconnected with the transmitter control circuits. Ross Burbidge was in charge of the installation as Project Manager.

With the rehabilitation of the station following damage by Cyclone Tracy in 1974, the dissipative load was dismantled and a 500 kW Brown Boveri Co., liquid load provided in the aerial switch building.

CONDUCTOR MATERIALS

Over the years, a range of materials have been employed for conductors associated with feeders, transmission lines, line switching systems and wire type aerial systems. Although phosphor bronze was used with many early cage, flat top and single wire aerials, it has not been employed for many years, but phosphor bronze in sheet form is still employed in some parts, such as contact springs. The most common materials include copper, cadmium copper, aluminium, copper covered steel, aluminium covered steel, beryllium copper, brass, aluminium bronze, and silicon bronze.

- Copper

  Copper of high purity can be readily obtained, and in terms of conductivity, ranks next to silver. The presence of impurities considerably affects the properties of copper, especially the conductivity and ductibility. Hence, in specifying copper for a particular application, the designer has to ensure that it conforms with appropriate Standards.

  Copper wire is available in hard drawn or annealed condition but for aerials, feeders and transmission lines, hard drawn copper is preferable on account of its greater strength. Annealing reduces the strength considerably and great care has to be taken during fabrication of conductors to ensure that soldered or brazed joints are kept to an absolute minimum. Joints under tension are usually made with splicing sleeves where practicable.

  Copper has the advantage of maximum transmission capacity for given power loss. As a result of the skin effect with the transmission of high frequencies, the energy is concentrated on the surface of the conductor. Corona and impedance considerations are important factors in determining the diameter of the conductor to be employed. Because of its comparatively low ratio of strength to weight, copper necessarily requires greater sag for a given factor of safety.

  Copper is a homogeneous material and follows definite laws as regards sagging characteristics and temperature co-efficients, and consequently, sag calculations for any assured or known conditions, are relatively simple. For heavyweight conductors requiring low sag, care is necessary in designing the terminating structures, particularly where they form part of the building structure. In the case of Radio Australia Cox Peninsula where each line comprised six 15 mm diameter solid copper conductors, special anchoring arrangements were built into the building design. Where a bend in the line between transmitter and aerial was required, steel towers mounted on concrete blocks were necessary.

  In order to reduce the overall weight of large copper conductors for high power transmitters, some designs use a standard copper bearer supporting one or more copper tubes in a vertical plane. This method was investigated during the design of 250 kW transmission lines for the Radio Australia Cox Peninsula station but was rejected. Trial installations showed that as a result of the different amount of expansion between solid copper and copper tubes the lines produced sideways movement of the tubes in relation to the tensioned solid conductor with increase in temperature. This affected the characteristic impedance of the line. Some Voice of America stations employed this arrangement in the 1960s.

- Cadmium Copper

  Cadmium copper is a copper alloy containing between 0.7% and 1.0% of cadmium. It is essentially a high conductivity material characterised by greater strength under static and alternating stresses and better resistance to wear than ordinary copper. Because of its marked superiority in tensile strength, cadmium found application where long spans were required such as for rhombic receiving aerial systems provided at off-air receiving stations and at some NBS transmitting stations for emergency program reception purposes. It was employed with a number of receiving aerial systems and 200 ohm open wire transmission lines at the Cox Peninsula Receiving Station when that station was established in the 1960s for picking up programs from Shepparton transmissions for rebroadcast by Radio Australia transmitters located on another part of the Peninsula.

- Aluminium

  Aluminium is now widely used in high frequency transmitting systems for both transmission lines and aerial systems in single wire, stranded wire and tube form.

  Its attenuation is slightly worse than copper, being typically 0.2 dB for a 300 m line at about 17 MHz compared with 0.17 dB for a copper line of the same configuration. Compared with copper wire of the same physical size, aluminium wire has about 45% of the tensile strength but only 33% of the weight. It is the weight factor that has made aluminium so popular with design Engineers, notwithstanding problems associated with soldering or welding in the field.

  Most of the aerial systems and transmission lines erected in Australia in recent years at short wave broadcasting stations have employed aluminium, aluminium alloys or aluminium covered steel conductors.

- Copper Covered Steel

  In this conductor, a coating of copper is securely welded to the outside of a steel wire. The copper acts as a protective coating to the steel thus giving the conductor approximately the same life as if it were made of solid copper. As far as radio frequencies are concerned, the composite conductor has almost the same conductivity as if it were solid copper. The conductivity of the conductor can be raised to any desired percentage depending on the thickness of the copper layer. The usual values of conductivity of wires as manufactured is 30 or 40 per cent.

  The combination produces a satisfactory yet inexpensive conductor. Its chief applications are for curtain aerial systems and transmission lines but it has also been employed for guy ropes when structures are located in an aggressive environment, such as near the sea or on a salt pan. One application was for guys of an NBS MF radiator located close to the surf where standard galvanised guys had to be replaced after only 18 months service.

  Copper-weld as it is known is also used as rods for terminating earth mat radials and for transmitter building earthing systems.

- Aluminium Covered Steel

  Aluminium is also used to coat steel wire and is usually known as 'alumoweld'. The advantage of aluminium covered steel is that it is lighter than steel of the same thickness, and also lighter than copper covered steel with the same thickness of steel.

  Aluminium covered conductors will quickly corrode if incompatible materials are used in joining, and care has to be taken in specifying materials. Strain type insulators are provided with aluminium alloy end caps to minimises corrosion problems.

  Short wave stations which employed this type of material include Radio Australia stations at Cox Peninsula, Brandon and Shepparton and High Frequency Inland Service stations at Katherine, Tennant Creek and Alice Springs.

- Beryllium Copper

  Beryllium copper is particularly suited to contact springs used in transmission line switching systems.

  A small percentage of beryllium results in a considerable increase in strength and hardness. After annealing at 800°C and quenching in water, beryllium copper is soft and ductile and can be rolled, drawn or otherwise formed into any desired shape. Subsequent heat treatment causes a degree of hardening which depends to some extent on the deformation to which the material has been subjected since the annealing treatment. In the heavily cold-rolled and fully heat treated condition, the tensile strength is about five times higher, and the hardness about six times higher than ordinary copper.

  In addition to line switching systems, beryllium copper has been employed with some designs used to remotely earth an AM broadcast radiator when that radiator has to be taken out of service for maintenance purposes and another radiator has been put into service on the same site.

- Brass

  Brasses comprise a wide range of alloys of copper and up to 50% of zinc with or without the addition of small quantities of tin, lead, nickel, aluminium and silicon. Their properties vary from those of nearly pure copper to special high tensile brasses with strengths in the cast state, about five times higher than copper.

The principal use of brasses is for nuts, bolts, bridging bars, end caps and castings for strain and stand-off insulators.
During the installation of Radio Australia Shepparton during the mid 1940s, brass was employed for castings for stand-off insulators with transmission line switches, end caps for strain insulators and various line fittings.

- Aluminium Bronze
This alloy is based on copper and aluminium but often contains other elements particularly iron, nickel and manganese. One outstanding characteristic is the readiness with which aluminium oxidises forming a very thin but continuous film of alumina on the surface. The film is so thin that it is quite invisible and, but for its protective effect, its presence would hardly be suspected. Aluminium bronzes are unquestionably among the best of copper-base alloys for service with high power dissipative lines, transmission lines and aerial systems close to the sea or near industrial areas where operating temperatures due to insulator dielectric losses may be high and where corrosion is a problem. However, they are somewhat difficult to braze but by suitable design, alternative fixing arrangements can usually overcome the problem. Although not used at Australian broadcasting stations aluminium bronze fittings have been widely used overseas.
- Silicon Bronze
This is another copper alloy widely used for transmission line fittings in high power broadcasting systems. The addition of silicon to copper not only enhances the strength and confers good resistance to corrosion but helps to improve weldability. Cast silicon bronze normally contains more silicon than the wrought material with 4 to 5 % being typical. A small quantity of zinc is sometimes added as well as iron and manganese. Silicon bronze castings were used as equipotential spacers and clamps with four wire and six wire high power transmission lines at Radio Australia stations.

Preformed Terminations

In recent years, preformed assemblies have been employed for terminating and repairing guy ropes, catenaries and aerial systems.

Since the basic design of preformed gripping devices is predicated on the concept of developing low unit pressure over a considerable area to develop a high total force, they have been successfully used on all types of insulated feeder, power and communication cables and are capable of developing full strength of these cables without damage to the outer jacket. However, the most widespread use of the assemblies is with stranded wires and ropes associated with guyed structures; aerial systems, particularly high frequency rhombic and curtain types; and transmission line pole guy ropes.

The grips work equally well and are more efficient in some cases when used on solid wire or bar and have been employed to terminate round steel bars up to 10 mm diameter to tension four and six wire open wire coaxial transmissions into a common counterweight system.

Preformed terminations have been designed for a wide range of sizes and grades having ratings well over 50 tonnes.

The materials are high grade spring type wires, generally made of alloys having a good combination of mechanical and electrical properties for their applications and each is similar to, and compatible with, the underlying strand for which they are designed. Typical terminations are made from aluminium alloys, galvanised spring steel, copperweld, bronze or stainless steel wires. As well as being used for terminations, the assemblies have also been used to splice two conductors or to repair a multistrand cable where one or more strands have been damaged.

The assemblies will not permit slippage under the types of loading experienced in the field and will withstand severe impact and vibration forces to a degree greater than most other types of splices. They are especially suited for open span applications either for joining wire or rope ends or for strengthening damaged long span conductors such as used for 100 kW rhombic aerials or for covering eroded conductors resulting from RF flame or lightning damage.

In field applications, the assemblies are applied without the aid of any tools or compression machines. They are simply wrapped on the cable or rope by hand. The cable or rope may be terminated within the assembly or allowed to continue through the assembly as was the case at Radio Australia Cox Peninsula during installation of curtain reflector systems during 1984.

Switching Systems

Simple Switches

Simple change-over switches have been installed at transmitting stations for many years. In most cases they take the form of manually or electronically operated single pole devices to allow the transmitter output to be sent to line or to dummy load. Their most widely used application is at short wave transmitting stations employing multiple transmitters and aerials where considerable flexibility is necessary to allow transmitters to access to station multiple aerials and dummy load systems.

At MF stations, switching systems are usually coaxial types allowing the transmitter to be fed to either the aerial or the dummy load. Where main and standby transmitters are employed, it is normal practice for switching facilities to be so arranged that when one transmitter is switched through to the aerial, the other is switched through to the transmitter or station dummy load.

Short Wave Station Systems

Whilst coaxial switching systems are employed at some overseas short wave stations, all systems at broadcasting stations in Australia employ balanced types, usually shielded.

A great deal of care is necessary to ensure that the switching system does not introduce undesirable impedance irregularities into the line and that crosstalk or coupling between lines is kept to a low level. To meet these requirements a number of switching systems have been developed over the years.

With the Radio Australia Shepparton station constructed during the mid 1940s, the switching system catered for three transmitters to access 19 aerial systems. This required the installation of some 24 switching stations located at various points throughout the aerial farm. The switches were designed to present to the transmission lines, an impedance of about 310 ohms, the characteristic impedance of the lines themselves.

The switches were operated by half horsepower three phase motors within the switchbox. Push buttons for remote operation of the switches were grouped on an aerial control desk in the transmitter hall with a desk being provided for each transmitter. A complex interlocking arrangement was provided to ensure safe and positive operation with indicating lamps being provided on the switching desks to indicate switching status.

The sequential switching system, although somewhat inflexible operated reasonably satisfactorily for many years. However, with plans for expansion of the numbers of transmitters and aerials over the 1952–62 period, a new more flexible system became essential.

Following experience with a system developed and put into operation by Steve Minz and Frank Norman, both of the PMG's Department at the Lyndhurst station in 1956, a more elaborate switch was developed for Shepparton by Doug Cliff, J M Fullarton and Leon Gemmell, also members of the PMG's Department. The switch, referred to as a matrix type, had capacity to provide for 10 transmitters to be switched to 36 aerials using up to 100 kW transmitter power. All switching operations were carried out from an Aerial Switch Control Desk in the transmitter hall. Lights indicated the status of all switching operations.

Switching was accomplished by the horizontal movement of transmitter 'arms' around a large semicircular steel frame, and the vertical movement of aerial 'arms' up/down the frame to enable an RF connection between transmitter and open wire transmission lines.

Transmitter and aerial arms were 5 metres long, fabricated from a sandwich of plywood and aluminium. Within each arm, an insulator supported a two conductor transmission line. The facility was put into operation during 1962.

Over the years, the switching mechanism, arms, wiring and other components reached the stage where reliable service could not be guaranteed. In addition, slow transmitter to aerial switching negated the advantage of modern transmitter 20 second band change times.

Doug Cliff, who played a major role in the design, installation and commissioning of the Shepparton matrix switching system joined the Postmaster General's Department Victorian Radio Section as Engineer in 1957 following graduation with a Fellowship Diploma in Communications Engineering from the Royal Melbourne Technical College.

In 1961, he was promoted to Group Engineer HF Station Division where he was associated with the expansion program at Radio Australia Shepparton involving the major reconstruction of the two original STC/AWA 100 kW transmitters which had been in service since 1946; design and installation of program input equipment; monitoring and control systems; provision of new short wave aerial systems; and the matrix aerial switching system. After completion of these works, he took over responsibility for operation and maintenance of the Lyndhurst Radio Station.

Doug was a member of The Institution of Radio and Electronics Engineers, Australia having joined as a Student Member in 1956 and becoming Associate Member in 1960.

Doug was the Author of the article 'The New Aerial Switching Scheme at Radio Australia, Shepparton-General Design and Performance', published in the June 1963 issue of 'The Telecommunications Journal of Australia'.

Late in 1989, a contract was let to G.E.C. Marconi Defence in UK, for the supply of a 500 kW Aerial Matrix Switch which provided for seven transmitter inputs and twelve aerial feeder outputs as the basis of a new modern switching system for Shepparton.

As the site was already equipped with a large number of single band aerial arrays there was a need to accommodate switching facilities for at least 22 of the existing aerial systems. The lack of aerial feeder outlets was overcome through the provision by Marconi Defence of 11, two position remote RF field switches. This approach allowed connection of two aerials via field switch to each of 11 aerial feeder outlets. The twelfth aerial feeder output was used for connection of an existing Brown Boveri, 600 kW artificial load.

Each field switch was designed to switch between a high/low band aerial system, and in doing so, provided for day/night transmission scheduling.

Installation was under the supervision of Kevin North, with Doug Brodie and staff as the installation team. Kevin was a Senior Technician involved with the installation of the original matrix switch, and as a qualified A Grade Electrician as well as Technical Officer, was able to provide a valuable range of experience in planning, design and installation.

Project Engineer Tech Chua provided overall direction, and supervision as well as contract interpretation, company liaison etc.

Specifically, the Marconi Matrix was of modular construction comprising 84 individual crossover switch boxes all interconnected by short sections of screened, balanced feeder lines. This arrangement allowed optimum isolation performance, and overcame the old problems of RF induction between switching feeders.

Owing to shipping requirements, each of the modular switch boxes had to be constructed on site. The temporary storage and movement of 84 switch modules as well as the fabrication of 40 actual RF switches proved to be quite an exercise in logistics.

The body of modular switch sections are supported above head height, to allow safe and easy access, and as such, all actions concerned with operation and maintenance were carried out below the switch.

The overall assembly was contained within a roofed building to provide weather protection as well as beam support for individual crossover switch boxes.

The control system allowed for remote operation of any matrix cross point or field switch and consisted of two major components — the first, a personal computer for the operator machine interface and systems control, and the second, a control unit for the switching and monitoring of cross points and field switches.

In addition, the system provided facilities for entering a set of commands in the form of a transmitter movement schedule, and had the capacity to carry out all switching at predetermined times. Overall, sufficient capacity existed to store in excess of 10000 switch combinations.

Control and monitoring functions were monitored by displays. The first of these was a Switch Matrix Display which was a graphical display showing the transmitter to aerial selections, while the Schedule Displays showed the schedule switching combinations and allowed the operator to add or delete additional combinations.

The switch was placed into service during late 1991 and completion of the project, upgraded station switching standards allowing the interface of modern transmitter plant. Station Officer-in-Charge when the switch was commissioned was Bruce Wilson.

The Lyndhurst switch upon which valuable experience was obtained and applied in the design of the earlier Shepparton Switch was known as a crossbar type, and was a manually operated system capable of expansion to give 100% access for 10 transmitters to 26 aerials.

Prior to the development of the Crossbar Switch, the needs of the station were met by various arrangements over the years. In 1938, when major expansion of transmitters and aerials were undertaken, remotely controlled switches were provided. The aerial systems comprised a vertical system, three curtain arrays and a reversible rhombic. The contactors were 230 V AC 2 pole power contactors modified so that the RF contacts on either side of the line, were spaced at 250 mm and mounted on long porcelain insulators. The switches were operated by 50 Hz power in buried lead covered cables controlled by two master selector switches on the front panel of one of the transmitter enclosures.

Later, changes were made and a rotary multiposition sequential type installed, capable of interconnecting two transmitters to any of 10 aerials. It was mounted indoors and stub lines associated with contact multipoles were switched out of circuit by means of simple auxiliary mercury tilt switches. Replacement became necessary with expansion of the station with additional transmitters and aerials, to meet short wave broadcast requirements associated with the 1956 Melbourne Olympic Games.

Physically, the switch consisted of a large iron framework along which sets of carriage mounted contacts, each one connected to a transmitter, moved horizontally so as to select complementary carriages moving in a vertical plane and which were connected to the aerials. The advantages of the system were that it gave full accessibility for transmitters and only one set of contacts was involved with each connection. The contacts on the transmitter carriage consisted of two copper U bolts which made contact with flexible phosphor bronze strips. When in the operating position, the U bolt exerted sufficient pressure on the phosphor bronze looped strips to compress it about 6 mm.

The switch was still operational when the station was closed down during 1987. Officer-in-Charge at the time was Max Fowler.

When Radio Australia Cox Peninsula began transmissions in 1969, a Brown Boveri Co., crossbar type switching system was installed. However, it differed from the Lyndhurst system in that it was electronically operated from a control desk in the transmitter control room and it employed multiple switch contacts. It gave full availability and was capable of switching transmitter outputs up to 500 kW power. Switches were rotary types with long low loss insulators and fast acting, allowing aerial changes to take place in less than six seconds.

Initially, the system comprised three transmitter inlets and six outlets covering five log-periodic aerials and the external dissipative line. During the station's rehabilitation in 1984 the system was expanded to cater for eight aerial outlets plus a dummy load located within the switch hut. Graham Shaw and Ron Falkenberg oversighted installation of the expanded facilities.

With plans to increase the station transmitter capacity by an additional 2 x 250 kW transmitters by 1993, a contract was let in 1992 to further expand the matrix switching system by installing 20 additional switches to provide a 5 x 10 matrix configuration. Barrie Morton, Graham Baker and Jim Finch handled on-site aspects of the project.

A Brown Boveri Co., matrix switch system was also installed at Radio Australia Carnarvon with the commissioning of that station during 1975. It was equipped with three inlets and five outlets.

RADIO CERAMIC INSULATORS

EARLY TECHNOLOGY

When the early wireless telegraphy Engineers began to design transmitters and aerial systems, they relied on the technology that had been developed for ceramic insulators over a long period of time by a succession of electric power, telegraph and telephone Engineers.

The techniques for manufacturing porcelain insulators to a wide variety of shapes and sizes had reached a high level of development, and a great deal was known of the physical and electrical properties of the material.

However, the Engineers soon ran into trouble when they began commissioning high power wireless telegraph transmitting stations. Insulators became excessively hot, resulting in cracking, and in some cases explosion, with disastrous consequences. To add to their troubles, little was known about corona control at high voltage.

RADIO REQUIREMENTS

It soon became evident that insulators of much higher quality and performance than those used with power station, telegraph and telephone networks were required to meet the more stringent demands of wireless station installations. Not only were the voltages much higher, but they operated at higher frequencies and in a steep fronted pulsing mode, resulting in high heat losses in the insulator material due to poor power factor considerations, and blemishes, not considered significant in other applications. The very high peak voltages caused a major problem with flashover due to corona and other factors. The shunt capacitance introduced by the insulator and its associated hardware also became significant in system design.

The Radio Engineers also posed other challenges for the ceramic chemists and designers for the production of insulators required for the aerial systems. In particular, these included strain types for aerial wires and cables, sectionalising insulators for steel guy ropes and thrust or base insulators to support tall radiators. Guyed tubular base insulated radiators as high as 200 ft (61 m) were in service as early as 1906 in USA and Scotland.

By 1925, there were at least 50 high power long wave stations in service throughout the world, some of which employed powers in excess of 500 kW with several 1000 kW designs on the drawing board. However, with development in short wave technology and the greatly improved traffic handling capability of these stations, there was a rapid expansion in station numbers. By 1928, there were at least 300 major radiocommunications stations in service and this brought further problems for the Radio Engineer in insulator design. The higher frequencies required material of even lower loss characteristics and new end cap designs that would not only handle high voltages but also reduce insulator capacitance.

RADIO RATING

To meet the special needs of Radio Engineering, the term Radio Rating (RR) was introduced for ceramic insulators. The RR was the 1 MHz sine wave RMS voltage that would produce a 50°F rise in temperature in the ceramic at the hottest spot. Engineers had a number of formulae available which were reasonably accurate for design purposes up to at least 10 MHz. The formulae enabled the designer to change the insulator RR rating to any other frequency, to change the insulator RR rating to any modulation factor (M), to change the insulator RR rating from a 50°F rise to a 70°F rise, to obtain the temperature rise at any frequency and voltage and to obtain the temperature rise when modulated, if the temperature rise unmodulated was known.

STEATITE

By this stage, steatite became available as an insulating material. The loss factor of an insulator made of steatite was less than 25% that of porcelain so that the RR of a steatite insulator was twice that of porcelain. For a typical 150 mm stand-off insulator, a steatite type had an RR of 36 kV compared with 18 kV for an equivalent porcelain type. For the same voltage and frequency, the temperature rise of a steatite insulator was generally less than 25% that of a porcelain type of the same dimensions. Design data available at the time shows that the average dielectric constant of a porcelain insulator manufactured by the wet process method was 6.3 with a power factor of 2% at 50 Hz and 0.6% at 1 MHz giving a loss factor at 1 MHz of approximately 3.8. Commercial steatite with an average dielectric constant of 6.1 had a power factor of 0.2% at 50 Hz and 0.2% at 1 MHz giving a loss factor at 1 MHz of 1.2. Even at 100 MHz — well above the short wave band the loss factor was less than 3. Low-loss steatite used mainly in valve sockets and plug inserts had even better characteristics.

INSULATORS FOR TRANSMITTERS

The transmitter in particular, employed a large range of ceramic components. Designs in the early 1930s included valve sockets, mounts for forced air cooled valves, water coils for water cooled valves, stand-off insulators of various designs, as well as plug and receptacle assemblies.

At the time, transmitter designers were devoting much time to the production of equipment, the appearance of which was in keeping with its high quality. Construction had reached the stage where transmitters were neat, orderly, well-finished and giving the impression of sturdiness and high reliability.

The designers demanded the same high standard from insulator manufacturers as other component manufacturers and this led to the production of high quality, blemish free ceramic, and hardware carefully designed and finished to provide an assembly of top performance and pleasing proportions in harmony with other components making up the transmitter.

Stand-off insulators were available in a range of sizes with uniform or tapered cross section or with corrugated sides suitable for heavy or moderate duty application. The tapered design had the same cantilever strength plus lower loss and lower capacitance than one of uniform side with diameter equal to the maximum diameter of the tapered unit.

Up to about 1930, there had been no suitable stand-off ceramic insulators for radio frequency application. Ordinary power pin types had been used for supporting copper tubing or cables within the transmitter but they had high loss and high capacitance. Hot air from the valves and components added to the heat generated within the insulator and cracked insulators were a major problem with the operation of some early transmitters.

In designing improved insulators for transmitter application, metal inserts which had been a feature of insulators of the 1920s were eliminated. Measurements showed that the internal temperature rise of an insulator fitted with a metal insert was approximately twice that of an insulator fitted with an end cap with rounded edges. With good end cap design, the operating voltage was limited by heating of the ceramic, with corona rarely being a problem.

INSULATORS FOR EXTERNAL PLANT

The design of insulators for external purposes such as lead-out, transmission line, aerial array, vertical radiator base and guy sectionalising insulators required great care. In addition to the need to meet the necessary voltage and frequency requirements they had to meet stringent mechanical and environmental conditions. Silicon-aluminium end caps were introduced during the early 1930s as they had superior characteristics for service in an aggressive salt laden environment.

Corona rings of large diameter were employed on aerial systems where high voltages were employed but when station operating frequencies moved up to the short wave band the high capacitance across the insulator due to the corona rings introduced problems necessitating a revised design of insulators end caps. Today, end caps used in short wave installations are very small compared with those used 50 to 60 years ago yet they can handle the highest voltages without excessive power loss due to corona.

Egg type insulators were widely employed for aerial conductor insulation and in guy ropes at broadcasting stations in the 1920s when T and L type aerials were in service. With the introduction of tall lattice steel radiators in the 1930s, cast metal assemblies were used to break up guy ropes with the porcelain being in compression. The principle is still employed today with variations being made to the metal assembly design to take account of increasing voltages resulting from the high powers of some modern transmitters. At some stations, particularly where transmitter powers were increased to 50 kW, opportunity was taken to upgrade the guy insulator assemblies when steel ropes needed replacement because of maintenance considerations.

Base insulators were introduced in the form of a push-pull design for insertion at the base of legs of self-supporting towers and as tubular designs for guyed masts.

Although practice in the USA almost from the start of broadcasting was to use a design known as a 'compression cone', the Australian practice when the first tall armature top radiators were designed for the NBS stations at 2NR Grafton, 3WV Dooen, 6WA Wagin and 2CR Cumnock in the mid 1930s was to stand the base of the mast on a group of tubular insulators 312 mm high, 225 mm diameter and 44 mm wall thickness. Much larger insulators were designed for the armature and inductor cable lead-in insulators. All these insulators were manufactured to PMG's Department designs by Sunshine Porcelain Potteries Pty Ltd in Victoria. At the time, the production was considered to be a significant achievement in ceramic insulator technology.

When tall radiators were constructed without armature tops for 3LO/3AR, 2BL/2FC and 4QS, large single tubular insulators were installed at the bases. In the early 1960s when 5CL/5AN and 5CK were erected, multiple base insulators were again used together with multiple insulators at the sectionalising points. These assemblies were oil filled and were manufactured in the USA. The guy insulators for these stations were imported from Japan.

ENVIRONMENTAL FACTORS

The electrical performance of an insulator is affected by a number of issues including on-site environmental factors such as relative humidity, rain and airborne contaminants.

Performance decreases considerably as the humidity is increased. For example, tests on strain insulators conducted during development of insulators for Radio Australia Cox Peninsula in the 1960s, indicated that for a 300 mm insulator designed for a flashover voltage of 110 kV under very dry conditions, the flashover voltage fell to 85 kV at 30% relative humidity and to 72 kV for a relative humidity of 95% which would be normal for the tropical site for much of the year. For a simulated rain test, the fall was even more dramatic. For four samples tested, average flashover was 44 kV at 50 Hz. On an equivalent RF basis, this is about 35 kV. This figure is the same as the peak line voltage for 100% modulation with 500 kW transmitter input to line so considerable effort was directed to redesigning end caps to improve the factor of safety.

Contaminants can sometimes have an even greater effect in reducing flashover characteristics than rain water. At some stations located close to the sea, such as 5CL/5AN Pimpala, wind blown salt deposited on the four parallel sectionalising insulators resulted in the transmitter going through a series of drop outs and recycling with the onset of rain and sometimes taking a minute or more to clear.

Salt and other contaminants appear to have a greater effect on horizontally mounted insulators than vertically mounted ones in an aerial system. With Cox Peninsular development work, studies were made by Jack Ross and Bill Gold of the influence of deposits of salt spray, carbon dust from bush fires, pulverised dry grass and powdered dust from the site.

Using sample of 40 mm diameter insulators, each 300 mm in length and fitted with similar end cap designs, the dry flashover voltage averaged better than 110 kV. Average flashover voltages for horizontally mounted insulators were 17 kV following a three second salt water mist spray, 45 kV for carbon dust deposit and 95 kV for soil dust deposit. The carbon and soil deposits were blown into a box in which the insulator was located and the material allowed to settle for a few minutes before tests were carried out. For vertically mounted insulators, there was improvement of 20 to 25% on the horizontal figures. Flashover voltages for the carbon dust and soil dust samples dropped significantly following the application of a three second mist spray of deionised water. During tests in connection with temperature rise characteristics, it was observed that dark brown glazed insulators were on the average, 2 to 4°C higher than white glazed types. The tests were conducted out of doors, and it was suggested that the rise differential may have been due to the greater heat absorption from the sun of the brown glazed types. However, the matter was not taken further at the time.

Whatever the reason for insulator flashover in the field, the result can sometimes be disastrous on the integrity of the insulator ceramic and/or its associated hardware. At high frequency stations in particular, with transmitters producing 250 kW and more into lines and aerials, discharges can occur over great distances. These discharges referred to as plumes or flares were observed at Cox Peninsula to extend up to two metres in length with one end terminating on the insulator end cap or corona ring, and the other diffusing in the air. The power dissipated was probably many kilowatts as on a number of occasions large metal components of the aerial system melted, with the metal falling to the ground and setting fire to dry grass as well as causing damage to the aerial system itself. On one occasion, an insulator shattered and broke away immediately beneath the corona ring, some 75 mm from the end cap.

At Radio Australia Carnarvon where the station was close to the sea, insulator deterioration was a major problem. Glazing was eroded and pitted as a result of high RF current leakage and arcing due to deposits of moist salt on the surface. Insulators at the lower end of the vertical element feeders were more affected than the others because of drainage of salt laden water from elements above, during rain periods. Several remedial activities were tried over the years including coating the insulators with a layer of silicon based grease of low conductivity.

DEVELOPMENT WORK

During the Second World War years, considerable work was undertaken in Australia on the development of ceramics to meet the radio needs of the Armed Services. In particular, the advent of radar with its exacting insulator requirements and the need to develop the production of steatite insulators involved participation by many local industries. Some of those involved include Nilcrom Porcelain (Aust) Pty Ltd, Sunshine Potteries, Ducon Condenser Pty Ltd, Kosters Premier Pottery and others.

Nilcrom Porcelain (Aust) Pty Ltd provided much of the specialised insulators required for the Royal Australian Navy 200 kW low frequency transmitter commissioned in 1942 near Canberra. Such items as pedestal insulators 1 m high, insulators for the 5 m high aerial loading coal former, cable rest insulators and aerial switch gear insulators were all produced using local resources. In post War years, the company produced insulators for NBS installations.

Kosters Premier Pottery of Adelaide provided many of the large strain insulators used in the development of insulator designs for the Radio Australia Cox Peninsula project in the 1960s in which a great deal of work was undertaken in designing low capacity end cap assemblies by Jack Ross, Bill Gold and Don Beames.

In more recent times, manufacturing and development work to meet the needs of broadcasters has been undertaken by Morlynn Power, a Division of Morlynn Ceramics Pty Ltd, Victoria in conjunction with Telecom Broadcasting Division. People involved in this technical development work include John Swarbrick, Leon Sebire, John Bray, Gary France, Dave Fuller and Ed Bondarenko.

In addition to high quality porcelain and steatite insulators, glazed alumina ceramics have also been employed at some stations. At the three NBS high frequency stations provided in the Northern Territory during 1986, the transmission lines and radiator were provided with alumina ($A1_20_3$) ceramic insulators.

RECEIVING AERIALS

TYPES

In 1935, the Sales Manager from AWA Sydney, during a talk to AWA representatives in South Australia on the subject of erecting receiving aerials for broadcast receivers said:

'This is important work because the performance of the finest receiver that money can buy will be ruined if it is connected to a makeshift aerial.'

Receiving aerials with early home broadcast receivers were an expensive part of the total receiver installation cost. Installations tended to follow transmitting aerial designs but on a less elaborate scale. The poor sensitivity of the average receiver in use meant that a large outdoor aerial was essential, especially where the receiver was located a long distance from the transmitting station.

An earthing system formed part of the installation together with a lightning arrester to prevent damage resulting from a lightning stroke to the aerial.

Operating instructions which accompanied many receivers provided details of the construction of a recommended aerial and earth system. The typical system provided was influenced by the area available and cost considerations.

The most widely used types were simple vertical wire, doublet, T type, vertex or 'bird cage', inverted L, horizontal V, umbrella, condenser, and box loop. Factory or homemade loop aerials were available where it was not practicable to install an outside unit. Room picture rails were also frequently put to use by tacking a wire around the rail.

Some manufacturers produced units which they claimed could be used in place of the aerial system. Typical of these products were ICA Insultenna Aerial Eliminator a 'black box' containing a length of a 'new type of filtered aerial wire and capacitors'. The manufacturer claimed the device would provide identical performance to an outside 18 m long aerial wire. Another unit was the Powertone Aerial Eliminator claimed to reduce static and man-made noise ordinarily picked up by outside aerials. The brochure enclosed in the package indicated that performance was at least equal to that of a 30 m aerial.

The Powertone Indoor Aerial Tape was popular for indoor aerial installations. It was a flexible metallic ribbon designed for placing around moulding, picture frames etc. The roll of tape which contained 18 m of ribbon had a lug fitted at both ends for connection to the receiver.

Other devices available included the Aeroformer which was placed in series with the aerial and tuned to resonance after spot tuning the receiver to a new station frequency, and the Powertone Universal Coupler which permitted the use of an ungrounded feeder or transmission line with a receiver without affecting the stability which grounding the chassis often provided.

INSTALLATION

In a booklet issued in 1924 by Morris and Skelley of Melbourne, describing the installations of aerials for receivers sold by them, they recommended a single wire aerial 100 ft (30 m) long and 35 ft (10.6 m) or more high to ensure good reception of signals. They recommended copper wire 7 strand 22 gauge as it was more flexible than solid copper or galvanised wire of the same diameter. It was suggested that one end of the wire be attached to the house in which the receiver was located and separated from the building with egg type porcelain or other suitable insulators. The far end was to be suspended by means of a wire or rope and insulators from the top of a barn, a tall tree or a guyed wooden or iron pole. It was suggested that the lead-in from the aerial should be brought in through a hole drilled in the window pane or a hole in the window frame via a lead-in insulator.

Some publications devoted considerable space to instructions for installing inside aerials. The American Atwater Kent Manufacturing Company which sold large numbers of receivers to Australian listeners through importers, recommended in their 1927 booklet, that successful indoor aerials could be installed in the attic under the roof, above a room ceiling, along a picture rail, surrounding the window or a square spiral format under a rug. Full installation procedures were given for each type.

Many enterprising manufacturers and radio shop owners advertised special aerial wires and earth devices which they claimed would result in vast improvement in reception.

One such aerial was called Electron Wire which was made in England and sold in a cardboard box for two shillings and sixpence for a 100 ft (30 m) reel. In an advertisement in 1927, in the •Listener-In', it was claimed that Electron Wire:

- abolishes insulators
- abolishes masts
- brings results
- promotes comfort
- is stormproof

- is troubleproof
- is foolproof.

Other brands of aerial wire which could be purchased at local Radio Shops included Ensign, an outfit packaged in a cardboard box comprising 100 ft of hard drawn stranded copper wire, 25 ft of rubber covered wire for lead-in and two porcelain insulators; Mars which comprised 100 ft of hard drawn phosphor bronze wire of 84 strands of very fine insulated wires spirally wound on a wooden reel; Claristal a packaged aerial of 100 ft of stranded copper wire, six insulators, an ebonite lead-in tube and a roll of cord; and Recepticon, stranded HDC inside a braided and weatherproof cover.

Among the non-long-wire types was the patented Perfex which consisted of two circular rims about 3 ft (90 cm) in diameter and spaced about one foot (30 cm) apart vertically, with wire wound around from rim to rim to form an open-ended basket. The bottom rim was fitted with four insulated spokes at the centre of which was fixed a threaded flange. A pipe was screwed into the flange and fixed to the chimney of the house. It was a great space saver and did not cause concern with neighbours as often happened with tall mast types erected near the neighbour's fence line.

The company used the same patented design to produce a number of indoor versions. One was the Light Shade Aerial. It was circular in form like the external model but only 50 cm in diameter. Instead of the flange, a fitting was provided to enable the aerial to hang from the electric light socket. The frame was covered in pleated silk material to provide an aerial of decorative appearance in the room where the radio was located.

A cage type aerial designed along the same lines as the English Perfex was the vertex or 'bird's cage' aerial. It comprised two circular metal rims, usually copper tubing, about 30 inches (750 mm) diameter and spaced about 12 inches (300 mm) apart with chicken wire covering the space between the two rims. Some enterprising bird lovers covered the bottom rim with chicken wire to encourage birds to build a nest in the cage. Mr L Ready of Eagle Junction in Brisbane installed one of these bird cages on top of a 65 ft (20 m) high mast in 1925 and it became a meeting place for a family of kookaburras for about 12 months even though they made no attempt to construct a nest.

A similar aerial with a mesh bottom was erected by Ern Baker a listener near a lagoon at Nashville, a Brisbane suburb in 1926. It became a nesting place for one of the birds from the lagoon.

George Bailey owner of experimental station 5GB in Mt Gambier, South Australia called his aerial a 'crabnet' aerial and employed one in 1924 with good results for both transmission and reception. His aerial comprised two half inch (12 mm) flat iron hoops 36 inches (900 mm) in diameter and spaced 15 inches (375 mm) apart separated by oiled wooden spreaders. He wound 100 ft (30 m) of 7/20 gauge enamelled copper wire around the frame in similar fashion to winding rope on a drum. The lead down wire was kept clear of the single supporting wooden mast by a projecting arm with an insulator and the wire fed into the house via an ebonite lead-in tube.

George said the idea originated with small vessels during the First World War when wire aerials were usually the first things shot away during an engagement. Also, many small vessels had only a single mast, making the installation of wire aerials difficult. The design details were published in an English magazine about 1920 and reports indicated the 'crabnet' aerial was more efficient as a radiator than a short single wire.

MASTS

The Manager of a Timber Yard in Brisbane which carried a large stock of Oregon Pine suitable for use with home aerial systems, while lecturing to members of the Sandgate Radio Club in 1927, made the following comments:

'When I travel around the suburbs of Brisbane, including the outer areas of Wynnum and Sandgate and observe the thousands of aerials put up for reception of broadcast programs, I am appalled at what I see.

Some installations are down right dangerous and are a danger to life and limb. I would not like to be a neighbour living under the shadow of some of the installations. I am struck by the non-descript collection of prop sticks, swaying bamboos, odd lengths of hardwood lashed or nailed together, water pipes with great bows because they have not been properly stayed, and in the other extreme, I have seen an enormous former telephone pole some 50 ft high which could support a hundred separate aerials on a hill at Hamilton.

There are great numbers which do not have any support poles. They are simply tied to the top of a stove flue, attached to the house guttering, tied to the swaying branch of a backyard tree, and in one case at Boondall, not far from here tied to a telephone pole carrying all the telephone lines from the city to Sandgate. I have no doubt that the Post Office does not know about it.

There is one set-up at Nundah where the owner nailed a 20 ft (6 m) length of sawn timber to each of the four corners of his house and ran a stranded copper wire around, to form a loop aerial, taking one end down to a lead-through insulator to the receiver.

In the inner city, around The Valley and Spring Hill, where there is little space for a fancy aerial, cage types about two feet in diameter attached to the chimney are popular.'

Although many people installed their own outside aerial system including the erection of masts, this activity was beyond the resources and expertise of others who called on experts who specialised in this type of work. Some of these experts also manufactured a range of masts which were sold to do-it-yourself enthusiasts.

Most of the large Radio Shops sold a range of parts for provision of an aerial including 3/22 SWG bare copper wire; 3/22 SWG enamel copper wire; 7/22 SWG enamel copper wire; 7/20 SWG bare copper wire; phosphor bronze wire; AWA Doublet aerials; aerial strainers; ebonite lead-in tubes; flexible lead-in connections; insulated screw eyes; button, barrel, cleat, reel, shell, mushroom, cowl, egg, shackle, glass strain, swan neck, stand-off, window pane and cone lead-in insulators.

Support masts were made in many forms but most were tapered round, or octagonal pole types usually made from Oregon timber, or steel types made from steel tubing. All required a guy system attached at one or more levels. It was the space required for installation of the guy system which caused the majority of problems in installing backyard aerials.

To simplify transport from factory to site, the support member was made in sections and assembled on site.

A typical 30 ft (9 m) wooden mast comprised two sections of timber together with six guys, strainers and lanyards, three wooden posts, aerial halyard with sister hooks, pulley, cleat, ground box and other sundry items. In many cases two such masts were required to support the aerial.

Steel mast were usually constructed of high grade steel tubing in 10 ft (3 m) and 5 ft (1.5 m) sections. Some tubes were joined at the junctions using hardwood turned rods fitted within the steel tubes and bolted through with galvanised bolts.

Another form of construction for steel masts was tubular steel telescopic sections. The sections were typically 2 inch (50 mm) diameter at the bottom and 1¾ inch (44 mm) at the top, so that one unit would slide into the other.

For a 35 ft (10.6 m) high mast a space of about 14 ft (4.2 m) diameter was adequate to erect the system.

Contractors who undertook this type of work during the 1920–30s included Mather and Payne, Torrensville, SA; Wireless Supply Depot, Adelaide; J J Love and Son Pty Ltd, Darling, Vic.; G H Busby, Stones Corner, Qld; Rosenfeld and Co., (Qld) Ltd, New Farm, Qld, and others.

LOOP AERIALS

The loop or frame aerial was widely employed with home receivers during the 1920s as an alternative to the large and sometimes expensive outside aerial. It comprised a number of turns of wire in the form of a circle, rectangle or square and provided a circuit complete in itself, in that it transformed the radiated energy directly into a voltage applied to the grid of the first valve. The loop was usually tuned. The selectivity was determined by the Q of the loop inductance and followed the universal selectivity curve.

Loop aerials more than 24 inches (60 mm) in diameter were usually constructed to be collapsible. Typically, they consisted of twelve to eighteen turns of fine stranded copper wire, sometimes Litzendraht, wound in the same vertical plane and held in place by ebonite, bakelite, hard rubber or varnished wood strips. One aerial provided with a receiver imported from Chas Freshman Co., Inc USA in 1927 used glass strips to accurately space the wires, with the holes being formed during the glass moulding process. It was a rotatable rectangular type with the wires being arranged vertically. The conductor was a thin silver wire covered in silk.

Kit sets made overseas and in Australia, were available from many Radio Shops. One kit set manufactured and sold in Adelaide in 1924 by Mackenzie and Maddern was a box type with the wires wound in the same horizontal plane rather than the vertical plane mode as was the case with the majority of assembled overseas models. The wire support frame was made of seasoned pine which has been soaked in a bath of very hot paraffin for several hours to prevent absorption of water by the wood. The base was cast brass, and provided with a ball bearing fitting to enable the loop to be rotated through an angle of about 100 degrees to obtain best signal reception.

In a kit set manufactured by Bullock's Cycle and Radio Stores in Adelaide in 1926, the four valve receiver incorporated a loop aerial which folded inside of the cabinet when not in use. The base was hinged so that the frame could fold down into a compartment between the back of the receiver chassis and the rear wall of the cabinet. The aerial was rectangular in shape and used twelve wires of 20 SWG with green cotton covering.

Imported models seen in homes in the early 1920s included Cosmos, Bowyer-Lowe, Wootophone and Sterling, all of which came from England. The Sterling model was typical of the construction techniques employed. It operated with a 0.0005 MFD variable capacitor and consisted of a polished walnut frame with dull black finished fittings. The arms had let-in ebonite strips upon which finely stranded silk braided wire was wound. The stand was metal, finished in black enamel with four base legs extended out to prevent the aerial from falling over. Rubber shoes were attached to the legs to prevent slipping when the aerial was rotated for directional reception. The wires terminated in a jack, and a two metre telephone cord allowed for connection to the radio receiver aerial terminals.

A number of models were also imported from USA either as separate units or fitted to receivers. Some of the receivers fitted with company made loop aerials in the mid to late 1920s included Radiola 25, Mohawk 105, De Forest seven valve D–17 Reflex Radiophone, Fada model 11, Zenith model 15, Ferguson model 14 and several Stromberg-Carlson models.

With the advent of mains powered receivers and their higher gain, particularly with the introduction of the superheterodyne circuit in the early 1930s loop aerials were rarely seen in Radio Shops.

However, with the advent of the 1.4 volt valve just before the outbreak of the Second World War, and its application to lightweight portable receivers, the frame aerial made a comeback. It was more widely known as a loop aerial and was usually in the form of a spiral fitted either in the lid of the set or at the back of the cabinet.

One popular model with home constructors was the RCS Loop Aerial Coil Kit type K116. The kit was prematched and tracked in the factory as a unit using a Q meter before being packed for sale.

Some local manufacturers also fitted loop aerials in their mantel models.

In the 1950s, the ferrite rod aerial replaced the wire loop model. It took up less space and was more efficient. With the introduction of the transistor radio in the 1960s ferrite rod aerials were used to great advantage in providing miniaturised radio receivers.

GROUND OR EARTH CONNECTION

The ground or earth connection was considered by experts of the day to be very important. Many installations were said to have performed poorly because of inadequate earthing and the importance of a good earth was often amply demonstrated during periods of lightning in the vicinity. The simplest arrangement was to take a copper wire to the nearest galvanised water pipe and fix it securely to the pipe by means of a clamp sold for the purpose. In the absence of a water pipe, a pipe driven into the ground or a buried copper plate would serve the purpose. Radio installation rules issued by Fire Underwriters Association forbid connection of the earth lead to gas piping.

Materials sold for earthing the receiver varied from a simple earth clip for connection to a metal water pipe, to a sheet of copper about 60 cm square supplied with a sweating lug and a length of wire. In addition, there were a number of earth tubes available. Typical was the Gecophone patented earth which consisted of a pointed metal tube filled with carbon granules and a top cap, through which was fitted a 5 metre length of stranded copper wire. The carbon filling enabled good conductivity to be maintained even after the metal tube had corroded away. It was claimed to be the solution of earth problems in dry areas.

Various materials were also available for mixing with water and pouring on the soil near an earth stake driven in the ground. The solutions were often plain salt which increased the conductivity of the soil, so improving the effectiveness of the earth.

Another approach was to obtain a syrup or treacle tin and pierce several small holes in the side and bottom. An earth wire of suitable length was soldered to the lid, the tin filled with salammoniac and the lid tightly fitted. The tin was buried in the ground to a depth of about 30 cm and covered with soil. These devices could be purchased already made up in the early 1930s from Radio Shops under brand names such as Super-Sal, No-loss Earth and others.

Although some people experimented with counterpoise systems as an alternative to a ground connection, a counterpoise was expensive to install, it was a hazard in the back yard and quickly lost favour. One listener in Prospect, an Adelaide suburb constructed a fan-shaped counterpoise of three wires which his wife used as a clothes line, much to the disgust of the designer.

Some receiver owners used the tin roof of the house as part of a counterpoise. Norm Allen, a farmer at Geebung out from Brisbane, installed two wooden poles about four metres high on the roof of his house and erected eight parallel stranded copper wires spaced about half a metre apart for the aerial. The poles were guyed by steel ropes broken up with small egg type porcelain insulators. The poles were spaced 10 metres apart.

Originally, the tin roof was connected to four buried copper plates by copper straps about two centimetres wide. Leads from the aerial and tin roof were taken into the receiver through lead-through ebonite insulators. Norm was not happy with the installation, and the following year, 1928, he removed the vertical earth leads which were each about four metres in length and with the aid of a buzzer test instrument checked that the roof iron was not earthed via down pipes etc. The roof then acted as an isolated counterpoise and he received better reception with distant broadcast stations with the new system. Stations which he had not previously logged included 5KA Adelaide, 3DB Melbourne, 2UE Sydney and 3AR Melbourne.

In a lecture to the Sandgate Radio Club members in 1929, he referred to the system as a 'condenser aerial'. Norm said he operated a DC generator with his home lighting plant and this produced a high level of noise from sparking brushes. When he removed the vertical earth leads from the roof sheet iron, the noise level in the receiver fell to a low level, enabling him to log stations that he has not previously heard.

The receiver was an Igranic Superheterodyne Kit which he had purchased from Wireless House Ltd in Edward Street, Brisbane for 25 pounds, and assembled himself.

High winds wrecked the aerial system about 1930, and it was replaced by a doublet type supported by two 20 m guyed steel pipes.

It is of interest that at the St Louis World Fair in the USA in 1904, a radio receiver was put into a hot air balloon for demonstration purposes to show the local newspaper, the 'St Louis Star' how radio could benefit the collection of news from aerial observations. The receiver operator threaded a wire through loops on the outside of the balloon and for an earth he filled a large tin pail with soil and stuck the ground wire into the soil. Reports indicated that the receiver worked satisfactorily over many miles from the take off point.

PROTECTIVE DEVICES

The Fire Underwriters Association rules on protective devices in the 1930s required the provision of such devices with outside aerials. The rules stipulated that the receiver be fitted with an approved lightning arrester which would operate at a potential of 500 volts or less. An aerial ground switch was desirable but did not obviate the necessity of an arrester. Any grounding switch had to be so installed that in its closed position, it formed a shunt around the arrester. The most popular switch was the single pole double throw type using either ebonite or porcelain base.

A reliable and effective arrester used in areas subjected to lightning at frequent intervals was the Siemens unit. It was a vacuum type fitted with a fuse for additional protection. The protector took the form of a spark gap with a very small space between two metal elements. The facing edges were serrated to increase the surface area and to assist in striking an arc when a lightning current arrived. The gap was supported in an exhausted glass tube having a metal cap at each end. A knife switch was fitted across the protector to allow any lightning current to travel to ground without passing through the protector gap. It was normal practice to close the switch when the receiver was not being used.

Another type of arrester was the carbon type similar to the types used on telephone lines. It comprised a U shaped metal piece mounted vertically and facing a carbon block. It was separated from the carbon block by a very thin piece of mica. Any lightning disturbance which resulted in the mica being punctured meant that the arrester had to be taken apart and the carbon dust removed, otherwise there would be signal leakage to earth.

Other units available from Radio Shops included HCR bakelite arrester; Radiokes arrester; moulded Marquis; Abbiphone, a combined lightning protector and double throw earthing switch mounted on a bakelite base; single circuit and double throw Chaseway lightning switches; Eelex, a combined lead-in, lightning arrester and earth switch and sold with lead-in rods of several lengths to suit wall thickness; Elwell aerial switch and vacuum lightning arrester mounted on an ebonite panel in a mahogany case; Ericsson lightning and power protector fitted with carbon lightning arresters and glass tube fuses mounted on porcelain base and enclosed in an enamelled iron dust cover; Gecophone bakelite moulded lightning arrester; Edison Bell automatic earthing plug lightning arrester using a push-pull rod in lieu of a standard knife switch; Igranic earthing switch; ICA Electrostatic Lightning Arrester made of black porcelain insulated base block and nickel plated brass terminals with choke coil and capacitor mounted in the arrester assembly and connected between the aerial and receiver terminals; Champion Arrester, a carbon resistor type; Short Wave Carbon Resistance Arrester designed specifically for doublet or double doublet aerials where two arresters were required for effective protection; Advance Combination; Parkson; Muter; Electrad; Fire Fly; Beanco; and others.

The Philips Aerial Cop was one of a number of arresters available in Radio Shops in 1930, which used a spark gap in a glass tube containing a rare gas. The device got its name from its appearance. It looked like a London policeman's helmet. The gas caused the spark gap to provide a discharge path as soon as the applied voltage reached 120 volts. The unit was encased in tough Vitrine glass with a green porcelain hood. It was fitted in a bracket below the aerial lead-in insulator. The top end was connected to the aerial and the other to a copper lead which went by the shortest route to an earth stake or buried earth plate. To cater for a high voltage strike, external spark gaps were shunted across the spark gaps inside the gas filled tube.

One Radio Shop which sold many of these units was John Lunn, a Chemist and Licensed Radio dealer who conducted a business at Sandgate out from Brisbane. In addition to a wide range of parts he had a stock of receivers, from crystal sets, one model of which featured a tapered coil with slider, to six valve battery operated models.

LIGHT SOCKET AERIAL

An alternative to the installation of an aerial, was to install a device which plugged into the electric light socket enabling the wires of the power mains to be used as an aerial. Typical units sold in Radio Shops during 1924–27 included brand names such as Antenalla, Dyna and Ducon. They were provided with an adaptor to plug into the electric light socket and a trailing wire which connected to the aerial terminal of the receiver.

Some receiver manufacturers provided Radio Servicemen with an order of excellence rating for various types of aerials. Rated number one, was outdoor types, followed by indoor types, light socket types and loop aerials.

In the light socket type advantage was taken of the fact that the electric mains acted as a long wire aerial, and by placing a capacitor of suitable capacity and voltage breakdown rating, in series with the electric conductor, it could be used as an aerial.

A typical light socket unit consisted of a plug which fitted into an ordinary lamp socket and a capacitor connected in series with each conductor entering the socket. On the side of each capacitor was a screw terminal to which could be attached a wire running to the aerial socket of the receiver. Because one of the wires in the electric circuit was isolated by the light switch when the switch was in the 'off' position, it was necessary to locate the unswitched line by trying both terminals before making a connection for the receiver.

Many people with radio receivers were still using this system up to the outbreak of the Second World War. Radio Shops like Homecrafts sold devices called 'Light and Radio Adaptors' which had been approved by the electricity authorities. They were available as 2-way Tom Thumb unit or 2-way unit fitted with two switches, giving separate controls for light and radio.

The technology of using the house electric wiring as an aerial was not new when broadcasting commenced. Staff of the USA Navy at Brooklyn Navy Yards had operated a crystal set in 1911 using one side of an electric power line as an aerial.

Ern Stanton of Adelaide is known to have employed this technique in 1913 with a receiver using a carborundum detector with his station XVN. Instead of fixed capacitors to isolate the 50 Hz power supplied by the Adelaide Electric Supply Company he used a variable capacitor in each leg. The capacitors were similar to those he made himself for the receiver tuning circuit. They comprised 12 fixed semi circular copper plates 10 cm diameter and 11 moveable plates 7.5 cm diameter.

About 1926, Roy Buckerfield who was in charge of the Transatlantic Wireless Manufacturing Company in Adelaide where Newkrodyne receivers were manufactured, built a device he called Aercap which could be plugged into the electric light socket. He installed one in the Workshop and used the mains as an aerial for testing the receivers. In a talk to the Glenelg Radio Club, Roy said that the mains aerial provided better signal strength from 5CL and 5DN than a fixed aerial looped around the workshop ceiling.

SHORT WAVE AERIALS

With the commencement of short wave transmissions from VK3LR Lyndhurst in 1934, the recommended receiving aerial for those country listeners able to receive the service was a doublet type. The doublet in its simplest form consisted of a half wave top section split in two i.e. two quarter wave sections with a transposed two wire lead-in connecting the two sections to the receiver. Theoretically, an aerial of this type was tuned and would only respond to the frequency for which it was designed to receive. However, in practice it was sufficiently broad to cover a reasonably wide band of frequencies. The aerial had a figure of eight directional characteristics which minimised noise pickup from side directions. A transformer was used with the aerial to enable the aerial to be also used for reception of MF stations where these could be received, usually during night periods. The transformer comprised a 100 turn primary with four tapped points and a 10 turn secondary. One side of the secondary was connected to the earth terminal of the receiver.

When Lyndhurst expanded, and transmitted on three frequencies from 1938, many listeners erected a variant of the doublet called a double doublet. In this system, two doublets of unequal length were crossed at their lead-in points and connection made between one side of one and the opposite side of the other. In effect, the entire arrangement was like two uneven T aerials crossed at their lead-in points. This gave the aerial two resonant frequencies and as these were arranged so that they fell in the upper and lower parts of any desired frequency band, a fairly even response over that band was obtained.

A typical kit obtainable from Radio Shops comprised receiver matching transformer with switch; cross-over insulator assembly; strain insulators; two coils of seven strand copper wire; a coil of balanced transmission line copper wire; transmission line insulators; insulating lead-in tube; cambric tubing; screw eyes; and a clamp and pipe for earth connection.

A J Veal Pty Ltd with six stores in Melbourne and which claimed to be 'The biggest radio and electrical store in Australia' in the late 1930s stocked doublet and double doublet aerial kits.

In 1935, AWA and Lekmek Radio Laboratories were two companies which manufactured aerials for domestic installations.

AWA produced a V doublet supplied with 100 ft (30 m) of twisted pair conductors, weatherproofed for use as transmission line from aerial to the receiver. The coupling transformer was automatic in action, in that it did not require any adjustment for operation on either short wave or medium wave bands.

The Lekmek aerial was a double doublet type claimed by the manufacturer to provide an even response over a wide range of frequencies. Two types of aerials were available, the first having a transformer designed for use with a 100 ft of transmission line, and the second, a transformer designed for a 200 ft transmission line installation. A switch was used in both types to adjust the transformer for operation on either short wave or medium wave bands.

In a report by Bert Harrington Radio Inspector, Adelaide following an inspection of a large number of aerial installations in the Adelaide area in 1937, he found that 15 installations employed AWA manufactured aerials, 22 employed Lekmek manufactured aerials, 104 employed unbranded types supplied as kit sets by local Radio Shops, while the rest comprising several hundred, were do-it-yourself designs comprising single or multiple wires, simple vertical tube, baskets or indoor types. Some of the most unusual installations included feeder connected to the iron roof of the house, a wire clothes line doubling as aerial and clothes line, feeder connected to the chicken wire of a fowlyard, feeder connected to the house guttering, feeder connected to incoming wire telephone line and many connected to the electric mains using commercially purchased light socket capacitors.

One listener at St Kilda, Melbourne who purchased an Essanay five valve superheterodyne receiver in the late 1930s erected an umbrella type aerial on the recommendation of Lay Cranch, the company Technical Engineer. The aerial was constructed using a 12 metre high Oregon mast recovered from an old yacht at Port Melbourne. He cut six stranded copper wires each about 10 metres in length, and before erection of the mast attached them to the top using a metal hoop but insulated from the hoop by egg type porcelain insulators. After erection of the mast, the bottom ends were attached to small poles spaced about 60 degrees apart and high enough to keep wires clear of anybody walking near the structure. A skirting copper wire looped all wires and a lead taken from the skirting wire to the receiver through a lead-in porcelain insulator. The listener reported that he obtained good performance on both medium wave and short wave bands.

Receiving stations installed by the Postmaster General's Department and Commercial stations for reception of overseas programs for rebroadcast purposes erected a variety of types, usually ones which provided a gain and with directional properties.

The Department's Liverpool Receiving Station during the War years, provided not only programs for rebroadcast, but handled incoming traffic for the British Pacific Fleet. The majority of the aerials were rhombic types beamed on Guam, San Francisco and Daventry as well as NBS short wave stations at Perth and Lyndhurst. Provision was made for diversity reception from Daventry in the UK over either the long or the short path. Altogether, there were 11 aerials in operation.

The Department's High Park Receiving Station which was commissioned during 1959, employed three different rhombic designs, an inclined Vee type, wideband dipole arrays, a top loaded vertical and an 11 metre vertical. Design staff included Jim Ward, Frank Norman, Keith Ferres and Bob Barton.

In the rhombic group, Type I was a two wire two tier general purpose aerial designed for path lengths greater than 3000 km. It covered the frequency band 10–26 MHz and had a gain of 11 dB at 15 MHz relative to a dipole of the same height. The Type III was a two wire two tier aerial designed as the second rhombic of a diversity pair to work on paths of lengths greater than 3000 km. It covered the frequency range 5–16 MHz and had a gain of 10 dB at 10 MHz. The Type V was a two wire single aerial designed specifically for the Perth-Melbourne circuit for use in conjunction with a Type I as a diversity pair. It covered the frequency range 7–15 MHz and had a gain of 9 dB at 10 MHz relative to a dipole of the same height. The inclined Vee aerial had a beam elevation of 12° at 15 MHz and a beamwidth of 14°. Gain was 14 dB at 15 MHz relative to a half wave dipole in free space.

The Cox Peninsula Receiving Station was designed specifically for off-air reception of transmissions from Radio Australia Shepparton. The station was provided with a pair of vertically polarised dual plane log-periodic aerials spaced for space diversity. Broadband baluns were provided to match the underground coaxial feeders. The system was operational up to the time of Cyclone Tracy in 1974 when it was severely damaged. It was eventually dismantled.

ATMOSPHERICS

A major problem with reception in the MF band, particularly during summer months in northern Australia is the high level of atmospherics or static, an irregular disturbing noise. It was particularly bad with early receiver designs and designers put a lot of effort into the design of static eliminators with varying degrees of success. These included special circuit designs and components connected into the aerial circuit.

In one popular circuit arrangement, the receiver input stage and the aerial circuit was modified to accommodate an anti-static circuit. The anti-static device which included a valve and associated L, C and R components had to be well-shielded from the receiver proper and grounded with a low impedance ground connection. The receiver batteries and battery leads had to be shielded also.

A receiver owned by a vintage radio collector in Adelaide and which had been fitted with an anti-static device by the original owner about 1926, was set to work, and although the circuit had some effect on reducing the level of static it also reduced the level of the signal at the output of the receiver.

Components for insertion in the aerial which could be purchased from Radio Shops during the 1920–30's included Noisemaster Aerial Kit with a patented 'Antennex' aerial energiser, Airzone Aerial Filterizer, Fortevox Atmospheric Bypass Valve, Lekmek Aerial Filter and others. Mains line filters made by AWA, Radiokes, Airzone, Lekmek and others were also available to minimise noise pickup via the power mains.

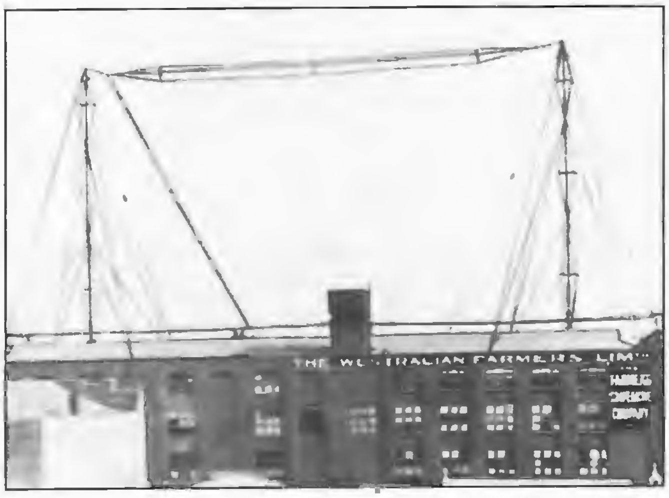
DEMISE OF THE AERIAL

From the commencement of broadcasting in the 1920s, up until about 1930, a good outside aerial was highly desirable, especially for listeners located some distance from a broadcasting station. Various inside types were often satisfactory for receivers employing one or more RF stages where the receiver was located within about 50 km from the transmitter and reception was during daylight hours. After sunset, reception was possible for infrequent intervals from almost anywhere in Australia due to sky wave reception, but the signals would, as a general rule, be subjected to considerable distortion and fading.

With improvements in valves and receiver technology, particularly the widespread employment of the superheterodyne circuit, gain, sensitivity and selectivity had improved to the extent that a console receiver would give good reception with only a small length of wire looped around the inside of the cabinet. Mantel models usually employed a basket or loop aerial.

Listeners located a long distance from a broadcasting station still required an outside aerial for good reception but by the late 1930s, manufacturers were providing a number of taps on the aerial coil to enable optimum performance to be obtained with the aerial in use.

The introduction of ferrite rod aerials in the early 1950s and further improvements in valves and receiver designs brought to a close dependence on wire type aerials whether erected outside or inside the home. Also, by the mid 1950s some 2 million licensed listeners were being served by about 170 MF broadcasting stations and very few large towns were not receiving a reasonably good signal during the daytime.

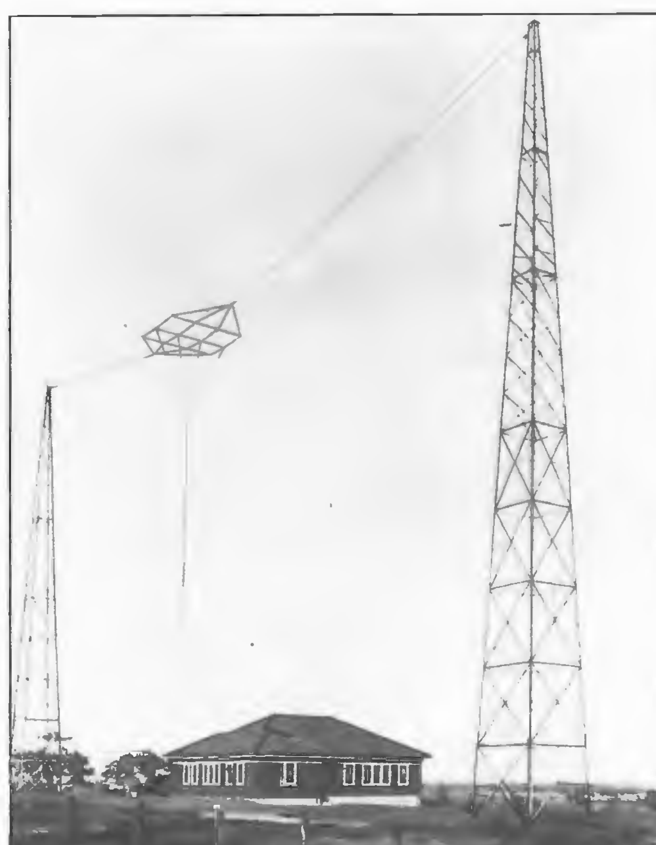


The original aerial system provided for 6WF Perth when it began operation as an A Class station for The Westralian Farmers Ltd in 1924. The aerial was an inverted L type using four wire cage of 1.8 m diameter and fed by a 200 mm cage feeder. Walter Coxon, Chief Engineer and Manager.

In the 1920s and early 1930s earth mats associated with aerial systems were laid as a grid, fishbone, a combination of these or as in the case of 7ZL, a rectangular grid with two semi circular radial systems. These systems were laid in trenches dug by hand. The 7ZL mat was laid in December 1926.
Construction Engineer Donald Macdonald.

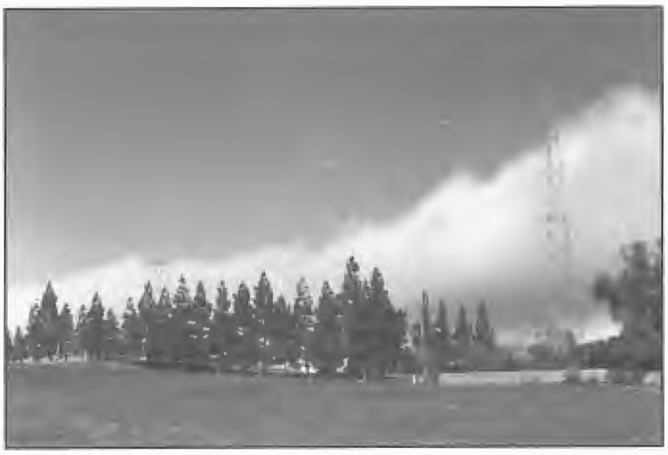
Installation progress at 5CK Crystal Brook 1931. Workman of tower erector Messrs Gibb and Miller, Port Adelaide preparing foundations watched by Engineer Laurie Billin. Material for the two 56 m high lattice steel structures was supplied by Johns and Waygood Melbourne.

The 5CL/5AN station at Brooklyn Park circa 1947. Station 5CL was established on the site as an A Class station in 1925 and in 1944, 5AN was removed from the city together with the self-supporting tower and installed in a new building alongside 5CL. Both stations ceased operation on 20 September 1961 when a new facility was provided at Pimpala.
Engineers associated with provision of early facilities included Frank O'Grady and Bert Retallick.



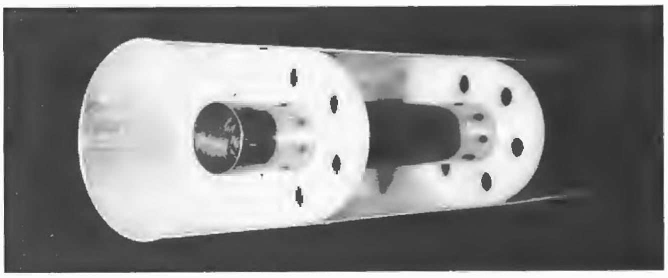
The 20 m flat top aerial supported by 40 m self-supporting towers erected in 1930 for 2NC Newcastle. The station was the first Regional station established on formation of the National Broadcasting Service. Installation Engineer, Harry Weir.

Alexanderson type aerials commissioned at 5CK, 2CO and 6WF in the early 1930s employed two tuned down leads at the ends of the horizontal multiple wire aerial. Feeders were cage types and terminated in variable inductors located in tuning huts near the support towers.



Multiple tuned or Alexanderson aerial system installed at 5CK Crystal Brook in 1932. Similar systems were installed at 2CO Corowa and 6WF Perth and were still operational 60 years later, mainly as standby units.
The multiple tuned aerial was developed by Ernst Alexanderson a prolific USA inventor with 290 Patents to his credit.

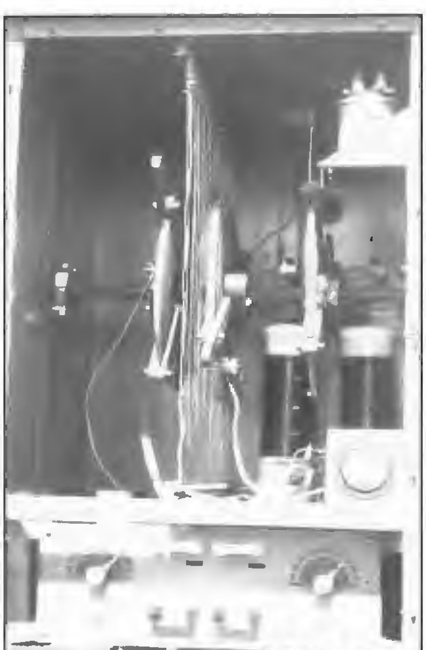
Six wire cage aerial at 5PI Port Pirie supported by two 41 m Oregon pine masts, 1934. It was an Alexanderson type with each end being tuned via variometer. Years later when it was dismantled, the Oregon masts were cut up and used as masts for small boats.



Cutaway view of a rigid coaxial feeder using copper tubing for inner and outer conductors and low loss spacer insulators. The first rigid coaxial line in Australia was used at 6WF Perth in 1932 when PMG's Department staff designed and constructed a new station to replace the original 1924 installation. An unusual application was at 5AN Adelaide in 1937 when a 500 watt transmitter was located in an annexe of the Telephone Exchange Building and fed a 62 m insulated tower on an adjacent building by an 80 ohm coaxial line with inner conductor 6 mm diameter and outer conductor 25 mm diameter.

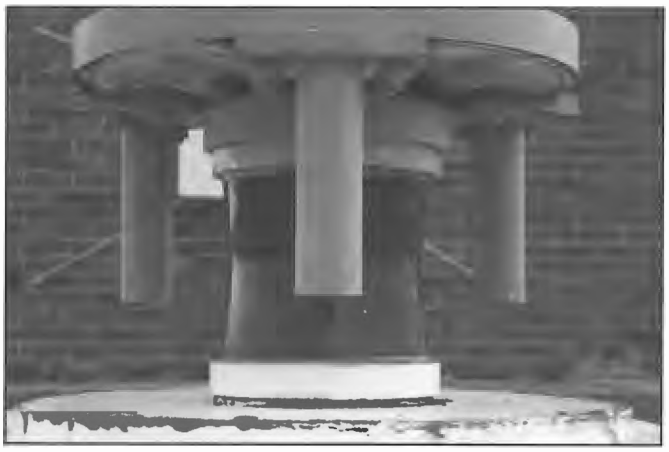
The 198 m lattice steel armature top radiator installed at 2CR Cumnock in 1937 and still in operation in 1998. The design was prepared by PMG's Department Research Laboratories in the mid 1930s and installed at many NBS stations. The horizontal armature is insulated from the vertical section and electrically connected via an inductor. The armature and inductor combination act as a termination equivalent to many metres of mast height. Alec McKenzie was responsible for design aspects.

Self-supporting 60 m tower on roof top of Perth GPO employed as the radiator for 6WN which went to air on 12 October 1938. The feeder linking the 500 watt transmitter to the aerial was an 80 ohm concentric type. During the War years, the tower was dismantled and the transmitter shifted to another site.



Faraday screen and spiral inductors provided an aerial coupling unit 4AT Atherton 1939. A two wire 600 ohm transmission line connected a 500 watt AWA transmitter to a 110 m steel pipe radiator. Chief Engineer, Ambrose Armistead.

Typical self-supporting tower used for broadcasting station located in city business area. This 50 m base insulated structure replaced a T type provided when 5AD Adelaide commenced transmission in August 1930. When a 2 kW transmitter was installed at a remote site at Cavan in 1954, the city radiator was taken out of service. Chief Engineer 1954, Don Gooding.



Base insulator of 3LO/3AR, a 215 m radiator erected in 1938. Similar designs were erected at 2FC/2BL and 4QS but of different heights. The 3LO/3AR structure was the first to be employed as a dual frequency radiator. Station 3AR now operates with callsign 3RN. First Officer-in-Charge 3LO/3AR, Stan Hosken.

Before the advent of the mole plough for laying copper wires for a radial earth mat for a vertical radiator, trenches were either dug by hand or excavated by using an agricultural type plough pulled by a horse or truck. After laying the wires in the trenches by hand the soil was backfilled using a scraper, again pulled by the horse or truck.

Single wire earth mat plough. Vertical MF radiators employ a buried radial earth system typically 120 wires at 3 degree spacing and buried about 150 mm below the surface. Copper wire is fed down a chute at the back of the tine while the plough is pulled along by a tractor or truck. Manufactured by PMG's Department Adelaide Workshops.

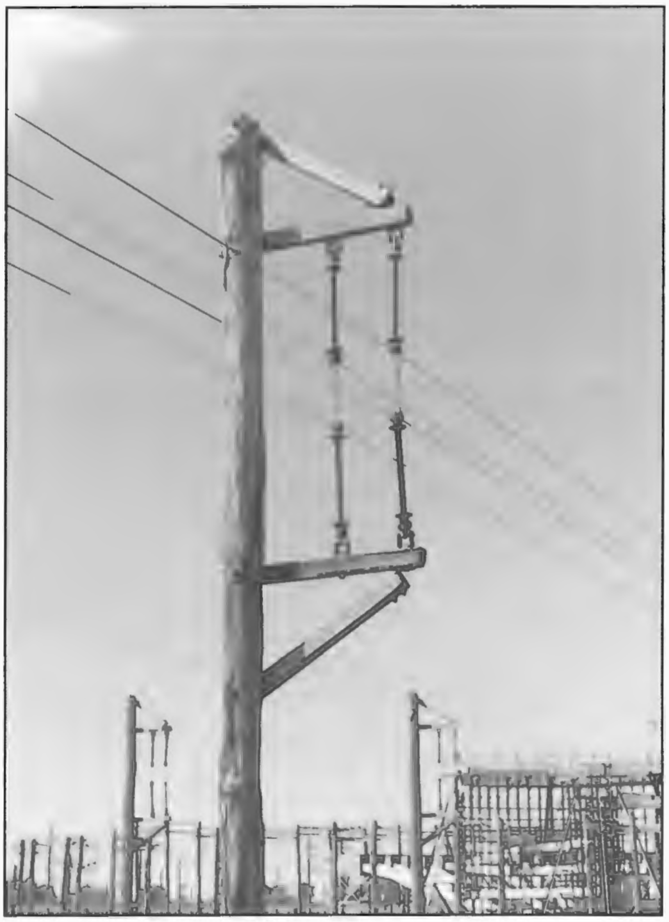
Tubular 50 m high radiator installed at 5MU Murray Bridge 1949. It replaced the original six wire flat top type installed when the station was commissioned in 1934 by Frank Miller.

Typical six wire transmission line consisting of four earthed conductors and two central conductors attached to stand-off insulators. Characteristic impedance is approximately 200 ohms. One of the earliest lines to this design was provided at 2BL in 1942.

The photograph shows one pole of two identical transmission lines with 50 kW capability erected for transmitters 5CL/5AN Adelaide in 1960 by Don Beames and staff.

Part of VLQ aerial system installed at Bald Hills 1943 using dipole and reflector format. Support structures were sawn Oregon masts. Transmission line was 600 ohm two wire type. The service which transmitted ABC programs was closed down in December 1993. Vern Kenna was in charge of installation.

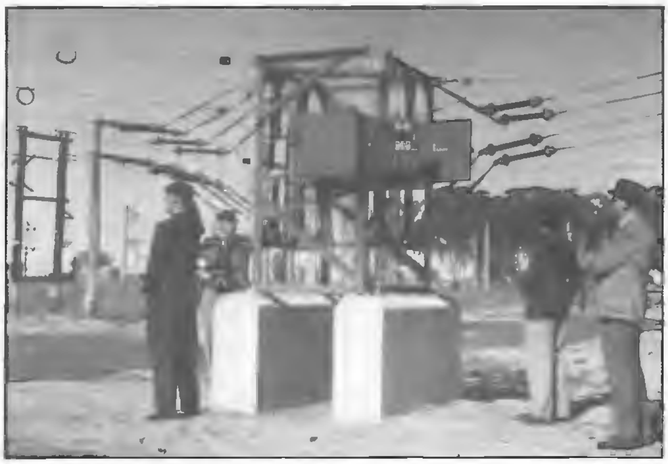
Main 6 and 9 MHz aerials employed at National station VLW Hamersley for ABC HF Inland service. Each aerial comprised dipoles and reflector curtain suspended by 40 m guyed lattice steel masts. The service was closed down during 1994. Station Officer-in-Charge, Murray Little.



Open wire transmission lines Radio Australia, Shepparton using wooden support poles installed 1945. Four 600 pound per mile (4.8 mm) copper wires were spaced 300 mm apart in square format to provide a line with characteristic impedance of 310 ohms. Installation Engineer, Jack Kyne and Project Line Foreman, Jack Laydon.

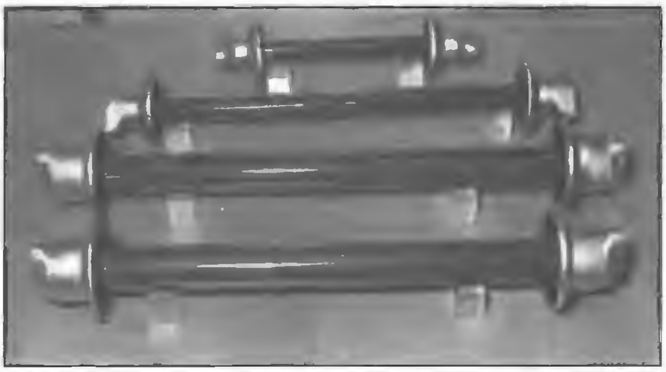
Single frequency curtain aerials provided at Radio Australia, Shepparton 1945. Nineteen directional arrays were supported by 14 guyed lattice steel masts each 66 m high. A switching system provided for reversing the direction of radiation of some aerials and also for slewing some in the horizontal plane. Engineer, Jim Wilkinson was associated with lining up and commissioning the systems.

Wooden poles were used for many years for support of aerial systems at receiving stations and transmission lines at transmitting stations. The disadvantage of such practice outweighed the advantages and today are not employed. At Radio Australia, Shepparton wooden poles served the purpose for about 50 years from the 1940s before being replaced by steel poles when new aerial systems were provided in 1993.

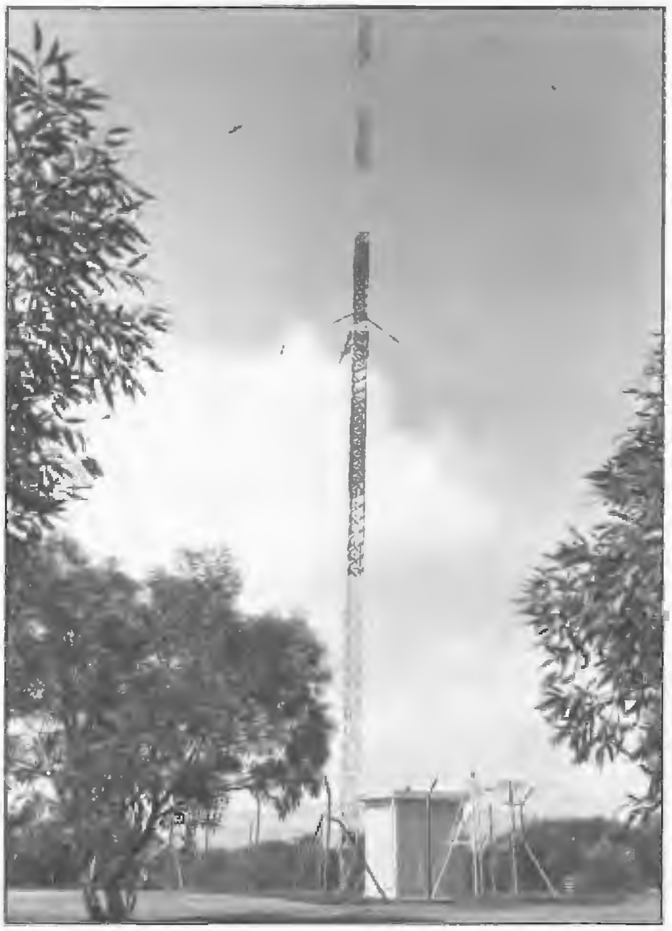


Transmission line switching unit Radio Australia, Shepparton 1945.
L to R: West Hatfield, PMG's Department; Tony Brettingham-Moore, STC; Sid Witt, Head PMG's Department, Research Laboratories; and Tim Bore, STC. Tim Bore subsequently became Managing Director STC 1949–61.

Aerial Switching Control Desk Radio Australia, Shepparton 1945. The desk controlled external line switches by means of push buttons. There was a push button for each aerial and aerial direction available to its associated transmitter. Once the transmitter was powered, the DC supply to the desk was removed so preventing shifting of power carrying switches. Officer-in-Charge, Jack Hargreaves.



Strain type rod insulators designed for transmission lines and aerial systems Radio Australia, Shepparton 1945. End caps were made of cast brass and insulators of high quality porcelain, glazed chocolate colour. Alec McKenzie was associated with the design and development of the insulators.



A 40 m lattice steel radiator at 5LN Port Lincoln placed in service November 1950. It was fed by a 200 ohm open wire transmission line from a 200 watt AWA transmitter. The mast was replaced in 1974 following problems with corrosion of steel members.

Armature being fitted to 198 m dual frequency radiator 4QG/4QR Bald Hills, 1948. The armature is insulated from the main vertical structure and electrically connected via an LC network. A similar structure was provided at 6WF/6WN Perth in 1953. Station 4QG now operates with callsign 4RN. Modifications were undertaken in 1963 to cater for increase in power of 4QR to 50 kW. Vern Kenna was associated with commissioning the system in 1948.

A 17 m pylon type radiator comprising slotted line sections provided for the ABC FM service Adelaide in 1951. It was originally installed at Mt Bonython but later transferred to Mt Lofty, the site of the present National TV and FM services. It ceased to be operational when the FM mono service was closed down in 1961 but in later years served as a standby when the FM Stereo service commenced. Engineers associated with the design and commissioning were Frank Norman and Frank Brownless.

Guy insulators for 180 m 6WF/6WN radiator guy system being prepared for installation by Project Engineer, Alan McCarthy 1986. The mast was erected in 1953 and the design of the original insulator mount was such that some operational problems had occurred due to arc-over. Senior Lines Officer, Stan Randall controlled the workforce, Senior Draftsman, Ian Gibbs checked mast alignment and Structural Engineer, Bruce Cook provided specialist advice.

Typical base insulator mounting arrangement at a site subject to flooding. The 2KP Kempsey sectionalised radiator base insulator and the aerial coupling unit are mounted 2.5 m above ground level. The 168 m sectionalised radiator was erected in 1954 and in 1965 was fed by a pair of STC type 4S55B 5 kW transmitters in parallel. The mast is located on a flood plain alongside the Macleay River and flooding of the site is a frequent occurrence.

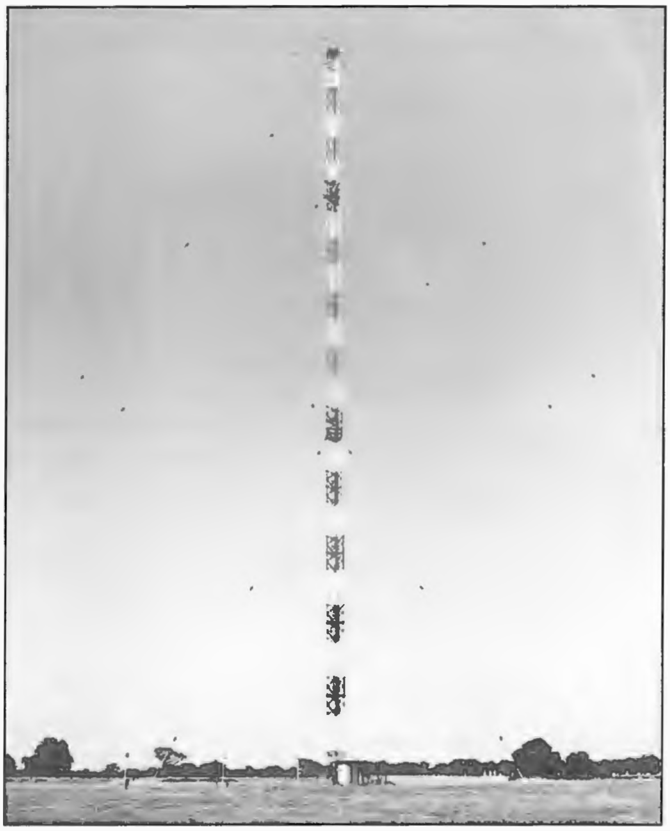
Nine conductor open wire transmission line in service at 10 kW NBS station 2KP Kempsey in 1994. It fed a 168 m anti-fading radiator. A similar line fed a standby radiator. This type of construction which utilised telephone line technology was employed at a number of stations in New South Wales and Queensland. The system comprised 4 active and 5 earthed wires and produced a characteristic impedance of approximately 100 ohms.

The 128 m sectionalised and top loaded radiator at 4RK Rockhampton erected 1954. It replaced the original four wire flat top aerial which had been in service since July 1931 when the station was commissioned. As at 1993, the original aerial was being used as a standby aerial. The new radiator was the first of the type installed in Regional Queensland. Commissioning Engineers, Mick Hall and Frank Sharp.

T type flat top aerial 22 m high using square section cage feeder at National station 5MG Mt Gambier. The station was commissioned on 26 September 1955 using main and standby 200 watt Philips transmitters. A PT29M coaxial feeder linked the transmitter to the Aerial Coupling Unit. Murray Higgins was Divisional Engineer-in-Charge of the installation. Station Officer-in-Charge, Bill Legg.

Crossbar switching system installed at Lyndhurst HF transmitting station 1956. It was manually operated and allowed 10 transmitters to access 26 aerials. The switch was still operational when the station closed down in 1987. Mark Chapman operating switch.

Typical lattice steel guyed omnidirectional radiator employed at Commercial stations in the 1950s. This 130 m radiator guyed at six levels was erected for 3SR Shepparton in 1956 at a site 12 km east of the town. It was fed by a 2 kW AWA transmitter operating on 1260 kHz. Chief Engineer was Ray Jenks. The radiator remained in service for 30 years until a new 130 m structure was commissioned in 1986 at another site following expiration of the lease at the old site.



Sectionalised and top loaded radiator installed at 5PA Penola 1956. The antifading radiator was 94 m high with 10 m diameter top loading armature. The mast was sectionalised at the 70 m point and an inductor placed across the insulator. It was the first radiator of this type to be installed in South Australia. Officer-in-Charge, Lew Grubb.

Base of the 134 m high lattice steel radiator at 3RPH Melbourne showing the base insulator, grounding system and lightning arrester. The system was originally commissioned in March 1956 for Commercial station 3KZ Melbourne when approval was given for Melbourne based stations to be transferred to Heidelberg-Lower Plenty area and for transmitter powers to be increased to 5 kW. Transmission line is a six conductor open wire type. The facility was transferred to the Print Handicapped group with callsign 3RPH when the owners of 3KZ acquired a licence to operate in the FM band from 1 January 1990.

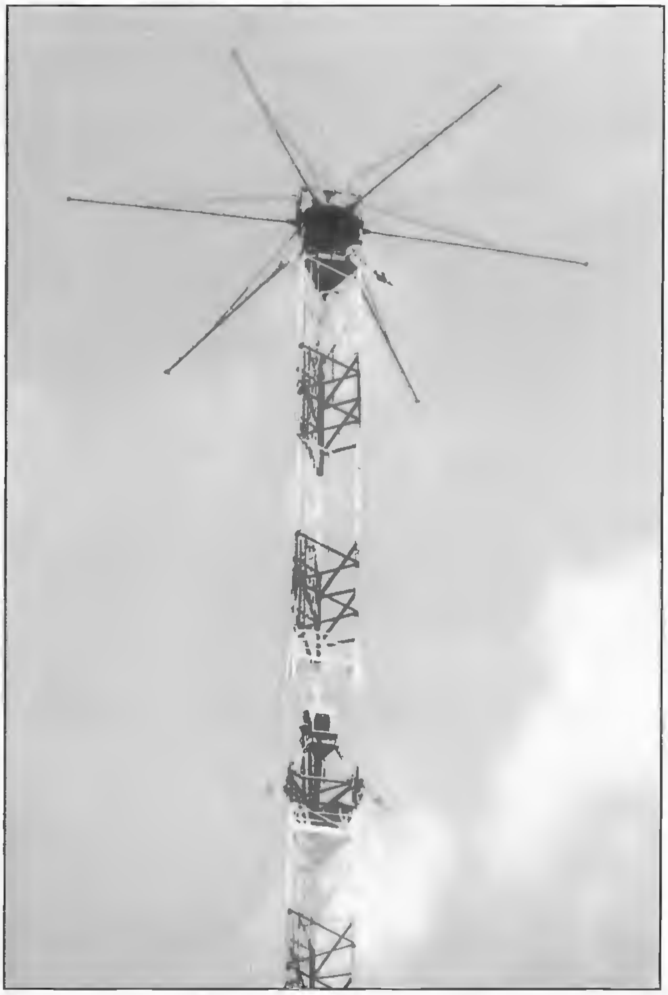
Base insulator assembly and feed arrangement to 134 m lattice steel radiator 3PB Viewbank near Melbourne. Input power is 10 kW on 1026 kHz. Originally installed for Commercial station 3DB (later 3TT), the station facilities were acquired by the Commonwealth's National Transmission Agency for use with the Parliamentary Broadcast Network when 3TT licence was surrendered for an FM licence. The radiator is also used as an alternative standby outlet for NBS station 3LO on 774 kHz as required using a remotely controlled switching system.

When the radiator was commissioned in 1958, Chief Engineer was Edgar Hooper.

Nine wire unbalanced open wire transmission line of about 100 ohms impedance at 4QA Mackay together with aerial coupling unit and radiator base during installation 1957. The line wires were bridged to provide four active and five earthed conductors. Commissioning Engineer, Brian Robinson.

Rigid coaxial lines installed at 5CL/5AN Pimpala 1961 to allow connection between transmitter output circuit and the outside unbalanced 200 ohm transmission line. The coaxial lines were maintained under pressure with dry air. Manufactured in PMG's Department Adelaide Workshops. Installation Supervisors, Don Beames and Frank Henschke.

One of a number of RF current transformers installed at 5CL/5AN Pimpala 1961 designed for 50 kW application. The transformer was developed by Phil Humphries, STC Engineer Sydney based on an STC England model provided for the BBC. The Pimpala station was the first station in Australia to be fitted with this type of current transformer. Major advantages were that it could handle high RF currents and voltages and did not involve a break in a conductor for insertion of a meter. Divisional Engineer, Jack Ross.

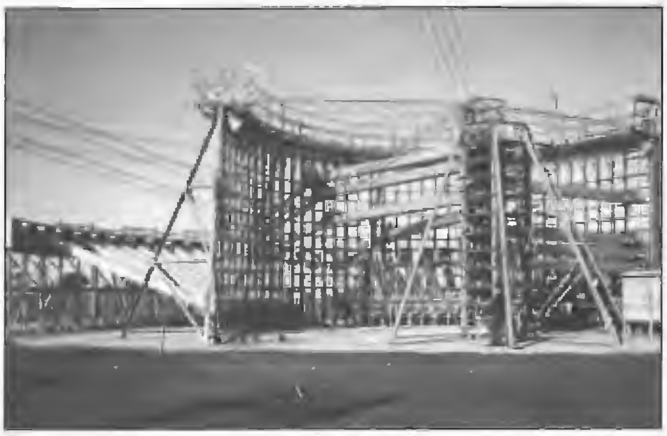


Sectionalising point and top loading of a typical NBS antifading radiator installed during 1960s. The maximum increase in effective height which can be achieved by series loading is limited either by the permissible voltage across the series inductance or by the resulting reduction in radiation resistance. The most economical design is obtained by employing series loading with a capacity hat. The capacity hat shown is a folding type which enables adjustment of effective height if required. The majority of sectionalising insulators were single units but in the case of 5CL/5AN Pimpala 1961, and 5CK Crystal Brook 1962, multiple oil filled units were fitted. Manufactured and erected by Electric Power Transmission, Sydney.

Twin RF chokes provided in mast lighting AC feed to 172 m 5AN/5CL Pimpala radiator 1961. The gradient wound chokes were designed by Bill Gold and installed by Frank Henschke. The chokes prevented RF leakage back to the station via the AC mains through capacitance leakage across the transformer. The wood used in the coupling hut structures was jarrah recovered from an old building erected alongside the Adelaide Telephone Exchange Building in the 1920s and dismantled in 1960. All fixings timber-to-timber were by wooden pegs.

Mast lighting transformer designed for use at base and sectionalising point for 5CL/5AN Pimpala 172 m radiator 1961. It was designed and developed by Bland Radio Ltd, Adelaide to specifications prepared by Bill Gold. It was an alternative arrangement for feeding AC power wiring through the tubing of an inductor or via RF chokes. The company subsequently supplied units for use at other NBS stations and also Commercial stations in other states.

On site test bed facility employed for pretensioning guy ropes installed with 5CL/5AN Pimpala 172 m radiator May 1961 and 5CK Crystal Brook 190 m radiator February 1962. Work was carried out by Electric Power Transmission, Sydney. The pretensioning operation checked all elements including insulators and eliminated non elastic stretch which would occur over a period of time in service requiring subsequent guy tension adjustment.



Matrix switching system commissioned at Radio Australia, Shepparton during 1962. Switching was carried out by horizontal movement of one set of arms around a semicircular frame and by another set of arms in a vertical plane. It had switching capability to allow 10 transmitters to access 36 aerials. It remained in service until 1991. Project Engineer, Doug Cliff.

Aerial coupling unit 5DR Darwin 1963, showing typical components for a 2 kW station. Meters enabled measurements to be made of transmission line, aerial and network circulating currents. Knife switches allowed line and aerial to be earthed during maintenance activities. Installation Engineer, Joe Brady. Station callsign was later changed to 8DR.

Guy insulator of the type installed at 5CL/5AN Pimpala and 5CK Crystal Brook 1961. The steel work was made in Australia but the porcelain insulator was manufactured in Japan. Insulator and steelwork were replaced by new designs in 1992.

Terminating towers and universal terminating and lead-in type porcelain insulators for 10 kW standby transmitters 5AN/5CL Pimpala 1960. The double bowl insulators were held together by a stud so that the two bowls were in compression when installed. The assembly was much stronger than a single bowl which was usually attached by several brackets or bolts. Design Engineer, Bill Gold.

The erection of lattice steel masts for broadcasting purposes, calls for a high level of skill and considerable field experience. During the erection of the lower sections of the mast a crane is often used. When the 172 m 5CL/5AN radiator was erected in 1961 a crane assisted in the erection of the bottom sections up to about the first permanent guy point. The structure was placed on wooden blocks until the first level guys had been installed. Hydraulic jacks lifted the structure to allow the base insulator to be put in place. Contractor Electric Power Transmission, Sydney.

Base insulators at the base of the 5CL/5AN 172 m dual frequency radiator 1961. The insulators are unusual in that they comprise four porcelain cylinders filled with oil. Similar unit were installed at 5CK the following year. The insulators were imported from USA by the contractor Electric Power Transmission. Divisional Engineer, Jack Ross. Line Inspector, Don Beames.

First sectionalised radiator installed for a Commercial station in South Australia. The 141 m structure (L) was erected in 1962 for 5DN. The nearby 61 m mast was erected in 1958 as a standby. Chief Engineer, George Barber.

When 5DN surrendered its AM licence to transfer to the FM band, the main radiator was used for 5PB Parliamentary Broadcasts on 972 kHz and the standby for 5RPH Radio for the Print Handicapped on 1197 kHz from July 1993.

Jacking arrangement to lift the 4AT radiator to enable base insulator to be placed in position. The radiator put into service in 1961 replaced the original which had been in service since 1939.

The original structure, a quarter wavelength radiator was an unusual design. It comprised 200 mm diameter steel pipe 80 m high topped by a 150 mm diameter pipe 30 m high. At the transition point a system of cross trees provided stabilisation for the top section. Seven sets of guys at 90 degree spacings were employed below the transition point.

Dual 200 ohm 6 wire transmission lines at 5AN/5RN Pimpala NBS station erected 1961. Two 50 kW transmitters fed the dual frequency radiator.

Photo shows turning tower (L) and anchor tower (R) near the transmitter building. An earth mat of parallel wires was laid in the ground beneath the lines. Both lines were replaced in May 1993 by underground coaxial cables type HJ8-50 series. Installation Line Inspector, Don Beames.

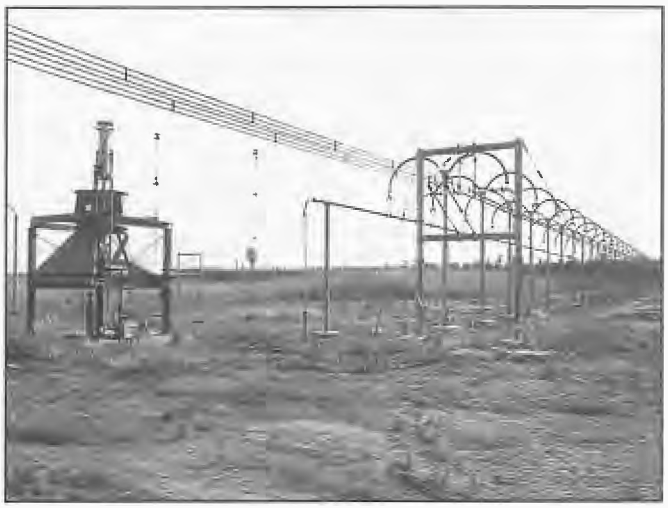
Erection of 61 m high 150 mm diameter pipe radiator 1961 for 4AT using falling jury method. The jury pole was 22 m high. A hand operated winch was used to pull the radiator to the vertical position. Electrical Design, Ron Tolmie; Structural Design, Clyde Manuel; and erection team under control of Duncan Russell-Hall.

Ceramic switching arms and phosphor bronze contacts of Brown Boveri transmission line matrix switch Radio Australia, Cox Peninsula 1969. The switches were remotely controlled from the station control room.

They were rotary types with long low loss insulators and could complete a change operation in less than six seconds. Additional switches were installed in 1984 and 1993 to provide a 5X10 matrix configuration.

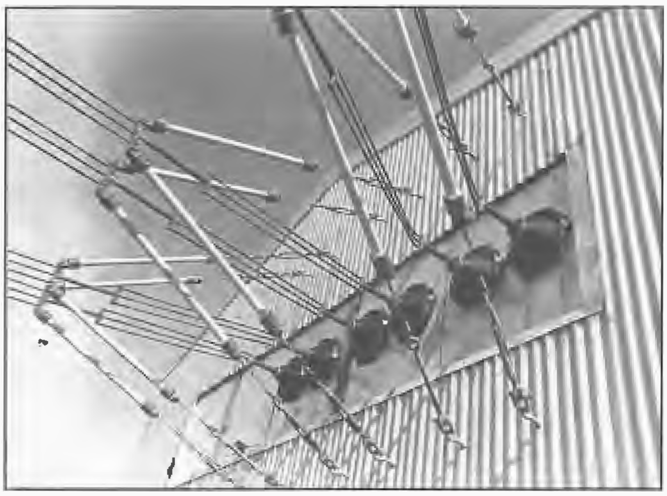
Steel support and terminating poles create a problem when located in areas of high field intensity and break-up insulators are frequently employed for poles and stay ropes. The photograph shows a sectionalised pole located at the feed point of a dual plane log periodic aerial fed by 250 kW transmitter at Radio Australia, Cox Peninsula 1969.

Method of gaining access to the dual plane log periodic aerial system installed in 1969 at Radio Australia, Cox Peninsula. The aerials were designed and manufactured by Complementi Elettronici S.p.a., Italy and installed by RCA (Australia) Pty Ltd. It was the first time the design had been employed to handle 250 kW input for International broadcasting purposes. RCA Engineer, Ross Burbidge.

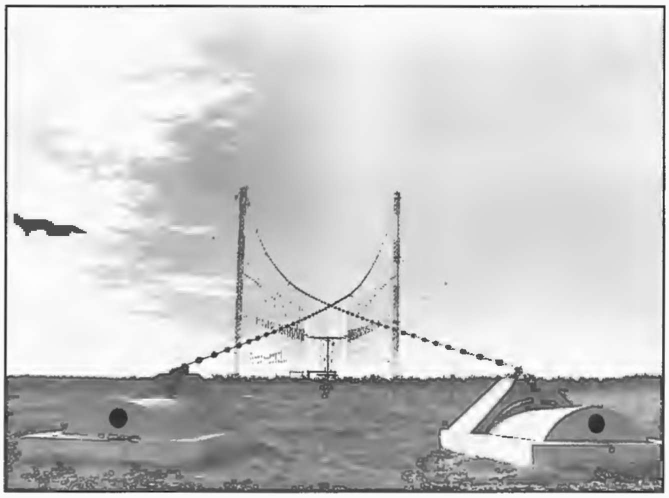


External type dummy load with water cooling system installed at Radio Australia Cox, Peninsula 1969. The 300 ohm dissipative line was constructed of 306 metres of 50 mm diameter stainless steel tubing through which water passed. The line had capability of dissipating 500 kW. It was damaged during Cyclone Tracy 1974 and dismantled.

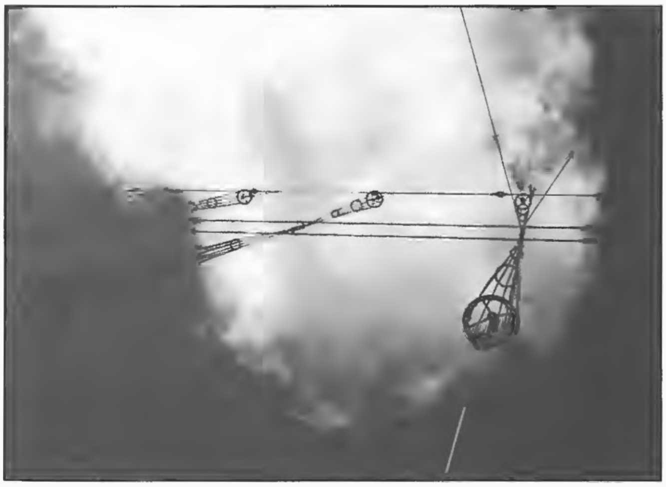
Strain type low loss ceramic insulator provided with aluminium alloy end caps to minimise corrosion problems with aluminium or aluminium covered steel conductors (alumoweld) employed with transmission lines and aerial systems at high frequency broadcasting stations including Radio Australia and NBS HF Inland Service in Northern Territory.



Original transmission line terminations at aerial switching building Radio Australia Cox, Peninsula 1969. The transmission lines comprised six solid copper 12 mm diameter conductors giving a 300 ohm balanced line. The lines were replaced during the station rehabilitation works in 1984 and the ceramic lead-through insulators replaced by PTFE types due to dust tracking and line movement problems. Resident Inspector, Jim Finch.



The catenary counterweight system employed with dual plane log periodic aerials Radio Australia, Cox Peninsula 1969. In each catenary, there were 60 break-up insulators each weighing 11 kg. Each catenary was terminated by a high density concrete block 1.83 m diameter and 1.4 m high housed in a concrete chamber 2.4 m square and 2.2 m deep. Fibreglass covers prevented rain water entering the chamber and raised sides prevented ground water flowing in. The aerials were extensively damaged by Cyclone Tracy 1974 and 10 years later curtain aerials also using concrete counterweight blocks were installed. Contractor's Engineer, Ross Burbidge.

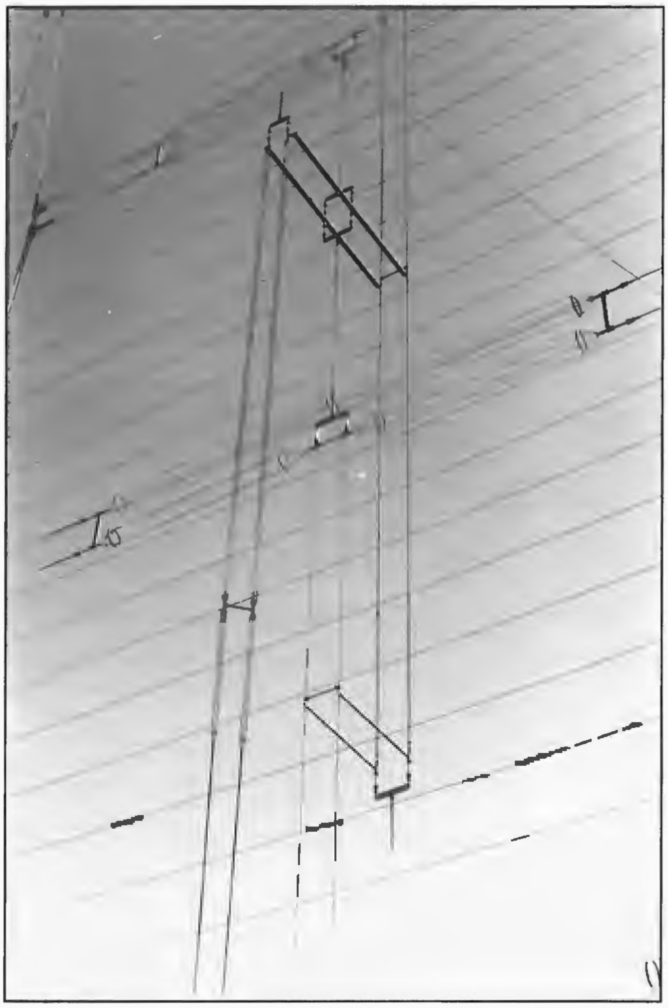


Some of the conically shaped dipole elements of the five dual plane log periodic aerial systems provided at Radio Australia Cox, Peninsula 1969. The vertically polarised aerials all covered the frequency range 5.95 MHz to 26.1 MHz and were fed by 300 ohm open wire balanced transmission lines. Contractor's Engineer, Ross Burbidge.

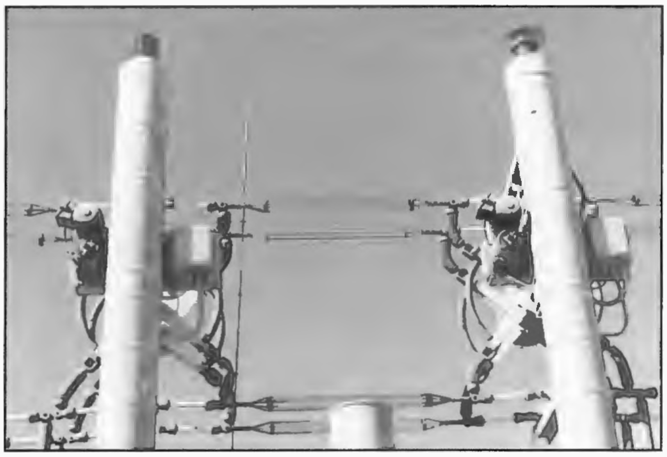
Damage to base of 2BL/2FC 230 m high dual frequency radiator Sydney as a result of vandalism in 1969. A charge of high explosive was fired at the base and destroyed the base insulator causing the 50 tonne mast to drop 60 cm. The aerial coupling equipment building was extensively damaged and 17 guy insulators were damaged by shock impulses transmitted to the structure.

Extent of damage from Cyclone Tracy 1974 to one of the aerial support masts Radio Australia, Cox Peninsula. The wind pressure on the structures was so great that concrete anchor blocks were ripped out of the ground. It was 1984 before the station was fully rehabilitated. Station Engineering Manager when the cyclone struck was Max Chadwick.

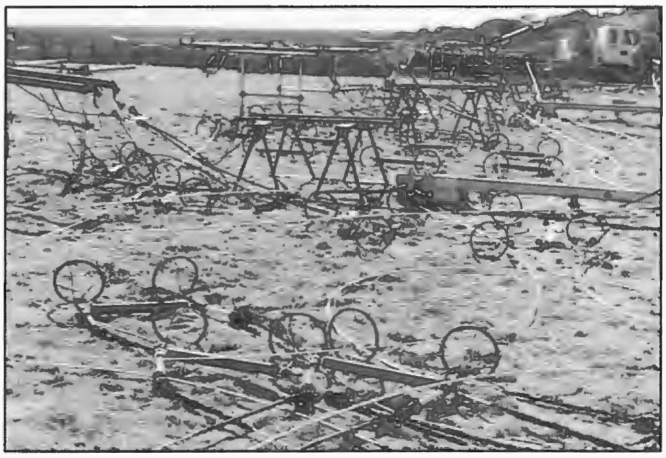
Damage to the dual plane log periodic transmitting aerials at Radio Australia, Cox Peninsula as a result of Cyclone Tracy 1974. The cyclone struck the station shortly after midnight on Christmas Eve December 1974 with winds estimated at 200 kilometres per hour. All five aerial systems and associated transmission lines were badly damaged.



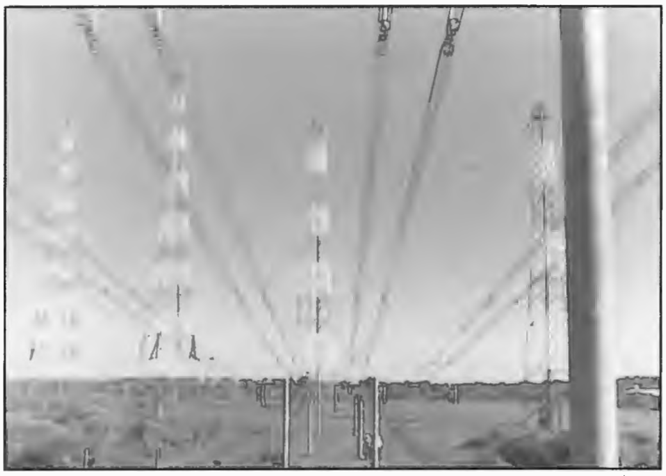
Wideband curtain aerials at Radio Australia, Carnarvon 1975. A passive non resonant reflecting screen was provided a quarter wavelength at the geometric mean frequency behind the dipoles. Each aerial covered three frequency bands. Design by Brown Boveri and Co.



Warning beacon (L) and siren attached to transmission line poles at Radio Australia, Carnarvon. The station operated with transmitters providing outputs of 300, 250 and 100 kW at HF and these warning devices were activated prior to sending power to line as a warning to staff and visitors.



One of the four aerials at Radio Australia, Carnarvon lowered to the ground for maintenance purposes. Each aerial consisted of an active curtain of 16 folded half wave dipoles arranged in four bays and four stacks with passive non resonant reflecting screen. The system being located close to the sea was subjected to an aggressive salt laden environment and required frequent maintenance.



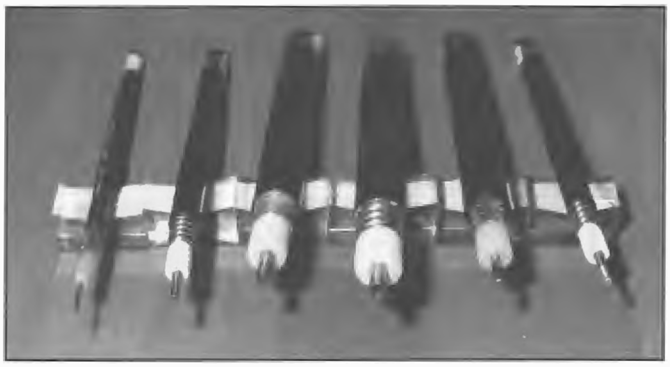
Transmission lines and curtain aerials at Radio Australia, Carnarvon installed 1975. The facilities comprised four aerials each employing 16 folded half wave dipoles. The horizontal sections of the dipoles were in the form of multiple wire cages. The feeders comprised two sausage lines each of six wires giving a characteristic impedance of 300 ohms. Contractor, Brown Boveri & Co. Telecom Engineers associated with the project included Giff Hatfield and Terry Sellner. The station ceased operation on 31 July 1996.

All four curtain aerials at Radio Australia, Carnarvon installed in 1975 were supported by counterweighted catenary ropes which were wound on to electric winches forming part of the counterweight. The winches allowed the curtains to be lowered to the ground for maintenance purposes and to be later raised to their correct operating positions. Carnarvon was the only station in Australia fitted with this facility.

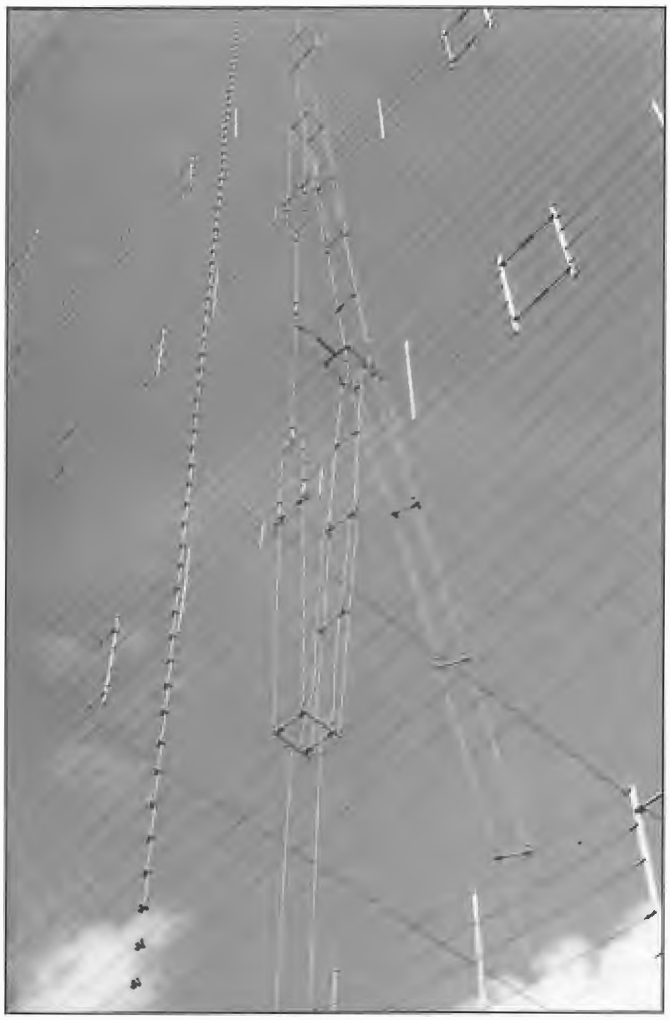
At Radio Australia stations where open wire transmission lines are employed, it is necessary to change direction of many lines and care needs to be taken in the layout design and construction to ensure the change takes place without introducing a change in the characteristic impedance of the line. The photograph shows the technique employed at Carnarvon installed 1975 and designed by Brown Boveri Co.

Assembly of 2HD Newcastle 134 m high lattice steel radiator prior to erection in 1983. The half wavelength structure was modified by the addition of a one eighth wavelength earth stub inside the lower portion of the mast to provide an electrically equivalent five wavelength anti-fading radiator. Chief Engineer at time of commissioning was David Suffell.

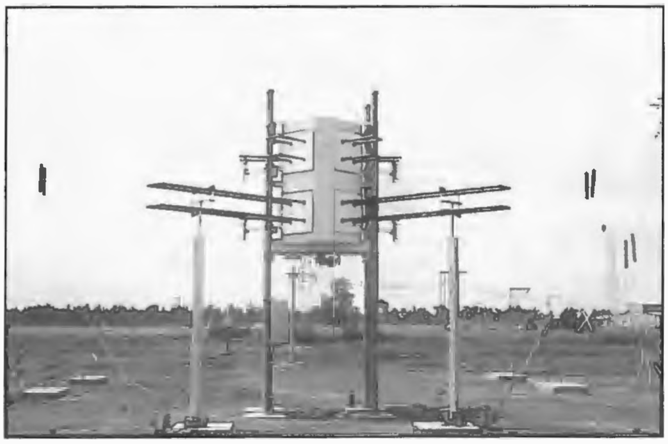
Aerial support towers Radio Australia, Carnarvon erected 1975. The structures designed by Brown Boveri Co., supported four aerial systems each of HR4/4/0.5 configuration. The tallest towers were 100 m high and supported the 6,7,9 MHz band aerial system.



Flexible and semi flexible coaxial cables are widely used to connect transmitter to aerial at nearly all FM stations and many AM stations operating in the MF band. Even at some 50 kW AM stations, overhead open wire transmission lines have been replaced by underground coaxial cables. Coaxial cables are available in a wide range of power levels and construction including outer conductors of braided, smooth tubular or corrugated materials; stranded, solid or tubular inner conductors; and solid, air or foam dielectrics.



TCI Model 611 curtain aerial system installed at Radio Australia, Cox Peninsula 1984. The radiator assembly used three 2.8 mm diameter/alumoweld wires twisted together with the vertical support cables being stranded wires of overall 6 mm diameter. The feeder line transformer section used 12 mm and 6 mm diameter stranded cables. Reflector screen wires comprised aluminium wires suspended by 6 mm diameter stranded vertical bearer cables. Transmission from the station ceased on 30 June 1997 and the station placed in a caretaker mode using maintenance staff.



Copper tube sections used with aerial slewing switch during installation stage at Radio Australia, Cox Peninsula 1984. Seven arrays were installed each with gain approximately 23 dB over isotropic aerial. Slew switches had capability of ± 30 degrees horizontally from centre bore sight. Project Engineer, Ron Falkenberg.

Drums of alumoweld wire used during assembly of seven curtain aerials for Radio Australia, Cox Peninsula 1984. Alumoweld has an inner steel conductor surrounded by aluminium giving the conductor high strength, good conductivity, high resistance to corrosion and light weight compared with copper. Station Engineering Manager, Graham Shaw.

Concrete counterweights assembled on site prior to attachment to catenaries supporting the Radio Australia, Cox Peninsula aerial systems 1984. Seven arrays were supported by lattice steel guyed masts 47, 67 and 97 m high. Construction staff included Volka Lange, Graham Hooper and Jim Finch.

Vertical incidence log periodic aerial provided at High Frequency Inland Service stations located at Katherine, Tennant Creek and Alice Springs in Northern Territory during 1986. Dipole elements were so positioned from a support catenary that the active elements were always a quarter wavelength above ground. Senior Lines Officer, Jim Finch.

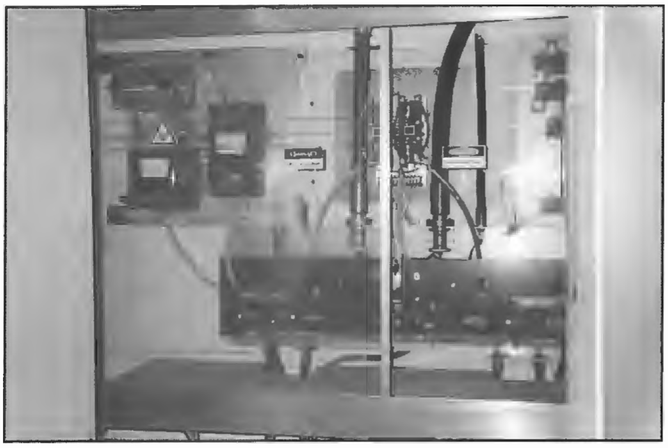
Four wire 300 ohm balanced transmission line using alumoweld supported by steel poles provided at NBS high frequency broadcasting stations at Alice Springs, Tennant Creek and Katherine 1986. Senior Engineer, Bruce McGowan.

Rotatable aerial installed at Radio Australia, Brandon 1989. The system had previously been in service at Lyndhurst. The support tower is 32 m high. The aerial has an input impedance of 120 ohms and a tapered transmission line is used to match the transmitter to the aerial. The rotatable log periodic aerial was manufactured in the 1960s by Standard Telephones and Cables Pty Ltd, Sydney. It covered the frequency range 4 to 30 MHz. Boom and elements were made from extruded sections of aluminium-magnesium-silicon alloy.

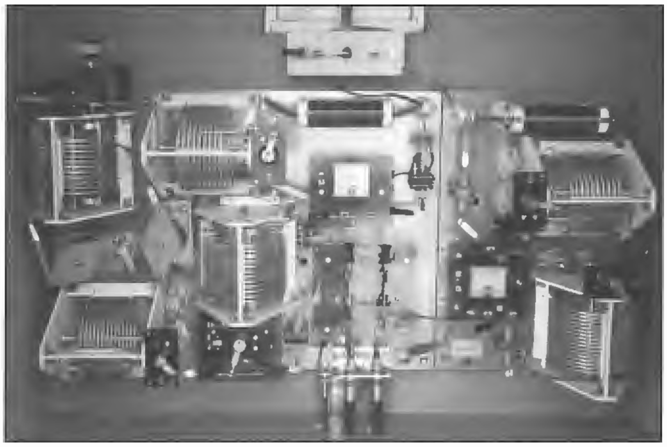
Open wire transmission lines at Brandon, North Queensland associated with MF and HF services. The 200 ohm six wire line is part of the MF NBS 4QN facility while the 300 ohm four wire line is part of the Radio Australia HF service. Masts in the background support HF curtains.

The 50 kW MF service was commissioned in 1959 and the 10 kW HF service commissioned in 1989.

Typical of measures at some transmitting sites to prevent interruption to service in times of flooding of the site. The station operated by 4RPH since 1990, was originally operated by 4BK. Transmitter building, aerial base insulator and aerial coupling unit are mounted above expected flood water level. The mast is one of a directional pair.



Part of aerial switching facilities at 4RPH Brisbane — formally 4BK. The service operated with two 10 kW transmitters each derated to 5 kW and feeding a two 85 m mast directional aerial system. The facilities began operation for the 4RPH service on 10 September 1990.



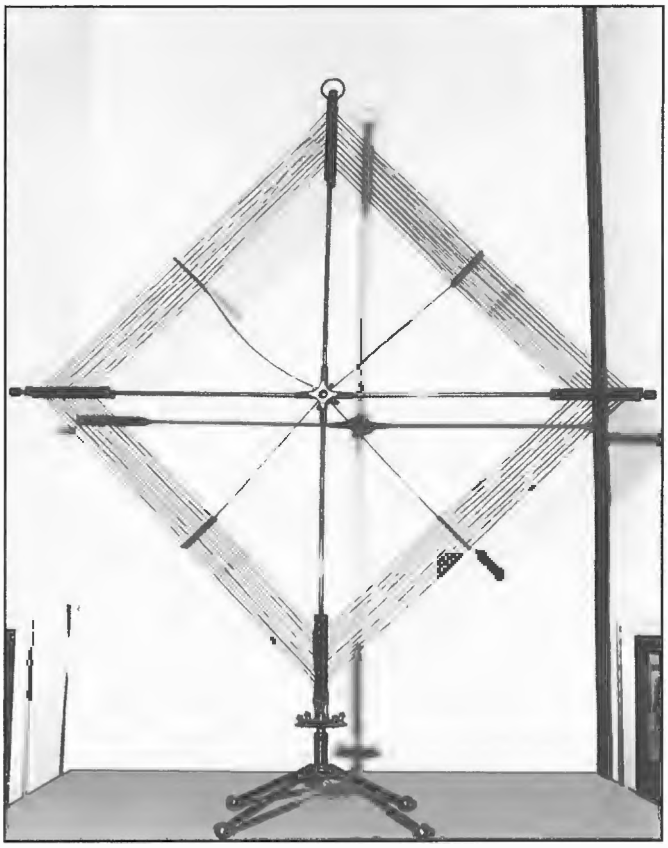
Aerial matching panel for masts 1 and 4 at 3EE near Werribee. The station commissioned on 3 July 1992 on 693 kHz was the only MF station in Australia employing a four mast directional system. Masts were each 90 m high. AWA Engineer, David Morris undertook design work with hardware being installed by Radio Masts Australia and Radio Transmission Engineering.

During 1992 Telecom staff undertook a program of works involving the replacement of guys at a number of major stations including 2BL/2RN Sydney, 3LO/3RN Melbourne, 5AN/5RM Adelaide, 5CK Crystal Brook, 5SY Streaky Bay and 6WA Wagin. Photograph shows replacement of one of the guys at 5SY Streaky Bay 137 m radiator. A temporary guy was installed to allow the working guy to be taken out of service and a new guy fitted. Project Co-ordinator Mike Dallimore.

The 500 kW Marconi matrix switching system installed at Radio Australia, Shepparton 1991 to provide for seven transmitter inputs and 12 aerial outputs. The switch replaced an Australian designed and built system that had been in service for some 30 years. Project Engineers were Tech Chua and Mark Stevens with Kevin North and Doug Brodie being in charge of technical support groups.

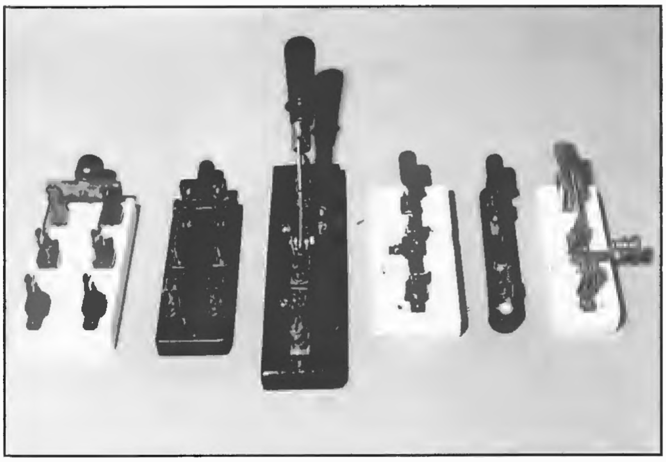
With the commissioning of five broadband aerial systems and associated transmission lines in late 1993 for Radio Australia, Shepparton, the transmission lines were extended as enclosed lines for some distance from the matrix switch before changing to four wire open wire types to minimise cross coupling effects between adjacent lines.

RCA type WX2E field intensity meter used for many years in the measurement of the field intensity produced by an MF radiator for a number of purposes including determination of figure of merit of the radiator, a field strength survey of the service area of the station and determination of the extent of night-time fading. The meter covered the range 540 kHz to 1600 kHz. An earlier RCA model employed in the late 1930s, the type TMV75B covered the range 515 kHz to 20 MHz. Operator, Brian Kennedy.

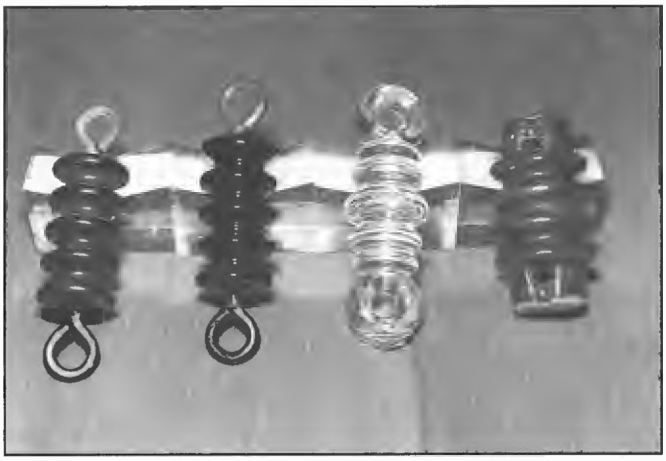


Loop aerials were widely employed with home receivers in the 1920s as an alternative to an outdoor aerial system. Loops more than 24 inches (60 cm) diameter were usually constructed to be collapsible and typically consisted of 12-18 turns of cotton covered copper wire wound in the same vertical plane. The wires were held in position by ebonite, hard rubber or varnished wood strips.

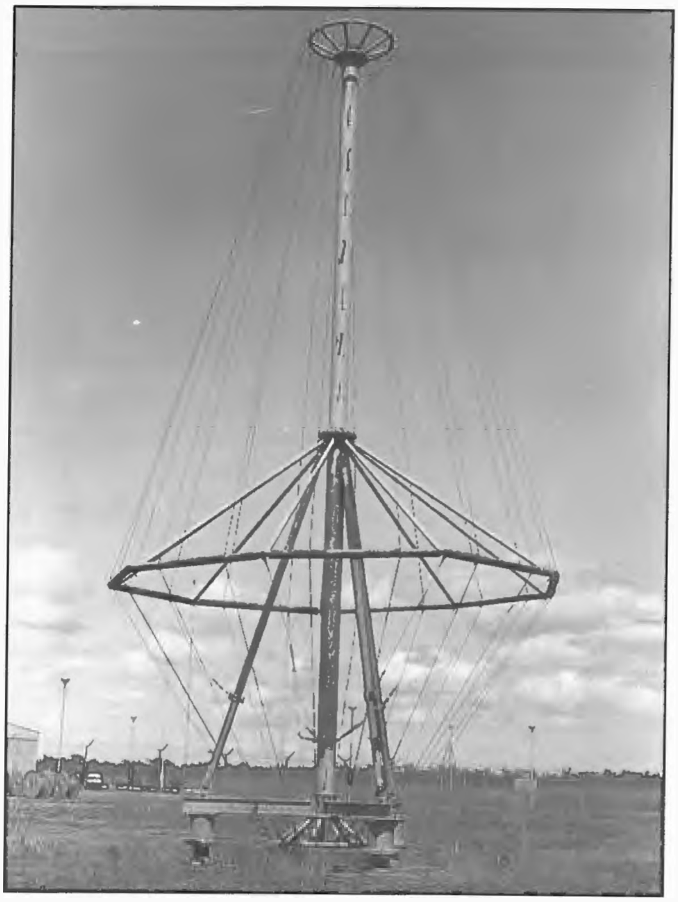
This imported model was supplied with a Rodaphone four valve receiver manufactured by A M Rodda, Adelaide 1925.



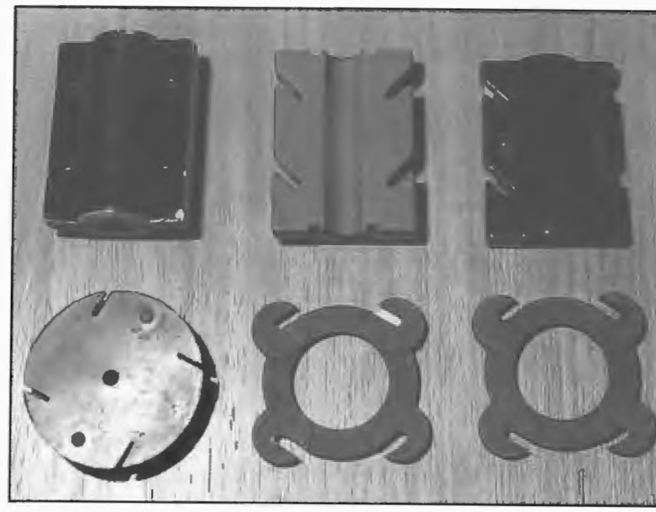
Typical base mounted knife or lever switches. Base material was usually ebonite, bakelite or porcelain although marble or granite was employed with some models. The knife switch employed a movable arm which wedged between two parallel spring clips. The switch could be designed to control any number of circuits depending on the number of arms. Most popular types included single pole or double pole types which could be single throw or double throw. One model was the lightning knife switch, a single pole double throw switch used to earth the aerial during a storm.



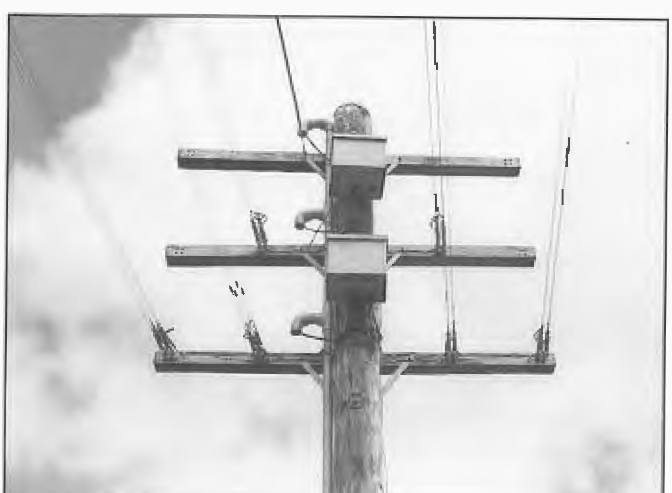
Typical insulators of the corrugated surface type used for home aerial installations. Materials commonly employed included porcelain, pyrex, ebonite, fibre and electrose. Outside aerials were rarely used after about 1946.



Omnidirectional wideband cone aerial installed at Receiving Station, Cox Peninsula 1969 for collection of band occupancy data associated with planning of Radio Australia transmission frequency schedules. The aerial was built in the PMG's Department Adelaide Workshops. Base insulators were originally used with a self-supporting 62 m tower built for 5AN Adelaide in 1937. Installation Supervisor, Jim Finch.



Spacer insulators used with four wire 200 ohm transmission lines at receiving stations. During installation of the line, a porcelain insulator with four holes was installed on a cross arm with a vertical bolt and wires threaded through the holes. When the insulator broke in service, it was replaced with a two section type so that the wires did not have to be cut. Lightweight types were used for transposition purposes between poles to minimise crosstalk problems between lines.



Four wire 200 ohm balanced transmission lines at High Park Receiving station 1959. Signals were taken to the building via coaxial cables. Balanced to unbalanced transformers were mounted on the pole to effect transition from open wire to cable. Engineer, Keith Ferres.

One of two dual plane log periodic vertically polarised aerials installed at Receiving Station, Cox Peninsula 1969 for off-air reception of programs originating in Victoria for rebroadcast by Radio Australia transmitters 16 km away on another site on the Peninsula. The aerials beamed on Shepparton were spaced 10 wavelengths apart at the lowest operating frequency. Signals were taken to the receiver hall equipment via an above ground rigid balun transformer line and a buried coaxial cable. The system was decommissioned during 1974 when direct program lines to ABC Radio Australia studios in Melbourne became available. Contractor's Engineer, Ross Burbidge.

Chapter Five

Transmitting and Receiving Valves

Transmitting Valves

Radio Telephony

In 1913, just prior to the outbreak of the First World War, radio telephony was a practical possibility with the technique being demonstrated using thermionic valve circuits. Within a year, it was possible to use valves in conjunction with continuously-tuned circuits in both transmitter and receiver for radio telephone communication. Major effort was applied to development during the War, particularly for voice communication with military aircraft.

By the end of the War, interesting developments in valve production by manufacturers in the USA included the following:

- Tungsten was found to be superior to most other metals for filaments, not only because of its refractory qualities and low volatility, but it was able to clean up any traces of gases remaining inside the envelope after completion of the vacuuming process.
- Many grades of glass were unsuitable for valve glass envelopes. Grades containing a high percentage of lead and a small quantity of silicic acid were easy to work, and produced high performance valve envelopes.
- Experiments indicated that aluminium anode and copper wire grid were the best combinations on account of their electrochemical relation to tungsten filament wire.
  Unfortunately, the choice of aluminium for elements created a number of problems in cleaning aluminium, and preparing the copper wire to close pores in the metal, was also difficult.
- Filaments were heated to incandescence for two hours using AC to get rid of positive ions.
- The vacuum was produced using a Gaede mercury pump backed up by a Geryck piston pump. The temperature of the valve was taken to 540°C and sealed off after five hours of continuous pumping. An alternative method of exhaustion was to place a voltage up to 2000 volts AC across filament and anode and utilise the electron current which flowed when the anode was positive to bombard and so heat up the anode, thus liberating occluded gases.

By the time broadcast test transmissions began in the early 1920s, a range of transmitting valves had been developed for radio telephony purposes and they were quickly adapted for broadcast transmitter circuits.

Valves available had very limited power handling capability, but some improvement was made in increasing the power output of a transmitter by operating valves in parallel, a technique suggested by Captain H J (Henry Joseph) Round of the Marconi Company in 1914. When the Marconi high power station was established at Caernarvon in North Wales, the transmitter had 56 valves in parallel to produce 100 kW output. In November 1921, it established communication with Australia.

Manufacturers soon solved many of the broadcast valve problems and special types with anode ratings of 200 watts and 300 watts were produced. The 300 watt model had a glass envelope 175 mm in diameter and 425 mm in length. The bulb was re-entrant at both ends in order to hold two metal bands supporting the electrodes. The filament was made in the shape of inverted letter 'V' with a spring at its centre to keep it taut when hot. The grid and anode surrounded the filament using cylindrical construction.

No base was provided, the valve being seated in a wooden block covered with asbestos or held in position by clamps. The leads which were passed through the glass were taken directly to the other components by flexible wires usually strung with ceramic beads of covered with heat resistant flexible tubing.

The British H.M. Signal School (Navy) had developed the re-entrant technology to a high degree of perfection with production of a number of valves for high power transmitters. One of the triodes designated T4A operated with 3000 volts on the anode and it was reputed to produce up to 750 watts into the aerial. A similar design of the diode type known as U2 was used as a half wave rectifier for providing high tension DC.

Power rating of valves obtainable from commercial sources were however, low compared with the transmitter output power required by designers. As a typical case, the AWA transmitter commissioned for 4QG in 1926 employed 10 triode type MT7B valves in parallel to provide sufficient power to modulate the power amplifier via a Heising choke circuit.

Although designers tried various shapes and arrangements for the anode, following experience with receiving valves, it soon became evident that the best form was a cylinder surrounding the filament. For manufacturing and assembly convenience, the performance was equal, whether the cylinder was fabricated in one piece or in two pieces. The advantage of the two piece arrangement was that it allowed one half of the anode to be fitted in position, followed by the grid and then the filament before attaching the other half of the anode. The two halves of the anode were welded in position after the other elements had been adjusted to be in their correct positions by the use of jigs or gauges. One of the other anode forms tried, was the use of two flat plates joined together and spaced at equal distances from the other elements. Like the split cylinder, it assisted in the assembly operations but its performance at high power was inferior to the cylinder. One of the major problems was that the temperature of the anode plate was not equal across its surface. The plate glowed red hot directly opposite the filament where electron bombardment was greatest, but showed no colour near the outer sides.

Cylindrical shapes for both anode and grid also resulted in greater mechanical stability. They counteracted any tendency for electro-static forces, resulting from the large potential differences between the elements, to cause unequal stresses.

Although nickel was suitable for low power transmitting valves, it was not suitable for the high power types. Molybdenum was more satisfactory, as an anode made of molybdenum could dissipate four times the heat of a nickel anode. Molybdenum anodes were initially made by weaving molybdenum tape to form a basket-like cylinder. Later, rolled metal sheet was used.

A great deal of development work in improving reliability and efficiency of valve elements has taken place over the years. In medium power transmitting valves, filament structures have been either spiral, parallel bar, hairpin or mesh configurations. The spiral filament has not been employed for some time because of problems with sagging on the filament wires. A widely used design in modern valves is the hairpin type. The design employs built-in spring compensation to allow for expansion of the filament as it is heated.

Grids use spot welded wires to form a circular structure that surrounds the filament emitting surface. Some grids are coated with special materials to suppress emission from the grid wires.

Anode structures vary with the cooling procedure. In shape, they are copper cylinders or drawn copper cups with the external area using air cooling fins or water cooling jackets brazed to the exterior of the cylinder.

With tetrodes used in high power short wave transmitters, the screen grid is a critical element. Limitation of its thermal load capacity generally dictates the valve's power limit.

Improvements in technology and materials have also resulted in considerable reduction in physical size of valves. By the early 1950s, the volume of transmitting valves for a given output power had been reduced by a factor up to 10 in some instances, by employing high temperature melting materials with good radiation properties for electrodes, improved types of glass and ceramics having superior thermal and electrical characteristics, and other factors.

When the USA firm RCA produced its 50 kW transmitters in 1931, the water cooled output valve was enormous compared with later designs. The original valve was 4 feet (1.2 m) high and had to be handled and transported with extreme care.

However, when the company provided a 50 kW transmitter for Radio Australia Shepparton which was commissioned in 1944, considerable progress had been made in valve design, and the 880 type provided was much smaller.

AIR COOLED VALVES

Air cooled transmitting valves, although now being rapidly replaced by solid state technology, were available in power ratings from a fraction of a watt to kilowatts, and valves which are still in production today, have reached a high state of efficiency.

When transmitters were being built for the commissioning of the A Class stations in 1923–25 the designers had a wide range of valves available from British, European and American sources but as the power handling capability of the largest valves available was not high, it was necessary to resort to arrangements of parallel or push-pull parallel combinations in order to achieve the desired output power from the transmitter. The B Class station transmitters were of lower power rating, and the selection of suitable valves was not a problem.

The majority of valves from British manufacturers came from the M.O. Valve Co., and the Mullard Radio Valve Co. The M.O. Valve Co's. T series ranged from an anode dissipation of 15 watts with the T15, to 450 watts with the T450, and for the MT series, dissipation ranged from 150 watts with MT1, to 600 watts with MT7A. In the Mullard Radio Valve Co., range, valves about 1923 in their O series had anode dissipations from 20 watts with the 0/20 valve to 1 kW with the 0/1 kW valve.

The main source of valves from Continental Europe at the same time, was Philips in Holland. They produced a Z series 1924–25 which ranged from an anode dissipation of 2.5 watts for Z1 to a dissipation of 500 watts with the Z5 type. About 1924, German valves of Telefunken and Mueller manufacture in the range 30 to 250 watts were also available. One Amateur experimenter in Adelaide equipped his transmitter with a 250 watt Telefunken valve and operated it with 2000 volts on the anode using a motor generator for the DC supply.

A wide range of valves was available from American sources to meet the rapidly expanding transmitter market there, but only a few of the low power types were imported into Australia initially. These included the UX210 valve of 7.5 watt output, the UX865 valve of 7.5 watt capability, the UV203A, a 50 watt valve and the UV204A, a 250 watt valve. The most popular of American manufactured valves were used with Amateur station transmitters, some of which were also destined to become Commercial station transmitters.

The 5 kW transmitters constructed for 2FC, 3LO, 6WF, 4QG and 5CL employed many different types and several parallel combinations to achieve the necessary power output for the stages. The transmitters were built over a period of some 18 months and not all transmitters were fitted with the same valve types. Types included DE5, MT4B, MT7A, MT7B, MR7, LS2, MOT250, MT6 and MR6.

Two DE5's were used in the line amplifier stage in front of the sub-modulator. The DE5 was basically an audio amplifier valve requiring 5 volts for filament and 200 volts on the anode. The MT4B used as the sub-modulator operated with 12.5 volts on the filament and 10 kV on the anode. It had an anode dissipation capability of 200 watts. The MT7A used in the master and main oscillator sections required 12.5 volt filament supply and 10 kV on the anode. It could operate with a maximum continuous anode dissipation up to 600 watts. It was a bright emitter valve. The MT7B used in the modulator circuit was a bright emitter valve with filament requirements of 12.5 volts and anode voltage of 10 kV. The rectifier section supply the EHT, employed six MR7 valves with filament voltage of 12.5 volts and applied anode potential of 12 kV. Each valve had a continuous anode dissipation rating of 600 watts.

The MT7A valve had another application when AWA designers employed it in 1924 during the course of experimental short wave transmissions to England. Transmitting with an output of 2000 watts, the first direct wireless telegraphy signals were received in England on a wavelength of 87 metres (3.4 MHz).

During the initial testing of the transmitter using an output of 400 watts on 120 metres, the glass envelope melted. The problem was partially solved by fitting an anti-corona ring around the neck of the valve. Further development work on the problem resulted in the valve being enclosed in an RF shield comprising spaced copper strips around the valve. Engineer-in-Charge of the project was Sydney Newman.

The years 1930 and 1931, were years of great activity in the construction of broadcast transmitting stations with 14 commencing operation during 1930, and 17 during 1931. They were all Commercial stations except 2NC, 4RK and 2CO which were National stations. Many different air cooled valves were employed in the various circuit designs. Records indicate that in transmitters up to 500 watts output, valve types of American origin included UX842, UX250 and UV845 in AF and modulator stages and UX865, UV203A, UX852, UX860, UV853, UV204A and UV861 in oscillator and RF stages. Valves of English and European origin were also widely employed, with Philips being the most popular of the European types.

By 1934, when there were nearly 70 transmitters licensed throughout Australia for National and Commercial services, ranging in powers from about 100 watts to 2000 watts for Commercial transmitters, and up to 7500 watts for the National transmitters, there was a large range of glass envelope valves available. Brands being marketed in Australia included Mullard, Osram, Philips, Radiotron and Sylvania. The Mullard and Osram ranges catered for valves with maximum anode dissipations less than 800 watts, although Mullard was still supplying silica envelope types with 2000 watts anode dissipation. The Philips, Radiotron and Sylvania types also were available to a maximum of about 800 watts, but all three had a wide range of water cooled models for high power working. The Sylvania air cooled glass envelope types used a graphite anode.

Typical of the many valves in service with Commercial transmitters in the mid 1930s included MA4/600 at 5KA in the final RF stage; 833A at 5PI in the final RF stage; TC1/75 at 3SH in the final RF stage and a pair of MC1/50 in a Class AB modulator; TC2/250 in the final RF stage and a pair of MC2/200 in push-pull modulator stage at 4BU and 4IP; four RCA 805 valves in the final RF stage of 2LM. The 805 had an efficiency of about

70 % which was considerably higher than other 200 watt valves in service prior to the mid 1930s.

The number of different types of valves employed in National and Commercial transmitters was very large during the 1930s when there were well over 150 transmitters including standby units in service throughout Australia. The most widely employed valves were of the so called 'Philips' and 'American' manufacture or designs. Direct replacements were not always readily available and Chief Engineers often had to resort to the use of alternative replacement types. Fortunately, many Philips and American transmitting valves were physically and electrically identical and could be employed either initially, for locally constructed or modified transmitters, or for replacement purposes. In the triode, pentode and beam power valve classifications replacement types included:

Philips Type	Description	American Type
PE 05/10E	General purpose RF Pentode	802
BB 06/30E	General purpose Beam Power Amplifier	807
TB 07/25E	High-mu Modulator and RF Power Amplifier	809
PB 1/40E	General purpose RF Pentode	804
TB 1/50E	Medium-mu Oscillator, Modulator and RF Power Amplifier	800
TB 1/60E	Medium-mu Oscillator, and RF Power Amplifier	834
MB 1/75E	Low-mu Modulator and AF Power Amplifier	845
MB 1/85E	Medium-mu Modulator and RF Power Amplifier	242A
MB 1/100E	Medium-mu Modulator and RF Power Amplifier	211H
TB 1/150E	High-mu Oscillator, Modulator and RF Power Amplifier	805
TB 1.5/50E	High-mu Oscillator, Modulator and RF Power Amplifier	808
QB 2/75E	General purpose RF Tetrode	860
PB 2/200E	General purpose RF Pentode	803
BB 2/250E	General purpose Beam Power Amplifier	813
TB 2/300E	High-mu Modulator and RF Power Amplifier	810
TB 2/500E	Medium-mu Oscillator and RF Power Amplifer	212E
BB 3/1000E	General purpose Beam Power Amplifier	827R
QB 3/500E	General purpose RF Tetrode	861
TB 3/150E	Medium-mu Modulator and RF Power Amplifier	806
TB 3/500E	Medium-mu Oscillator, Modulator and RF Power Amplifier	204A
MB 3/750E	Medium-mu Modulator and RF Power Amplifier	279A
TB 3/800E	High-mu Modulator and RF Power Amplifier	833A
TAL 10/10E	Low-mu Modulator and RF Power Amplifier (air blast cooled)	891R
TAW 10/10E	Low-mu Modulator and RF Power Amplifier (water cooled)	891
TAL 12/10E	High-mu Modulator and RF Power Amplier (air blast cooled)	892R
TAW 12/10E	High-mu Modulator and RF Power Amplifier (water cooled)	892
TAW 12/15E	High-mu Modulator and RF Power Amplifier (water cooled)	220C

Some manufacturers equipped their transmitters entirely with Philips valves. Typical was Transmission Equipment Pty Ltd, Melbourne with a design by Ted Ashwin and Rudolph Buring. The first transmitter off the production line was commissioned at 7HT Hobart on 19 April 1937. The initial power to the aerial was 250 watts but twelve months later it was increased to 500 watts. The valve line up was PE05/15, crystal oscillator; PEO5/15, first buffer; TC1/75, RF driver; a pair of TC2/250 in push-pull, final amplifier; a pair of TC2/250 in push-pull, modulator; a pair of 866A rectifiers for RF and audio driver power supplies; and three DCG2/1000 rectifiers for final amplifier and modulator.

With the outbreak of the War in 1939, Philips valves became difficult to obtain and many Chief Engineers modified their installations to use more readily available types including 810 and 807 types. Fortunately, AWA had its valve factory in full production. Bill Nicholas of 7HO Hobart modified his 500 watt transmitter on Mt Nelson to accommodate 810 and 807 types about 1940, and when he became Chief Engineer of 7HT, also in Hobart, in 1941 he replaced the Philips valves in the station's Transmission Equipment 500 watt transmitter at Rosny Hill with types available from AWA. He was assisted in the modification work by Norm Stone who had installed the transmitter with the then Chief Engineer Gil Miles.

By about 1940, the range of valves available to transmitter designers had increased considerably and types were available for a new series of Australian built 2 kW transmitters. They included 4251A, a large radiation cooled triode; 4282B, a tetrode frequently employed to drive the 4251A; 4242A, a triode used in modulated amplifier stages; 4279A, a radiation cooled triode with anode dissipation capability of 1.25 kW; 4279Z, a radiation cooled triode used in STC 2 kW transmitters to replace the original 4279A; 4030A, used in high power modulator stages; 833 frequently employed in push-pull for 1 kW amplifiers; 807, a multi-purpose valve sometimes used in frequency multiplier circuits; 889R, an external anode air cooled valve; and 827R, an external anode air blast cooled tetrode.

The 4279Z valve was manufactured in the STC Sydney valve factory. It had an anode dissipation of 1200 watts and when employed in STC 2.5 kW transmitters had extremely long operating life. Operating hours exceeding 40000 were not unusual.

With the need to replace the high maintenance water cooled valves in transmitters, large air blast cooled valves were developed for incorporation in a new range of transmitters in the 1950s. The STC 10 kW model 4–SU–11A was typical. The power amplifier employed two 3J/221E types with the modulator also employing two. These air blast triodes were very heavy and a hydraulically operated lifting mechanism was provided for the easy and safe handling of these valves. As a result of subsequent difficulty in supply of these STC 3J/221E valves, they were replaced by Philips TBL12/25 types.

In the early 1950s, Philips produced a range of transmitters which were installed at a number of National and Commercial stations. At National stations they were usually installed as a pair with main and standby units being of the same power. The 200 watt model employed Philips QB3/300 tetrode valves in the main stages with two being used in push-pull as a Class AB1 modulator and a single valve as the RF power amplifier arranged for simultaneous anode and screen modulation. The 2 kW transmitter employed Philips TB4/1250 triodes in the main stages with four in push-pull parallel combination for the Class B modulator stage, and four in parallel for the RF power amplifier.

With the development in late 1950s of 55 kW main and 10 kW standby transmitters for the National stations, valves selected by STC for these transmitters included 3J/192E air blast types in the RF power amplifier and modulator stages of the 10 kW transmitters and types 3J/261E air blast cooled triodes for the 55 kW RF power amplifier and the modulator. The RF amplifier was driven by a 3J/192E type, while drivers for the modulator were 3C/150A type in push-pull coupled to 3J/192E cathode followers.

Designers of the AWA 50 kW transmitter installed at National station 2CR, employed valve types OA3 regulator, AR63 main rectifier and electronic crowbar, 6146 first audio amplifier, 7094 second and third audio amplifiers, BR1121 modulator, 6AK5 crystal oscillator, 7094 first and second RF amplifiers, BR191 RF driver and BR189 power amplifier. The AR63 valves originally used in the main HT rectifier were subsequently replaced with silicon diodes.

In the mid 1960s, when solid state devices were becoming popular, hybrid designs employing a combination of semiconductors and valves were introduced. Valve numbers were consequently reduced, particularly in the low power and rectifier stages. Valve types employed in a 2.5 kW transmitter manufactured by Commonwealth Electronics Pty Ltd, included 4CX250B as RF driver, 4/1000A as modulator and RF power amplifier, 6DQ5 as modulator driver, OD3 gas filled voltage regulator as screen stabiliser and 5V4G as RF demodulator.

When STC manufactured a 50 kW model 4-SU-61 transmitter for the VLW HF service in the 1960s, the transmitter consisted of a 10 kW driver based on a 4-SU-48B model followed by a high level modulated 50 kW unit. The service was still operational in the mid 1990s with the modulator using two Machlett ML6427 valves operating in Class B push-pull, modulating two RF PA Machlett ML6427 valves in Class C push-pull giving the required 50 kW over the short wave band.

An unusual feature of the design of the air blast ML6427 was that the cooling fins were mounted horizontally, rather than vertically, as was the more usual practice. As a consequence, the socket design was quite complex, and in operation, the valve exhibited a 'well-cooked' appearance after a normal service averaging 15000 hours. Filament heating requirement was 8 volts at 200 amperes. Typical anode dissipation was 13 kW with power output being 31 kW.

The 10 kW driver of the transmitter employed the 3CX2500-A3 type valve. This valve was also an air blast design with a filament requirement of 7.5 volts at 50 amperes. Typical anode dissipation was 2.5 kW with power output of 5.3 kW.

With the application of solid state technology, even into high power stages of transmitters, very few AM transmitter designs of 50 kW and below employed valves after 1993. However, manufacturers of FM transmitters were still producing designs mainly with one air cooled valve in the output stage of 10 and 20 kW transmitters. Typical valve types employed included 3CX3000A, 4CX7500A and 4CX12000A.

WATER COOLED VALVES

A major problem which prevented the employment of the thermionic valve to handle high power was the difficulty in removing heat from elements, particularly the anode.

Lee de Forest in USA during trials in 1915 to increase the power output of his Oscillion valve immersed the five inch (125 mm) diameter Corning glass valve envelope in a large cannister of water. Elements came out at the end of a stem fixed above the water level. The trial was not a success due to poor heat transfer from elements to the water.

New glass envelopes were manufactured so that the anode was much closer to the glass wall. The glass envelope was in the form of a tube 2½ inch (37 mm) diameter and 10 inch (250 mm) in length, with leads protruding as before from one end. However, the trials were deferred following receipt of an urgent order from the USA Navy for manufacture of valves to Navy design and specifications. The Navy specified glass envelope 1¼ inch (30 mm) diameter and 5 inch (125 mm) in length with all terminals coming out at the bottom of the valve and suitable for mounting in a plug-in type socket.

As the Navy were not interested in water cooled valves, de Forest did no further work on the technology.

By 1922, glass envelope valves of about 600 watts were common, but above this power rating, they were expensive and unreliable. Many techniques had been developed to remove the heat, including air jets, enclosing the valve in a wind tunnel and enclosing the envelope in an oil bath.

These approaches had only limited success, and although the substitution of silica for glass enabled the power rating to be increased, it was the development of the external anode which allowed valves to be manufactured to meet the demand for high power transmitters.

William G Housekeeper in the USA, had in 1919, patented a method of sealing base metals through glass. With his method, it became possible to make the anode part of the vacuum envelope and to cool its outer surface directly by passing oil or water over it. By 1922, 5 kW valves became available using a seal comprising a nickel-iron ring of suitable expansion coefficient lightly coated with copper and sealed direct to the glass. The ring was brazed to the copper anode before sealing. Later, the procedure was to taper the copper to a feather edge and then seal the glass to the thin edge of the taper. The thin copper was sufficiently flexible to equalise the difference in expansion and contraction between the glass and metal.

By 1925, valves with water cooled anodes were in commercial production and marked the beginning of the manufacture of transmitters where one or two valves could be used in high power stages instead of banks of low power air cooled types.

Not all valves had copper anodes, nor were they all water cooled. At 5CL Adelaide, a Philips valve with a chrome-iron anode was in the modulator at one stage during 1930. It gave more trouble with scale build-up than copper anode types used in the same cooling system. It was observed that the scale was always deposited in the form of a four long elliptically shaped areas, running vertically up and down the anode and evenly spaced around it with quite clear spaces elsewhere. The reason for this pattern of depositing the scale was never resolved. Philips water cooled valves TA 12/20000K, TA 10/5000K, TA 12/20000, MA 12/15000 and DA 12/24000 produced during the period, all used chrome-alloy anodes.

Early Marconi designed cooled anode triode (CAT) valves used an alloy of nickel and iron with expansion characteristics close to that of glass. This was plated with copper and turned to a knife edge to seal it to the glass.

CAT valves were employed in a number of Commercial station transmitters. One such transmitter was the 2 kW transmitter supplied by AWA for use at 3SR Shepparton. The transmitter was commissioned in February 1937 on 1260 kHz and even by today's standards the transmitter was a giant, especially for an output of 3 kW. It was divided into five sections and overall, took up 8 m of floor space. A feature was the use of a Marconi CAT6 valve nearly one metre in length and costing at the time, one hundred and sixty pounds each. The valve operated with a filament voltage 18 to 20 volts with nominal filament current of 75 amperes. The 4 kW heat dissipated, was taken away by a water cooling system pumping water at the rate of 4 gallons per minute through a copper core cooling radiator. Station Chief Engineer responsible for operating the equipment was Ray Shortell.

Station 4SB Kingaroy also employed a transmitter fitted with CAT valve.

The CAT6 was popular with designers for many years. One valve data sheet still in existence is dated April 1932 while another is dated July 1954. The latter sheet provides design data for employment of the valve as a HF amplifier Class C providing up to 8.3 kW output up to 15 MHz. Operation above 15 MHz required reduction in anode voltage. It was also suitable as a HF power amplifier in Class B telephony mode.

The 20 kW transmitter VK3ME known as 'The Voice of Australia' operated by Amalgamated Wireless (A/Asia) Ltd prior to the Second World War utilised 22 air and oil cooled valves. It is likely that the design closely followed the BBC station 5SW which began operation in November 1927 using two oil cooled valves in the final stage.

Another coolant employed with transmitter valves was power kerosene. The Marconi CAT2 type designed for low and medium frequency application was a double ended valve originally designed for water cooling but when it was fitted to the high frequency beam wireless transmitters in Australia, the cooling arrangements were modified to use power kerosene in order to reduce losses at the higher frequencies.

All the original A Class transmitters employed banks of air cooled glass envelope valves, with the exception of 3AR which used silica envelope types, but when water cooled types became available in Australia about 1927, Engineers soon replaced the multiple valve high power glass envelope types with water cooled types. The 5CL transmitter was one so modified when a pair of 4220B triodes were installed by the Chief Engineer, Harry Kauper. He had seen the valves in the USA and arranged for two to be sent to Australia.

When the PMG's Department took over 4QG Brisbane, the four MT7A air cooled triodes of the power amplifier were replaced by a single 4220C valve by Roy Ferguson and George Olsen.

The 2CO and 5CK 7 kW transmitters commissioned in 1931 and 1932 respectively, employed a pair of 4220B triodes in the final stage. The EHT supplies for the first linear amplifier and the final stage were provided by three 4222A high vacuum water cooled rectifier valves in a three phase half wave configuration. The cooling system comprised a 450 litre reservoir of distilled water, circulated at the rate of 37 litres per minute.

For transmitters required to produce 10 kW of power, four 4220B valves in parallel push-pull configurations were usually employed. Stations 6WA, 3WV and 2CR were typical installations in 1936–37. Stations 2GB is an interesting example of multiple water cooled valves for a Commercial station. In their locally constructed transmitter which went to air in 1937, the output from the modulated amplifier was link coupled to the input of the linear amplifier which consisted of a pair of 4220C water cooled triodes in push-pull. The rack housing the linear stage was arranged to take four 4220C valves so that a spare pair was available to switch into service in short time.

For transmitters of lower power, the 4228A type was widely employed. Typical stations were 4RK 1931, 5DN 1933, 5AD 1931, 5PI 1934 and 2UE 1930. For Class C telephony operation, the valve had capacity of producing carrier output of 2.5 kW with anode voltage of 4 kV. Filament requirement was 22 volts, drawing a filament current of 41 amperes. Another type employed with 2 kW transmitters was the Philips PA12/15 pentode type. Station 2TM employed this type with a standby valve housed in a spare jacket with its transmitter built in 1937 by Colville Wireless Equipment Co., Ltd.

In 1938, a range of transmitters installed at 4QS, 3LO, 2FC and 2CY used two separate cubicles to produce 10 kW output with each cubicle producing 5 kW. Each 5 kW amplifier used a pair of 4220B water cooled types with one spare also fitted for quick restoration of service, should one valve fail. The EHT supply was provided by six 4078A hot cathode mercury vapour rectifier valves in a three phase full wave rectifier circuit. Later installations used 4220C type amplifier valves. The 4220C type was, in turn replaced by the 4220Z which had similar electrical characteristics, but the dimensions and position of the grid connection were different. The 4220Z was manufactured by STC in their Sydney valve factory. Tom Basnett played a leading role in their manufacture.

In addition to valves mentioned above, marketed under WE, or STC or Philips labels, there were others of various types made by the Marconi Co. They had the prefix CAT (cooled anode transmitting) to the numbers. Station 4SB was one station with Marconi valves fitted to one of its early transmitters. They were also used with some transmitters employing series modulation in the mid 1930s, such as 2SM.

A water cooled valve of unusual construction in service with short wave transmitter VLQ Brisbane was the SS1971 introduced during the late 1930s and early 1940s in STC transmitters. The VLQ transmitter was commissioned during 1943. The valve was a doubled ended triode with the water jacket being an integral part of the valve. It was employed for both MF and HF transmitter designs using two valves in parallel. Each valve required a DC filament supply of 20 volts which was provided by selenium rectifier and a step down transformer. In addition to VLQ, the valve was used with MF transmitter 4QR installed at the same site at the Bald Hills Radio Centre and HF transmitter VLX Hamersley, Western Australia.

The initial Radio Australia Shepparton short wave station with transmitters put into service in 1944–45 employed a number of water cooled valves. These included Federal F124A triodes in push-pull parallel configuration in the 100 kW final amplifier and push-pull STC4030C triodes in the modulator. The 4030C valves were later replaced by GEC BR189 air blast cooled triodes, but by 1984, the original 100 kW transmitters were replaced by transmitters employing vapour cooled valves. A 50 kW RCA transmitter was equipped with 880 water cooled triodes.

With the commissioning of Radio Australia Cox Peninsula near Darwin, with its three Collins 250 kW HF transmitters in 1969, new technology in the form of vapour cooled valves was introduced into Australian broadcasting. Transmitters later installed at Carnarvon and Shepparton were all equipped with vapour cooled or condensed vapour cooled type valves. Valve types include EIMAC 4CV100000C and 4CV100000E tetrodes, Hypervapodyne TH573 tetrode, BBC CQS200/3 and EIMAC 4CV50000. The Continental transmitters installed at Katherine, Tennant Creek and Alice Springs for the Northern Territory high frequency service also use EIMAC 4C100000C valves.

When two 250 kW Thomson-CSF TRE2326 transmitters were installed at Radio Australia Cox Peninsula in late 1993, each transmitter was equipped with a single Thomson-CSF TH558 type valve. The valve was a ceramic-metal tetrode with Pyrobloc grids and was capable of an output power of 550 kW with anode being cooled by the patented Hypervapotron arrangement.

Water cooled valves are no longer used with MF broadcast transmitters and this has reduced considerably, maintenance requirements at stations. The proper care and maintenance of this type of valve and the associated water and circulating system was of primary importance in ensuring minimum loss of transmission time. Distilled water supply was a major problem for country stations and also transmitters located on top of multistorey buildings. The water was usually supplied in 20 litre carboys and manhandling 20 to 30 carboys filled with water to replace the water in the system was not a welcome chore.

The quality of the water was important to ensure trouble free operation. The specific resistance had to be not less than 10000 ohms per centimetre cube to ensure minimum current leakage from the high voltage applied to the anode. Porcelain coils were used with many early installations to take the water to and from the anode but these were fragile and often broke. Rubber based high pressure hoses replaced many of the porcelain types.

However, in the case of the 50 kW RCA HF transmitter commissioned at Radio Australia Shepparton in 1944, ceramic insulating coils were still in situ 50 years later.

Because formation of scale on the anode prevented the efficient removal of heat, the hardness of the water had to be less than 5 grains per gallon. Although some station operators used rain water collected from the building roof, most employed distilled water.

Even with the best water, some scale still formed on the anode and this had to be regularly removed. The usual procedure was to dip the anode in a 10% solution of hydrochloric acid until the scale dissolved and then thoroughly wash the anode before placing the valve back in the jacket. This operation had to be carried out very carefully as breakages through handling were frequent.

To reduce the effects of electrolysis on the water jacket and other parts of the installation, targets were installed projecting into the hoses. Regular inspection of the targets was necessary to ensure that parts did not become loose in the hose as the metal corroded away.

Even with the best quality material, the hose had a relatively short life and replacement was a difficult and time consuming operation. Each hose was some 5 metres in length and a hose which burst or broke free at a clamp would cause considerable damage within the cubicle. At one 10 kW station a broken hose resulted in the loss of three valves and put the station off-air for five hours.

Although freezing of the water was not a usual occurrence, it happened at 4QS Dalby, and the expanding ice burst the radiator.

It was well into the afternoon before transmission could be resumed after effecting repairs.

Sediment in the pipes was also a problem where maintenance procedure was lax. When the 5CL transmitter was dismantled in 1961, following erection of a new station at Pimpala, the 25 mm diameter hose was found to be choked with sediment to an extent that water was forced to pass through a hole in the sediment less than 6 mm diameter, at very high pressure.

With water cooled valves, designers worked on an average cooling surface temperature of 30–60°C and a specific dissipation of the cooling surface of 30–110 watts per square centimetre.

Where water was obtained from bores on the station site, it was important to have the water analysed to ensure that appropriate equipment was installed in order to produce water of quality recommended by the valve manufacturer.

In the case of the Radio Australia site at Cox Peninsula near Darwin, analysis of the bore water showed values of pH 5.3, specific conductance 60 microSiemens/cm, sodium 6 mg/1, dissolved solids 35 mg/1, iron 6 mg/1, chloride 6 mg/1, nitrate 4 mg/1 total hardness 10mg/1, total alkalinity 18 mg/1 and bicarbonate mg/1. Installation of deionizing and other plant brought the water to an acceptable standard.

SILICA ENVELOPES

To meet a requirement for the British Navy for high power valves, envelopes of pure fused quartz (or silica) were developed towards the end of 1918. Whereas glass softened at about 150°C, silica could work at temperatures up to 1500°C. Silica also allowed a reduction in the physical size of the valve to be achieved. It was possible to produce a silica valve of size smaller than 1.5 kW glass valves using special heat resisting glass, yet capable of dissipating at their anodes as much as 6 kW. Another advantage of using a silica envelope was that the envelope could be easily opened for repair purposes to allow replacement of the filament. The silica was cut with a carborundum wheel and after completing repair, the envelope was re-fused with an oxy-hydrogen flame.

The first use of silica envelope valves for an Australian broadcast transmitter was with 3AR. The power amplifier and main rectifier valves employed types manufactured by Mullard. The transmitter was later transferred for use at 7ZL where it remained in service until about 1937. The connecting leads were taken out of the valves through long stalks which were filled with lead to allow for expansion of the conductors. The valve was mounted in a fibre tube through which air was blown to prevent the lead plugs from melting. The anode of the power amplifier consisted of a basket of woven tungsten. The transmitter 8 kV EHT supply was produced by a single phase alternator, the output of which was stepped up, then bi-phase rectified by two silica envelope diode valves.

The reason lead was used, was that it was the only metal that adhered satisfactorily to silica. The technique adopted was to embed internal and external conductors in a thin pencil of lead inside a thick walled cylinder of silica.

In more recent times, other insulating materials have been employed to handle the high temperatures produced by transmitting valves. In 1960, the National Berryllia Corporation in the USA announced the development of pure beryllium oxide ceramics with application for transmitting valves. The material has a melting point of 2570°C and a very high tensile strength as well as possessing other exceptional refractory properties. The material is widely used in ceramic insulated transmitting valves and warning notices explaining the dangers of grinding the material are included with the operating instructions.

The beryllium oxide ceramics are used as thermal links with some conduction cooled power valves. The link may be brazed to the anode section of the power valve or it may be a separate accessory but dust or fumes from the ceramic is highly toxic.

RECTIFYING VALVES

Over a long period of evolution and development, the high vacuum thermionic rectifier and the hot cathode mercury vapour rectifier became the standard DC power supply systems for transmitters while the cold cathode gaseous rectifier, copper oxide and selenium rectifiers were employed occasionally, but to a diminishing extent. Copper oxide rectifiers were employed with receiver power supply systems and to provide DC for electromagnetic loudspeaker units in the 1920s while selenium rectifiers were used in some transmitters in the early 1930s and even later.

At least six different rectifier connections have been developed by designers over the years. They include single phase full wave, single phase full wave bridge, three phase half wave, three phase distributed Y, three phase double Y and three phase full wave. The single phase full wave and single phase full wave bridge performances were identical in relation to the fundamental ripple frequency (100 Hz) and the second and third harmonic ripple voltages; the three phase half wave and three phase distributed Y performances were identical in relation to the fundamental ripple frequency (150 Hz) and the second and third harmonic ripple voltages and the three phase double Y and three phase full wave performances were identical in relation to the fundamental ripple frequency (300 Hz) and the second and third harmonic ripple voltages. The fundamental ripple frequency had a major influence on the design and cost of the filter circuit components.

Valves used in the early high power transmitters were high vacuum thermionic rectifiers. The important characteristic of this class of valve was the allowable peak anode current and the maximum allowable peak inverse voltage. The exact relationship between the DC output voltage and the allowable inverse voltage depended upon the rectifier circuit employed.

High vacuum rectifier valves were basically standard amplifier triode valves less the grid element. In the early high power AWA transmitters of the 1920s, type MR7A valves which were air cooled, were employed for EHT supply. The DC supply, about 9000 volts was provided by a three phase double star connected rectifier employing six valves. Mains transformer input was 415 volts and secondary output, 12000 volts AC.

In STC transmitters built in the 1930s, the valves were water cooled and employed tungsten filaments. The most widely used water cooled valves were the STC4222A and RCA214 types in three phase half wave circuit configurations. The Philips DA 12/24000 was also employed with some transmitters.

The STC Sydney valve factory later produced the 4222Z as replacement for the English STC 4222A rectifier. However, there was not a great demand, as most transmitters were converted to HCMV types.

Not all HT supplies were provided from valve rectifier systems. Some early stations employed motor generator sets. In the case of 2NC, three generators were connected in tandem. Motor generator sets also provided filament and grid bias supplies.

For medium and small power supply requirements, valves were air cooled and used thoriated-tungsten or oxide-coated cathodes. The size of the filament was determined by the required maximum peak current while the element separation and degree of vacuum determined the inverse peak voltage for safe working conditions.

A major drawback in the use of the high vacuum valve was the voltage drop across the valve during operation. Also, the supply regulation was poor, being governed largely by the voltage drop in the valve.

One of the great advances made a transmitter technology was the development of the hot cathode mercury vapour (HCMV) rectifier valve. It solved many of the problems associated with high vacuum rectifiers such as the variable voltage drop characteristic, high heat generation and high power requirement for the tungsten filament.

The HCMV rectifier was basically a high vacuum thermionic rectifier containing mercury vapour in equilibrium with liquid mercury. The distinguishing characteristic was that the valve under normal operating conditions had a constant drop of 15 volts regardless of load conditions. Because of the low drop, even large HCMV valves were air cooled. The efficiency was much higher than high vacuum types, being about 98% compared with 87% for high vacuum types.

Although the HCMV valve eventually replaced the high vacuum type, it was a gradual process. For example, when the Postmaster General's Department set up an organisation in 1931 to handle the major upgrading and replacement work when it took over the A Class stations to form the National Broadcasting Service, the Engineers in their first major design work of building a high power transmitter for 6WF, opted for a mix of HCMV and high vacuum valves. There were four rectifier units providing the anode supplies for the various transmitting valves. The master oscillator unit was supplied from a full wave single phase rectifier employing UX866 HCMV valves to provide 1.1 kV; the speech amplifier, modulator and modulated amplifier were provided by a three phase half wave rectifier using Philips 1763 giving 4 kV, with regulation being provided by an auto transformer, while the anode supply for the third power amplifier was obtained from a three phase double Y rectifier system fitted with MR9 high vacuum valves.

Typical HCMV valves which have been employed by designers in various transmitter models include 866/866A and 872/872A for low and medium voltage stages, and 4078A/4078Z, 2V/561E, 4080A and 857B for high voltage stages. The 4078Z type was manufactured in the Sydney STC valve factory.

In the 10 kW STC transmitters installed at 4QS, 3LO, 2FC and 2CY in the late 1930s, six valves type 4078A were employed for the EHT supply in a full wave three phase arrangement and in order to obtain maximum life from the rectifiers, a temperature control unit was provided. For maximum life the temperature of the condensed mercury in the valves had to be maintained between the limits of 15°C and 40°C. The condensed mercury temperature was taken to be the ambient temperature where forced cooling was applied, or 15°C above ambient where no artificial cooling was used.

The temperature control unit used an air blower in continuous operation. Two thermostats were provided, adjustable from 7°C to 24°C and 15°C to 32°C. The former controlled a contactor which operated a bank of heaters while the latter operated a spray cooler. The action of the spray was to bring the temperature of the air near to the wet bulb temperature of the outside air. The thermostats were normally set at 18°C and 35°C. With the system, the temperature was maintained between 18 C and 35 C for ambient temperatures between 0°C and 55°C. This enabled each rectifier to operate at maximum efficiency at its full output voltage under the most extreme environmental conditions likely to be encountered in the transmitter hall.

The spray cooler consisted of a make-up tank with a float controlled inlet valve from which water was circulated by means of a centrifugal pump, through fine mist nozzles in a cooling tower. The air was drawn through the spray, and all moisture in suspension removed by a system of baffles.

At some stations, the system had restricted use because the environment was such that extremes in temperature seldom occurred.

As a general rule, HCMV valves required greater care in operation than high vacuum types, and manufacturers issued guidelines on operation and care of the valves. Typical instructions for 866A and 872A valves included:

* When a 866A or 872A rectifier is first placed in service, the filament should be heated at normal voltage for about 15 minutes without anode voltage in order to distribute the mercury properly.
  The procedure need not be repeated unless during subsequent handling mercury is splattered on the filament, anode and top part of the bulb.
* The ambient temperature should not be less than 15°C and not more than 60°C, the ambient temperature being the temperature of the air coming into contact with the heated parts of the valve and which carries off the heat.
* Care should be taken when starting up on a cold morning to allow sufficient time for the valve to warm up before applying high tension.
* The filament voltage of each valve should be carefully adjusted to 5 volts. It is dangerous for these valves to have less than 5 volts on the filament.

For 4078A valves, instructions included:

* When a 4078A valve is first placed in service its filament should be heated at normal voltage for 30 minutes without anode voltage, in order to distribute the mercury properly. Anode voltage should then be applied at reduced voltage and the valve maintained under this condition for about 15 minutes. The voltage should be gradually increased in steps, making use of the Star-Delta switch and transformer tappings in the rectifier. The load should be applied gradually, and when normal operating voltage and current are reached, operate the valve for 20 minutes before applying the modulation.
* In the event of an arc-back occurring, reduce voltage and repeat the process.
* All HCMV valves should operate at their rated filament voltage, plus or minus 2%.
* The mains voltage should be regulated so that under no conditions will the filament voltage vary more than plus or minus 5% from its rated value.
* The inside surface of the glass of most mercury vapour rectifier valves tend to darken with age in service. This does not indicate the end of useful life and valves should not be replaced on this account.

An unusual rectifier type used with the AWA 50 kW transmitter at 2CR for the main HT rectifier system employed English Electric AR63 mercury arc excitrons of a single anode mercury pool type. Ignition of the rectifier was obtained by means of a pivoted electrode which rested in a pool of mercury which formed the cathode. A gapped choke was mounted outside and close to the valve wall. When energised, it attracted an armature plate attached to the pivoted (ignition) electrode lifting the latter out of the pool. At the instant of switching, the total excitation current passed through the ignition electrode as it rested in the pool of mercury. The current was limited to about 4.5 amperes by series resistors.

The energising of the choke lifted the ignition electrode and established an arc at the point of contact at the surface of the mercury. The hot spot in the mercury took the place of the cathode in an ordinary rectifier valve. Attraction of the armature by the choke due to the normal excitation current flowing through it kept the ignition clear of the mercury pool. During normal operation the rectifier glowed blue and the ignition anode frequently operated at dull red heat.

This type of rectifier had a number of advantages and was widely employed at the time at overseas high power broadcasting stations, including BBC transmitters.

With the 2000 watt transmitter constructed by Colville Wireless Equipment Co., Pty Ltd under licence from Philips for use at Commercial station 2TM Tamworth in 1937, Philips rectifier valves were employed for all power supply systems.

Anode and screen voltages for the two parallel valves type PC PC1.5/100 employed as the modulated amplifier, and the screen voltage for the linear amplifier, were provided by a three phase full wave rectifier system employing six Graetz-connected Philips DCG2/1000 half wave gas filled rectifiers. The valves had oxide coated filaments and operated with 5 volts on the filaments drawing a current of 10 amperes.

Anode supply for the water cooled pentode type PA12/15 linear amplifier valve which delivered the 2000 watts to line, was obtained from a three phase full wave rectifier system using six Graetz-connected Philips type DCG5/2500 half wave mercury vapour rectifiers. The valves operated with a power of 5 volts at 10 amperes on the filaments. The valves were 310 mm in length, 90 mm at the largest diameter and used a chrome-iron seal which permitted a relatively high value of inverse voltage.

Like many other features in transmitter technology, mercury vapour valves were gradually replaced by new technology such as silicon diode stacks and it is unlikely that mercury valves would now be in service, except perhaps with a very few early valve transmitters retained for emergency purposes by sentimental Chief Engineers.

By the mid 1960s, many transmitter rectifier systems featured all semiconductor units. For example, the Commonwealth Electronics 2.5 kW transmitter employed 96 silicon diodes type MR326 in the main HT rectifier and 18 in the screen supply rectifier. In the case of the HT unit, the three phase double connected system used 16 diodes per leg. Type MR323 diodes were employed with the bias supply rectifier, the auxiliary supply rectifier, the 24 volt supply rectifier, the 50 volt control supply rectifier and the base addition rectifier.

In addition to three layer silicon diode devices, three layer germanium diode devices have also been used with some transmitters. However, the silicon type has a number of important advantages including maximum reverse voltage of 4000 volts compared with 800 volts and a maximum operating temperature of 200°C compared with 120°C for the germanium type, with designs available during the early 1970s.

For general DC power supply applications for transmitters, the diodes are mounted on heatsinks to remove internally generated heat. Where large dissipation levels are involved, forced air circulation or other methods are employed to provide necessary cooling. With the three 250 kW Collins 821A-2 HF transmitters installed at Radio Australia Cox Peninsula in 1969, the EHT rectifier stacks which provided 15250 volts DC at 40 amperes for modulator and power amplifier valve anodes using a 12 phase bridge system were mounted in the oil inside the transformer case.

VALVE COOLING SYSTEMS

Even a low power transmitter such as one producing 50 watts into the aerial with early transmitters, required some cooling of main valves, otherwise there was the danger of the glass envelope softening or the anode being destroyed. With powers of 500 watts and more, there was an alternative to the all glass envelope valve in the form of a design whereby the anode was no longer inside the envelope, but formed part of the envelope itself. This required a different technique for removing the generated heat.

In the formative days of broadcasting, valves were expensive and difficult to obtain and at many small stations very few spares were held. Operators soon found out that correctly designed systems for cooling of the valve envelope and seals were essential if long operating life was to be obtained. Increasing temperature had a number of adverse effects in a valve including shortened life and reduced performance. Even today, experience shows that excessive dissipation is perhaps the single greatest cause of catastrophic failure in a transmitting valve.

All high power valves have external anodes so that large amounts of heat can be dissipated quickly. The heat can be removed by air cooling where the anode is fitted with a large number of lamellar cooling fins and a stream of air is forced over them, by water cooling where smooth copper walls dissipated heat to a fast current of water which is passed over the anode or by vapour cooling where the anode is fitted with specially shaped fins and immersed in water which operates at boiling point. Perhaps there is some truth in that popular program, 'Steam Driven Radio'.

In addition to cooling of the anode, other electrode connections such as screen and control grid connections and cathode bushings require air jets in order to remove heat resulting from resistance, dielectric and eddy current losses. For a typical vapour cooled valve, as used at Radio Australia, giving an output power of 250 kW, a flow of air of 60 ft³/min (1.7 m³/min) was provided via a 2 inch (50 mm) diameter nozzle and directed into the filament header during the application of power in order to limit the temperature of the filament and grid seals to less than 140°C. The anode seal temperature had to be maintained below 180°C.

Operating frequency is a major factor in the production of heat which has to be removed. Valves operating in the short wave bands are inherently subject to a greater heating action than those operating in the medium wave band. This situation is brought about by increased dielectric losses, larger RF charging currents into the valve capacitances and the tendency of electrons to bombard parts of the valve structural components other than the anode and grids in high frequency application.

- Force Air Cooling.

  A conventional air cooler comprises a copper core with a central bore for the valve and a set of copper fins usually extending in a radial direction and secured to the outer surface of the core.

  The amount of heat dissipated by a cooler is proportional to the average temperature difference between fins and air, the rate of heat transfer from copper to air and the total area of the cooling surface. Average cooling surface temperature is 150–200°C with specific dissipation being 0.5–1 watts per square centimetre of cooling surface.

  Cooling air is drawn in through filters to remove dust and foreign bodies, particularly insects, and passes through the fins at high velocity. As the air is impeded in its flow through the fins, a back pressure is created, caused by friction of the air against the surfaces of the fins and by turbulence of the air in the passages. With high efficiency radiators, some valves had ratings up to 20 kW but above this figure the weight and size of the radiator tended to become excessive. The 3J/221E type was typical of a heavy valve. It required a hydraulic jack mechanism to transfer it to and from the STC 10 kW transmitter.

  The selection of a blower for a particular valve requires that air flow requirements and static pressure at the blower outlet be known. The airflow required depends upon the amount of anode dissipation and upon the maximum ambient temperature expected at the site. This value of required airflow and the corresponding value of anode temperature rise above the ambient value are given as part of the valve data in manufacturer's data sheets. In no case should the sum of the ambient temperature and the anode temperature rise above the ambient, exceed the maximum rated value of anode temperature as given in the valve ratings sheets.

  Photographs of damaged high power valves in 55 kW transmitters during hot summers for stations located at some sites bear witness to the problem of very high ambient temperatures. During one very hot summer in Adelaide, 5CL lost two type 3J/261E air blast cooled triodes in two days due to very high air temperature.

  The static pressure at the blower outlet depends upon the pressure versus airflow characteristics of the system into which the blower must deliver the required volume of air. This pressure is determined by the static pressure rating of the valve cooler when the required airflow is passing through it, the friction losses in ducts, pipes, bends and air filters and to changes in cross sectional area of the duct.

  Proper maintenance of the blower system is important with an air cooled installation. Stations which operate in dusty rural environments require particular attention. Station 8TC Tennant Creek was one such station where dust was a major problem for many years, prior to relocating the station to another site. The collection of microdust on the blades and cage of a blower or along the sides of the discharge duct or boot often results in reduced air-system efficiency. A reliable method of checking the efficiency of the cooling system over a period of time involves recording the back pressure that exists within the air cavity. A manometer is used for this purpose.

- Water Cooling.

  The efficiency of cooling a hot anode by moving fluid depends on the physical constants of the fluid, its velocity, the dimensions of the cooling arrangement and the thickness of the wall of the anode. Heat generated on the inside surface of the anode passes through the wall, is transferred to the moving liquid and carried by it away from the valve. Valves using this method of cooling have been made with anode dissipations of 200 kW and dissipation rates of about 60W/cm^2 of anode surface.

The water must not be allowed to boil and the flow must be great enough to prevent steam bubbles forming on the anode surface. In a typical valve, the temperature rise across the water jacket is usually restricted to limits of 15°C–20°C maximum with an outlet water temperature of 65°C. The piping should be arranged to avoid air traps in the jacket. Excessive water hammer may develop peak water pressures sufficient to deform the anode. Distilled water is used for good insulation purposes and for cooling because it greatly reduces scale formation on the anode. No Commercial stations have used water cooled valves for some years, but at the end of 1989 there were still short wave transmitters on air with the National service. However, the technology was brought to a close within about 12 months. Even 500 watt transmitters at some stations in the late 1920s and 1930s, employed water cooled valves. Many of the early cooling systems, even with the high power installations, used materials which soon introduced serious maintenance problems. For example, standard galvanised iron piping, galvanised water tanks, cast iron irrigation water pumps and motor car radiators for cooling the water were widely employed. Very soon, galvanising products were stripped — physically or electrolytically — and deposited on the valve anodes. With rusting of iron, the problem was aggravated by deposits of iron oxide on the anodes, making it extremely difficult to keep the anode clean. A dirty anode had reduced capacity for transfer of heat from the anode to the circulating water. Also, the presence of metal particles etc, increased the conductivity of the water, so increasing leaking of high tension currents to ground.

In 1927, at 5CL when a water cooled valve was installed to replace a bank of air cooled types, the cooling system was made up of galvanised piping, galvanised tanks mounted on wooden stands and a Ford motor car radiator. From 1931, when installation of NBS regional stations began, the installations employed all non-ferrous materials. This arrangement was still employed for those installations still in operation up to 1990.

Although most station Engineers used distilled water for the water cooling system, a number opted to use rain water caught from the station roof. Commercial station 5PI Huddleston erected in 1932, employed two water cooled valves type 4228A to provide 2 kW from the power amplifier. The building roof consisted of corrugated cement sheeting and after filtering, the water was stored in a 18000 litre underground tank. The active water cooling tank was placed inside the building and topped up from the underground tank. The quality of the water exceeded the valve manufacturer's specifications. The temperature of the circulating water was reduced by a large refrigerator condenser and an air blast fan. The water was circulated by two centrifugal Marell pumps.

- Vapour Cooling.

  The vapour cooling technique is used with transmitters at Radio Australia Shepparton. It is also employed with the Katherine, Tennant Creek and Alice Springs high frequency inland service stations. The Radio Australia transmitters at Carnarvon and Cox Peninsula also employed the technique when the stations were operational.

  In a water cooled system, the outlet water temperature rise varies directly with anode dissipation. The flow of water required in order to ensure safe operation can be determined from the basic fact that 1 gram of water absorbs 1 calorie of heat for 1°C rise in temperature. In the vapour cooling system a different principle is employed. The thermal energy is absorbed by a change of state of the coolant. Water is converted to steam at 100°C and 545 calories are absorbed for each gram of water. In the vapour cooled arrangement, the steam temperature is fixed and it is the flow of steam which varies with the anode dissipation, thereby providing greater protection against thermal overloads.

In the Cox Peninsula, Collins 821A transmitters installed in the 1960s, two single boilers were used in the modulator unit and one double boiler in the radio frequency power amplifier. A small pump forced distilled or deionized water into the boilers with the minimum flow rate to each boiler being at least twice the maximum steam dissipation rate, thus providing a safe overflow at all times.

Steam from the boilers passed through pipes to the steam-to-air heat exchanger where it condensed. The condensate returned through the vent tank and back to the main reservoir. The system was equipped with interlocks and monitor circuits to provide protection for the transmitter. The water lines were equipped with expendable targets that protected boilers from electrolytic deterioration.

High quality materials and workmanship are essential. Open venting in the steam and water circuits may result in localised corrosion problems because of oxygenation of the water. Copper is ideal for the steam pipes but care should be taken to ensure that brazing or soldering materials have very little zinc content. Steam header sections are usually of glass or resin bonded fibreglass.

The latest high power valve provided with Radio Australia transmitters, was the Thomson-CSF TH558 tetrode, incorporated in two Thomson-CSF transmitter type TRE2326 installed in 1993 at the Cox Peninsula station. It was the only valve used in the transmitter and was a development of Thomson-CSF/Division Tubes Electroniques, France.

The valve has a maximum anode dissipation of 500 kW using the company patented Hypervapotron anode cooling arrangement. Minimum water flow requirement is 200 1/minute. Electrode terminals and ceramic insulator cooling is by forced air with minimum air flow requirement being 1.6 cubic metres per minute at maximum air inlet temperature of 45°C.

The valve uses a thoriated tungsten type of cathode with heating being either direct DC or single phase AC source. The operating heater voltage depends on the specific operating conditions but is approximately 500 amperes for a 23 volt RMS heater voltage. The heating surge current needs to be kept below 1000 amperes peak, on the first cycle.

Demineralised water is used for removing heat from the anode. Recommended resistivity requirement is 500000 ohms per cubic centimetre at 20°C.

A considerable amount of research by Thomson-CSF has gone into high power tetrode technology in recent years by combining new materials and new techniques.

Heating is by direct heating whereby the current flows through the cathode itself. Thoriated-tungsten in the form of thin tungsten wire containing a small percentage or thorium oxide is used. The wire is wound in the form of a cylindrical cage with plates at each end of the cage being used for the heating current connections.

Conventional grid materials used in the past are not suitable for modern high power valves. The company employs pyrolytic graphite to provide a new type of grid known as Pyrobloc grid. Advantages include improved thermal conductivity, high heat radiation capacity, reduced secondary emission effects, good mechanical strength with the strength increasing with temperature and excellent electrical resistivity properties.

The patented Hypervapotron cooling of the anode with Thomson-CSF valves is a development of the Vapotron, a company discovery of the early 1950s. The heat removal process relies on the complex boiling phenomena within narrow slots on the anode surface forming a vapour which is then expelled. The water vapour is then condensed in a fast moving flow of relatively cool water, passing the slots at right angles within the water jacket in which the valve sits. The hot outlet water from the jacket is then routed through a heat exchanger unit. Using this technique valves are rated at 1 kW per square centimetre although the theoretical limit is twice this level.

HEATING OF FILAMENTS

When the 5 kW AWA transmitters were installed during 1923–25, for 2FC, 3LO, 5CL, 4QG and 6WF, all the main valve filaments were powered from 50 Hz mains supply using an auto transformer followed by filament transformers.

Separate transformers were provided for master oscillator, modulator, power amplifier and high tension rectifier stages. However, filament power for the submodulator valves was provided from a battery supply. The 3AR installation which was a different design, employed AC mains power to heat all valves, including the submodulator stage.

When the National Broadcasting Service began expansion to regional centres, direct current was employed for filament power. At 2NC Newcastle and 4RK Rockhampton — both 2 kW transmitters — a 24 volt generator supplied power for all valves in the transmitter. The generator was a compound wound self-excited type. Resistances were provided in the filament circuits of the various valves to reduce voltage to the correct values. The oscillator-modulator valves were fed with 14 volts and the master oscillator, speech amplifier and separator with 10 volts.

The 2CO Corowa and 5CK Crystal Brook transmitters — both 7.5 kW rating — fed the filaments of valves up to the first power amplifier with a motor generator delivering 16 volts, with the voltage being adjusted with the series resistances to suit valve requirements. The filament of the last stage was heated by DC from a 24 volt generator. The filaments of the high tension rectifier unit which used water cooled valves were heated by raw AC obtained from three phase specially insulated transformers, the output voltage of which was controlled by rheostats in the primary circuits. However, when 3GI Gippsland was installed in 1935, motor generator sets were not employed, but DC was still used to heat the filaments. With the exception of the final stage, the 14 volt power supply for filaments was derived from Westinghouse copper oxide units. The filaments of the final water cooled valves were heated with 24 volts AC.

In the late 1930s and early 1940s when a new series of STC water cooled transmitters was developed using SS1971 double ended valves, the filaments of these valves were fed by 20 volts direct current at 64 amperes. The power for a 1942 transmitter was derived from step-down filament transformers and a bank of selenium rectifiers for DC conversion. The rectifier provided an output of 20 volts 130 amperes DC.

The element of a selenium rectifier was formed of a thin film of selenium applied to one side of a nickel plated steel disc. The selenium was subsequently converted to a crystalline state by heat treatment, and contact was made by spraying an alloy on the surface of the selenium.

When STC Sydney began using this type of rectifier with its transmitter designed to cover both MF and HF bands using the SS1971 type valves, the rectifier elements were assembled using imported discs supplied by STC England. However, with the outbreak of the War in 1939, and likely disruption to supply, the Australian company undertook considerable scientific and engineering development work in order to produce its own units. It became one of the few companies in the world with know-how to manufacture selenium rectifiers.

Manufacture commenced in 1941 and continued for two decades until selenium was superseded by more efficient semi-conductor devices. One problem with the use of selenium units in transmitters was that designers and operators had to be careful that the rectifier did not become overheated. Material radiated from excessive heating could cause respiratory and other irritations to workmen.

One Engineer involved in the development and manufacture of selenium rectifier units in the STC factory in England, was Bill Gold, who migrated to Australia after the War, and worked on a number of design projects for the National Broadcasting Service stations in South Australia and the Northern Territory including Radio Australia Cox Peninsula.

With improvement in valve technology and the introduction of negative feedback into transmitter circuitry from about 1939, the employment of AC heated filaments became standard practice.

The major problem experienced with the early employment of AC heated filaments, resulted from modulation of the emission current by the alternating current at double the mains frequency. Various circuits were employed to minimise the unwanted 100 Hz hum with various degrees of success. Some circuits used three phase heating circuits and although it reduced the level of the noise, the frequency problem shifted to a point six times the mains frequency. Other circuits employed two phase heating and this, coupled with negative feedback, resulted in a major improvement. The most widely employed method to obtain two phase transformation from a three phase system was to use a Scott connected transformer.

In the 1923–25 transmitters of AWA design, the circuitry employed centre tapped resistors across the filaments. By connecting the grid and anode return leads to a point having the same potential as the centre of the filament, the hum effect of the AC current could be minimised. In the 3AR design, centre tapped filament transformers achieved the same purpose.

The use of direct current for filament power was not without its undesirable effects. Emission from the filament wire was greater from the negative half due to the higher anode potential with respect to the anode. To spread erosion evenly throughout the life of the filament, the polarity of the generator was reversed periodically, or as was the case at some stations including 5DN Adelaide, 5PI Huddleston and 3UZ Melbourne, the leads at the filament were reversed at monthly intervals. At 3UZ, the generator provided 14 volts output. It fed a number of Philips TB2/250 valves and as they required a filament voltage of only 11 volts, a variable resistance was placed in series with each filament.

Generations providing DC power for large transmitting valves had to have good inherent voltage regulation usually obtained by level compounding the field and a flat speed/load characteristic of the motor. Cables connecting generator to the valve filament had to be of very low resistance to minimise voltage drop with the large current being carried.

The use of DC for high power valves still had its supporters in some more recent designs. As an example, the AWA 50 kW BTM50 MF transmitter still in service until early 1994 at 2CR was designed with a DC filament supply for the power amplifier valve, a directly heated triode type BR191.

The supply unit comprised a transformer, six STC type RS80 silicon diodes, associated limiting resistors and a stepping contactor. A regulated three phase 415V AC supply was connected via the limiting resistors to a star connected secondary to which was linked a full wave bridge rectifier. Relays connected across the output control circuit operated contacts which successively shorted out sections of 16 ohm wire wound limited resistors. Normal operating voltage was 9 volts.

When the 2000 watt transmitter manufactured under licence from Philips by Colville Wireless Equipment Co., Pty Ltd, Sydney was installed at 2TM Tamworth in 1937, the transmitter employed Philips pentodes throughout, and filament supply to the entire transmitter valve complement was provided from a low tension rectifier system employing Philips type 1059 full wave mercury vapour rectifiers in a conventional star type, three phase, full wave configuration. The system provided a supply of 22 volts at 80 amperes, and with aid of a few series resistors, maintained all valve filaments at the recommended temperatures. It had very good regulation and failure of one filament in the load, had negligible effect on the potential applied to the remaining working valves.

At some centres where broadcast transmitters were installed, the public power supply system was direct current. This created a problem, not only for power for the valve filaments, but also for HT and EHT supplies. Two transmitter installations which had to deal with the problem were the temporary 500 watt 4QG Brisbane transmitter which went to air in 1925, and the 2UW transmitter in Market Street, Sydney. At both centres, DC/AC rotary converters were installed enabling the required voltages to be obtained by suitable transformers. In the case of the 4QG station, the supply was available at 400 volts DC unearthed, or alternatively, 220 volts positive to ground or 220 volts negative to ground.

HIGH VOLTAGE DC GENERATORS

One area where designers of early broadcast transmitters differed, was in the method of supplying high tension for value anodes. Of the original installations, the AWA designed transmitters were equipped with three phase rectifier systems supplied from 415 volt 50 Hz mains to provide up to 9000 volts DC for submodulator, modulator, master oscillator and power amplifier. Stations 2FC, 3LO, 4QG, 5CL and 6WF were so equipped in 1923–25. The 3AR locally designed transmitter of 1925, and later 7ZL where the same transmitter was reinstalled in 1927, the installation employed a combination of DC generator and single phase AC power. A DC motor generator set provided 2000 volts for master oscillator and submodular while a single phase 350 volt 150 Hz local motor-alternator provided power to a full wave valve rectifier system to provide for the modulator and power amplifier. Later, at 7ZL, all motor generating equipment was replaced by rectifier systems using mercury vapour valves fed from 50 Hz mains.

During 1930–31, the 2NC and 4RK transmitters were equipped with three high tension DC generators connected in tandem giving 750 volts and 1250 volts for anodes of air cooled valves and 4000 volts for the final power amplifier stage. Machines were also provided for the 24 volt filament and 250 volt bias supplies.

The high power stations 2CO and 5CK commissioned during 1931–32, had an installation comprising DC generators and a 50 Hz mains valve rectifier system. The DC generators provided 800 volts for valves up to the modulated amplifier stage, 1600 volts for the modulator and 4000 volts for the first power amplifier. The 12000 volt supply for the final power amplifier was supplied by a three phase half wave rectifier energised by AC mains.

The technique employed to obtain the various DC voltages from the generators was to use a series of machines. The 800 volt supply was provided by an 800 volt generator, the 1600 volt supply was derived from a unit having two series 800 volt armature windings driven by a common shaft, the 4000 volt was obtained by joining the 1600 volt supply in series with a 2400 volt generator on the same bed plate. The machines were fully duplicated and in addition, spare armatures were held at the station.

The motors were started by remote push-button control auto starters using star-delta starting with eddy current time lags. The push-buttons were on the transmitter control panel but equipment for change-over of machines was located on the main power board in the power room.

Although the high voltage DC motor generators gave reasonably reliable service, maintenance was more demanding than for valve rectifier systems. A good deal of attention was required to commutation, insulation between segments had to be kept very clean and high humidity conditions had to be avoided where possible. Condensation of moisture on the commutator was frequently a problem when equipment was started up early in the morning and unless a standby unit was available, long delays could occur in commencing transmission due to the need to use hot air blowers to remove the moisture from the generator. Staff at 5CK Crystal Brook frequently experienced problems in this area.

The machines were characterised by high insulation of the armature windings and brush gear, and by the need for more commutator segments than for a standard generator. For safety reasons, the negative terminal and machine casing and bedplate were heavily strapped to the main station earth system. Terminals and brush gear were well insulated and shielded for safety and also, to prevent radiation from arcing causing interference in the program input equipment circuits. To smooth out ripple, a choke-capacitor unit was placed in the output feed of the generator.

The reason why machines continued to be used with broadcast transmitters for so many years was probably due to the fact that Electrical Engineers understood generators very well, and were more confident with them than the troublesome early valve rectifiers which frequently were subject to arc-back and catastrophic flash-over problems, even though the machines could be difficult and hazardous to maintain. By 1926, machines had reached a high level of development in Radio Engineering with the commissioning of the high power long wavelength station at Rugby in England. The station had a large plant installation including motor generators which provided DC of 1500 kW at 18000 volts for anodes, and alternators producing 2000 VA at 415 volts for filaments.

Even large banks of batteries were provided to supply high tension and bias voltages at some stations. The AWA 5 kW transmitters provided at A Class stations in the early 1920s used batteries for some sections of the transmitter. For example, at 4QG a large battery room housed two main banks. One bank produced 720 volts to provide high tension for the MC1/50 sub-modulator and the other produced 162 volts for bias voltage to 10 MT7B modulator valves connected in parallel.

When STC produced a new transmitter design for installation during 1935–36, at 7NT, 3GI, 2NR, 4QN and 6GF, no machines were employed for generation of valve voltages. Grid bias and high tension DC voltages were provided by copper oxide rectifiers, the EHT by thermionic valve rectifiers and the PA valve filaments by Scott wired transformers connected to the 50 Hz mains supply.

Except for a few stations in the late 1930s where generators provided filament power for water cooled PA valves, generator machines are no longer used in broadcast transmitter installations.

However, where provided, Chief Engineers obtained long service by ensuring careful and regular maintenance routines were implemented. In the case of 2UE Sydney where Murray Stevenson was in charge, generators were provided for a pair of STC 4228A valves. The generators provided power for the filaments and two 2000 volt DC generators in series provided High Tension. The generators were in service for 12 years following commissioning in 1930 at the Lilli Pilli site.

VALVE SUPPLY PROBLEMS

Up until the outbreak of the Second World War in 1939, supply of transmitting valves for maintenance purposes was not a great problem. Even valves sourced from overseas manufacturers were readily available from local agents or distributors.

However, supply of overseas manufactured valves from Europe ceased abruptly with damage to factories and the need to divert resources to the War effort. USA manufactured valves were still available for some time, but Philips valves manufactured in Holland were no longer available in Australia and Chief Engineers had to take swift action to deal with the situation.

Bill Nicholas Chief Engineer of Commercial station 7HT Hobart operated by Metropolitan Broadcasters Pty Ltd, was responsible for a 500 watt transmitter manufactured by Transmission Equipment Pty Ltd in 1937 and fitted throughout with Philips valves. The valve line up comprised PEO5/15 crystal oscillator, PEO5/15 first buffer stage, TCL/75 second buffer stage, two TC2/250 in push-pull final RF amplifier, two TC2/250 in push-pull modulator, two TCL/75 in push-pull submodulator, two EL2 push-pull audio driver and DCG2/1000 for all rectifiers. Bill replaced all the Philips valves carrying out necessary modifications to the transmitter without any loss of scheduled transmission time. The new valves comprised 807 crystal oscillator, 807 first buffer, 810 second buffer, two 810 in push-pull final RF amplifier, two 810 in push-pull modulator, two M81/75E push-pull submodulator, two 6A6 push-pull audio driver and 83V, 866A and 872A as rectifiers. The 500 watt transmitter remained in operation at Rosny Hill until the late 1950s when a new transmitting station with an AWA 2 kW transmitter was built at another site near Droughty Point.

Efficiency was an important factor in the days of transmitters employing valves, particularly when power charges were on the increase. Designers set about designing transmitters employing more efficient valves and less of them, to provide the required power output.

In the 10 year period 1972 to 1982, the number of valves employed in a typical Australian made 10 kW transmitter as widely used in the National Broadcasting Service for ABC programs, fell from about 14 to zero with the availability of all solid state models. Over the period, overall efficiency increased from about 40% to 70%.

Nevertheless, the availability of valves for those transmitters still using valves was a major problem for station operators.

As old transmitters were phased out of service, manufacturers were reluctant to support production lines for manufacture of valves and associated high voltage components.

At some stations in the 1970s, after only 10 years of transmitter service, it became necessary to redesign stages to accommodate alternative types of valves which were more readily available.

The opportunity was also taken to incorporate high efficiency circuits, particularly in the radio frequency stages, by using high gain tetrodes. This also allowed the circuit to be simplified particularly in the driver and neutralising stages.

Up until the outbreak of the Second World War, this type of problem would not have occurred as transmitter manufacturers were able to guarantee long term supply of valves. For example, AWA who supplied a great many of the broadcast transmitters at that period, were able to supply off-the-shelf, a wide range of Radiotron valves which included 809 a 35 watt triode, 814 an 85 watt beam amplifier, 808 a 100 watt triode, 805 a 140 watt triode, 810 a 250 watt triode, 806 a 350 watt triode, and 833 a 635 watt triode. The 833 was a major work horse in AWA transmitters and hundreds could be seen in operation throughout the country right up to the time when valve transmitters were replaced by solid state types.

One of the AWA Engineers employed in the Transmitting Valve Department at the period was Doug Sutherland. He graduated B.Sc. in Physics in 1931 and joined AWA Research Laboratories in 1935 after spending some time on research work. In 1937, he was in charge of the Measurements Section in the Laboratory and later in the same year was appointed to the Transmitting Valve Department of Amalgamated Wireless Valve Co., Pty Ltd. In 1938, he visited the USA to make a study of developments in transmitting valve design and manufacture.

In the 1940s, senior staff at the factory included Jack Anderson in charge of Transmitting Valves; Doug Sutherland, Engineering Manager Power and Receiving Valve Design and Quality Control; Colin Stockbridge, Quality Control Department; and Ron Aitchison, Engineering Manager Special Devices including magnetrons, klystrons and crystals for radar application.

Standard Telephones and Cables Pty Ltd, also manufactured transmitting type valves. The company began manufacturing valves with Ken Brown in charge in 1938, for use in telephone repeater equipment and produced the first models in 1939.

The availability of specialised skills in vacuum techniques, glass working and the metallurgy of rare metals placed STC in a good position at the outbreak of the War to manufacture top secret and other types of valves for the Services. These included VT90 pulse triode, E1189 multicavity magnetron, CV56 strapped multiple cavity magnetron, CV35 velocity modulated reflex klystron and after the War, a 2C39A disc sealed triode.

Other thoriated tungsten filament valves made in the factory included 4282A, 4242A, 4251Z and 4279Z types. These were followed by the 3J160E, a forced air cooled triode. Hot cathode mercury vapour types including the 4078Z were also produced.

Tungsten filament MF transmitting valves manufactured, included the 4220Z, a water cooled triode with anode dissipation of 20 kilowatts and the 4222Z, a high vacuum water cooled triode rectifier.

The majority of high power valves used in Australian made STC transmitters were imported, but the factory carried out testing functions before the valves were released for employment in new equipment or sold to customers. These included 3J261E, F124A and SS1971 types.

The plant continued its role with transmitting valves until 1962 when work was phased out due to falling demand.

One of the senior staff associated with the STC valve manufacturing activities was Tom Basnett. He joined the company from CSIR (later CSIRO) Radio Physics Laboratories in 1942 and left the company in 1964, two years after closure of the valve manufacturing facility.

In a large network when many transmitters are in service such as the National Service, the replacement cost of all valve transmitters was enormous and could only be carried out over an extended time period. As at 1990, many valve types were still being purchased for the operation of the service. These included RCA833A triode, RCA802 pentode, RCA810 triode, Philips TB4/1250 triode, RCA827R tetrode, STC 3J/192E triode, RCA 4E27A pentode, RCA 9C25 triode, EIMAC 3CX2500A3 triode, EIMAC 3CX2500F3 triode, EIMAC 4CV100000C and 4CV100000E tetrodes, EIMAC 4CX3000A tetrode, Brown Boveri CQS200.3 tetrode, EIMAC 4CV50000E tetrode, EIMAC 4CX1500A tetrode, Brown Boveri CQS 50.1 tetrode, EIMAC 5/500A pentode, Philips TBL7/8000 triode, Philips TBL12/25 triode, and Siemens 2CX10000F diode.

By 1996, with the large scale replacement of valve transmitters with solid state designs, the types of valves being purchased had fallen considerably.

By the late 1960s, the supply of transmitting valves to meet the needs of the National Broadcasting Service was a very large and time consuming undertaking. A lot of work went into forward planning to ensure appropriate numbers of the various types were available on station as required. Scheduling and the preparation of Tender and Contract documents and ongoing dealings with suppliers was almost a full-time job for George Joosten one of the PMG's Department Engineers in the Headquarters Radio Section. At stations, a History Card was maintained for each valve.

EXTENDING LIFE EXPECTANCY

From the beginning of broadcasting, transmitting valve costs have been a significant part of the total station operating cost. Unlike many of the other components of the transmitter, the valves had a relatively short life span and any practice which would extend the life of a valve was sure to receive the attention of the Chief Engineer. Many valves were imported from overseas manufacturers and because of their cost, only minimum quantities were held as spares. Any catastrophic failure such as breakage by staff during handling or fitting into the transmitter, or premature filament burn-out, in many cases, caused some concern to the technical staff and also the Accountant in the Office.

Notwithstanding the increasing installation of all solid state transmitters, existing transmitters employing valves will still be in operation for some years, and supply of valves will become more difficult as manufacturers cease making them.

One way of offsetting the rising procurement costs and to reduce the frequency of replacement is to prolong the valve life. Over the years, station operators tried many techniques to extend the operating life with greater and lesser degrees of success. These included:

- Provision of a regulator to hold the filament voltage at a constant level.

  Before the extension of the present electricity grid, many country towns had local power houses which produced power that was not ideal for a broadcast transmitter connected to the supply. At some towns, the voltage applied at the valve filaments varied in sympathy with primary line voltage changes and the effect on the valve life was devastating.

A typical example was 8TC Tennant Creek in the Northern Territory, where the town supply was originally provided from the local gold mine. Whenever large buckets of ore were being lifted from the mine floor, the voltage at the transmitter would frequently drop as much as 20%.

- The operation of valves under conditions of ample reserve. Designers ensured that the valve was not in the operational situation that the demand for performance was so great that the minimum output power levels could only be met at the rated nominal filament voltage.
- Provision of adequate metering or facilities to allow all elements to be accurately metered for both current and voltage.
- Transmitter maintenance routines included an examination of valve and socket for signs of discolouration with particular attention being given to the colour adjacent to the anode core and the bottom of the valve stem where the filament contacts were made. Discolouration was frequently a sign of overheating.
- Implementation of a program of filament voltage management. Operation of the filament voltage of many thoriated tungsten valves slightly below the rated nominal voltage could extend valve life if properly managed. Valve manufacturers recommended that for the first 200 hours of life, the valve should be operated at its rated nominal voltage because the getter was more effective at a time when contaminants were more prevalent and also because at the early stage, filament emission increased.

  The controlled application of filament voltage was a complex and time consuming operation with early transmitters. The start-up operation was often carried out manually by inserting in the circuit, stepped or variable resistances or reactors. With some installations, and certainly at a later stage, this was done automatically by means of timed contactors controlling the switching of stepped resistances.

Various methods were adopted by designers for application of filament power. These include:

- The two step system. This was often used with motor generator supplies. The set was started with a resistance in series with the generator field. The initial current fed to the valve was limited by the run-up time of the machine, armature reaction and the inductance of the field winding. After a period — usually about 30 seconds — by which time the filament temperature had stabilised, the field resistance was shorted out by a delayed contactor.
- The hand wheel potentiometer method. This method was widely employed with water cooled valves heated by DC generators. A hand wheel operated a stepped potentiometer connected across the generator exciter. The transit time was adjustable up to 60 seconds to cater for a range of filament sizes.
- Primary control. A typical system with AC powered filaments comprised a variable or stepped resistance or reactance in series with the filament transformer primary circuit.
- Leakage transformer. Filament transformers designed to have a large leakage flux were common for AC powered filaments. This type was adaptable to automatic switching as the output voltage was automatically reduced to a safe value when the transformer was energised.
- On-load tap switching. This switch was placed in the primary circuit of the transformer where current was low, and employed a large number of studs so that the voltage increments were small.

The purpose of all these devices was to ensure that the heavy current rush which occurred when voltage was applied to a cold filament was limited to a value low enough to restrict the mechanical stresses set up by strong magnetic forces as a result of high currents. The resistance of a cold tungsten filament was only about 1/14th of the resistance at working temperature, and mechanical stresses on the elements were proportional to the square of the current.

Whereas the temperature of thoriated tungsten filaments could be operated in range 1950–2000°K, pure tungsten had an operating temperature in the range of 2500–2600°K. Although the total filament emission current available for tungsten filament transmitter valves varied as the seventh power of the filament voltage, it was essential that the filament voltage be maintained within close limits to the manufacturer's recommendation for each valve where operating data was supplied.

Filament life was closely linked to operating temperature. Valve manufacturers estimated that a 3% increase in applied filament voltage would result in a 20°K increase in filament temperature and produce a 20% increase in peak emission. However, it also resulted in a 50% decrease in valve life because of carbon loss. During the manufacturing process, a layer of ditungsten carbon formed on the surface of the filament and the end of the valve's useful life occurred when most of the carbon had evaporated, depleting the carbide surface layer. The depth of the layer formed during manufacture was a compromise between long operating time and other factors, particularly shipping. Should the carbide layer be too deep the filament would be too brittle to withstand the rigors of transport over long distances.

The life cycle also worked in reverse. For a small reduction in operating temperature and peak emission, the life of the carbide layer could be extended.

During the Second World War, and for some time thereafter, when valves were difficult to obtain, many transmitter operators reduced the filament voltage somewhat below the rated voltage to prolong the operating life.

With thoriated tungsten transmitting valves, the emission could often be improved by applying a filament voltage about 30% above normal for 10 minutes and then reducing the voltage for half an hour with the anode and grid bias voltages removed. At least three Chief Engineers at Commercial stations in Queensland adopted this practice during the War years.

Over the years, many improvements have been made in the construction of the filament to ensure maximum possible operating life and so maximising performance of the transmitting system as a whole. Modern practice for large valves is to employ mesh filament construction. This technique is more rugged and resistant to physical shock than simpler geometrics and it also offers lower distortion in high level AM modulation circuits.

REBUILT VALVES

Except for catastrophic failures which are usually the result of some external influence, the normal end of useful service of a valve employed in a transmitter occurs when the filament emission is insufficient to meet the full output power or acceptable distortion levels. Factors which influence the number of operating hours over which a valve will provide acceptable transmitter performance include the amount of carbon originally processed into the filament during the manufacturing stage, the residual vacuum level and the operating temperature of the filament.

Many valves are no longer being manufactured and where alternatives cannot be used, the broadcaster has to arrange for a failed valve to be repaired or rebuilt in order to continue operation. AWA in Australia was one such organisation which undertook rebuilding of some types. Not all types of valves were suitable for rebuilding. Generally, rebuilding work was restricted to types with ceramic-metal seal construction with anode dissipation greater than 2 kW.

The rebuilding process consisted of the following basic stages:

- Dismantling by typically machining the vacuum seal on the external envelope.
- Replacement of tungsten cathode filaments by spot welding on the mount assembly.
- Carburising new cathode filaments by flashing in a hydrocarbon vapour bell. This process ensured correct hot filament resistance and electron emission level and stability during service life.

- During replacement, grids were concentrically lined up with respect to the filament strands to ensure correct electrical characteristics.
- Exhaust tubes were replaced on the anode radiator assembly by silver brazing in either a hydrogen atmosphere or vacuum furnace.
- Final assembly of the repaired valve mount and anode radiator was by argon arc welding of the vacuum seal on the external envelope.
- On the exhaust bench the sealed valve was evacuated typically to below 10^5 Torr pressure and baked at temperatures up to 600°C to remove residual gases. Finally, after filament activation and electrode bombardment, the valve was pinched off at the copper exhaust tubulation by hydraulically operated jaws.
- After electrical ageing, the exhausted valve was statically and dynamically tested in either an oscillator or PA stage to the relevant electrical specifications.
- After silver plating and branding, the finished valve was packed ready for delivery.

Many years of field experience indicated that a rebuilt valve had a similar life expectancy to that of a new valve.

During 1988, valves being rebuilt by AWA for the National service transmitters included RCA 6166A tetrode and EIMAC 4CX500A tetrode types. The rebuilding operation ceased when AWA sold the Ashfield site.

Valve rebuilding was still available from some overseas sources in 1990. One USA valve rebuilder was Econco, represented in Australia by Engineering Design and Systems (EDS), Marrickville.

However, it is extremely difficult to find rebuilders who will handle glass envelope valves but a few will rebuild ceramic envelope valves.

TESTING TRANSMITTER VALVES

Although transmitter valves are rapidly disappearing from the broadcasting scene, they were basically the life of the transmitter at all power levels for many years. Even today, there are many standby transmitters still using valves waiting their turn to be replaced by all solid state models.

Transmitting valves are expensive, can fail catastrophically without warning, and are more fragile than their appearance may indicate. The holding of suitable numbers of spares and the care of those spares during storage and handling, has been an important part of the duties of transmitter operators since early days.

The valve designer had not only to ensure that the valve was rugged enough to carry out its electronic function, but also that it could be safely shipped to the site of the purchaser, who often was located half way round the world. In some cases, the transport involved handling many times by people who had no appreciation of the fragility of the item, and to this end, the manufacturer developed special transit cases, boxes or crates to minimise the risk of damage. Some high power water cooled valves of 50 kW transmitters in the early 1930s, were 1.2 metres in length. They were followed in the 1940s by very heavy air cooled finned types that required a special device to lift them into position in the transmitter socket, and in the 1960s there arrived the heavy ceramic and anode grooved vapour phase cooled types.

The development of shock absorbent cases and spring suspension systems in solidly built crates resulted in the manufacture of many unusual transit containers for transmitting valves. It is a credit to the designers that there have been so few breakages over the years. Large valves brought to Australia during the past 60 odd years have come from such countries as Great Britain, France, Germany, Switzerland, Holland and the USA.

Many station Engineers set procedures which were followed on receipt of new valves. Typical procedures included:

- Physical Inspection.
  A thorough inspection was carried out to look for damage to pins, terminals, leads, fins, and jackets, as well as scratches on the glass envelope and corrosion due to spilt acids or salt water during shipment.
- Gas Test.
  Normal anode voltage and a grid bias giving a prescribed value of anode current were applied, and the reverse grid current measured. As example, the 4220C water cooled valve used in transmitters from the later 1920s for at least 30 years, was operated with an anode current of 0.9 amperes and grid current of the order of 30/150 micro-amperes. Manufacturers supplied anode current and permissible grid current values for their particular valves.
  A gas test measured the quantity of electrons required to neutralise positive gas ions, created by current through the valve. Gas currents ranged from a few micro-amperes to about 1000 micro-amperes for large valves.
- Pirani Test.
  It was not always possible to test a valve in an operational transmitter due to a number of reasons, and at those stations the Pirani Test was often employed. The principle of the test depended on the cooling effect on the filament of any residual gas which may have been inside the envelope. A prescribed current, as recommended by the valve manufacturer was passed through the filament and the voltage across the filament measured by an accurate voltmeter. No voltage was applied to the other elements during the test. The measured voltage had to lie within prescribed limits for a good valve.
- Peak Emission Test.
  Various emission tests were carried out on valves which had been in operation but which were still within their guaranteed life period, if the operator had reason to suspect an emission problem. In a peak emission test, the saturated emission capability of the cathode was evaluated. A typical test method was to operate the valve as a diode with high voltage pulses applied across the valve, and the cathode current measured. The power output could be predicted from constant current curves supplied by the valve manufacturer.
  Where many large valves were held as spares at a multi-transmitter station, it was important to test the spares from time-to-time and to give them a simulated work-up to ensure they did not deteriorate during storage. The rotation of large numbers of spares in working sockets was not always practicable, and an alternative was to provide a valve conditioner on the station.
  One such station with a conditioner was 5CL/5AN Pimpala, initially with one 55 kW and two 10 kW transmitters, and later two 55 kW and two 10 kW units. The conditioner was commissioned soon after the transmitting complex became operational in 1961 and enabled regular tests to be undertaken on the major amplifying valves without the need to involve working transmitter sockets.
  The facility was designed for conditioning 3J/261E and 3J/192E types, the major valves employed in the STC transmitters. The 55 kW unit employed three 3J/261E valves in the RF power amplifier and two in the modulator, one 3J/192E valve in the RF driver circuit and two in the modulator driver. The 10 kW transmitter employed three 3J/192E valves in the RF power amplifier and two in the modulator.
  Due to procurement problems in subsequent years, the STC 3J/261E valves were replaced by Philips TBL 12/25 valves and the STC 3J/192E valves replaced by Philips TBL 7/8000 valves.
  In the operational mode, a 15 kVA 450/4500 volt oil filled Crompton Parkinson transformer provided up to 4.5 kV AC to the anode of the valve with negative bias being applied to the grid. A 3 phase motor driven fan removed heat produced by the valve.
  With some minor changes, the valve conditioner continued to be used for its intended purpose right up to the time when the STC valve transmitters were replaced by solid state types at the end of 1994. The unit was designed by Bill Gold an Engineer associated with the station establishment.

Bill Gold joined the PMG's Department in Adelaide in 1956 and worked on a number of major design and development projects associated with the establishment of a new Metropolitan Transmitting Centre for 5CL/5AN Pimpala, 8TC Tennant Creek. 8KN Katherine and the Radio Australia Cox Peninsula transmitting and receiving complex.

Prior to joining the PMG's Department, he had worked in the Radio Division of Standard Telephones and Cables Ltd in England and during the period with the company was granted British Patent Number 561977 for an invention for automatic tuning of high power medium wave and short wave transmitters. The specification was submitted in December 1942. Automatic tuning is now a basic feature of all high power short wave transmitters. The advantages of automatic tuning are so great that there is now no place for human intervention in transmitter tuning when changing frequency for a new transmission schedule.

RECEIVING VALVES

SUPPLY SOURCES

By the time broadcasting stations began transmission in Australia in 1923, broadcasting had been well-established overseas and in the United States in particular, there were 253 broadcasting stations on air in 1922 with millions of potential listeners clamouring for broadcast receivers. Manufacturers were hard-pressed to meet the demand for components and complete receivers. The Radio Corporation of America, the largest radio company in the USA sold 1.25 million receiving valves in 1922, 4.26 million in 1923 and in 1924, sales topped 11.25 million. Receiving valves were also being manufactured in Great Britain, The Netherlands, Germany, France and other countries, so the valve had reached a reasonable stage of development and availability to meet world broadcasting requirements. In Australia, there was heavy demand for overseas made valves until about 1938, when the customs tariff on Australian produced valves was reduced and the tariff on overseas made valves increased considerably.

* **THE UNITED STATES**

Although RCA was established in 1919, it had no manufacturing facilities until 1930 when the subsidiary company RCA Radiotron was formed. Up to that time, it operated as a distribution agent for valves made for it by the General Electric and Westinghouse companies.

The first valves marketed by RCA were the UV200 detector and the UV201 amplifier. They were sold from late 1920, and the carton containing the valve indicated that it was 'sold for amateur and experimental use only'. The 'U' signified that the valve was an apparatus unit and 'V' that it was a vacuum tube. The initial productions of these valves were structurally identical. Both had tipped, pear shaped bulbs. The UV200 was filled with about fifty microns of argon gas, while the UV201 had a vacuum as high as the pumps at the time could produce.

Filament requirements were 5 volts at 1 ampere. The bases were of sheet brass with a ceramic insert which provided insulation and also secured the contact pins. The voltage of 5 volts was chosen so the valve could be operated from a 6 volt car battery off-charge and allowing for drop in the leads and clips.

It is of interest that during the manufacture of one batch of UV201 valves, a worker accidentally used some filament wire which contained thoria. It was found that some of these thoriated filament valves operated satisfactorily at a filament voltage half that normally required. Internal investigations were initiated, and resulted in the development of thoriated filaments.

The first thoriated filament valves produced for receiving purposes were the UV199 and the UV201A. The UV199 was intended for dry battery power supplies of 3 volts. It became available to the public in 1923, but in 1925 it was replaced by the UX199 type. The UV201A with its thoriated filament and requiring only a quarter of the filament power of the UV201 was the most widely sold valve in the United States. It had a good operating life and had few problems. Hundreds held in Radio Museums and private collections in Australia bear witness to the popularity of the valve in Australia.

In 1924, tipless construction of the valve was introduced and the phosphorus getter was replaced by the magnesium getter. The phosphorus getter resulted in the valve having many colours deposited on the glass.

In 1927, the Arcturus Radio Company marketed valves with transparent blue glass for about six years, and today these valves attract more than their fair share from collectors because of the coloured glass envelopes. Even when supplies of blue glass ran out, the company was so keen to maintain what was virtually a trademark, that they painted clear glass with blue lacquer.

A great deal of research went into manufacturing techniques in the United States and the basic methods changed very little over subsequent years. The central portion called the press was made from tubular glass.

The element lead wires and exhaust tube were placed in position and the upper portion heated and flattened to form the press. The exhaust tube was blown open so as to form a channel through which the envelope was later exhausted. The lead wires which passed through the glass were made of material which had an expansion coefficient very close to that of glass to ensure that the glass did not crack when current passing through the wires heated them.

All the components comprising the various elements, were made separately and assembled using jigs specially developed to ensure proper adjustment and spacing of the elements. The parts were spot welded in position to form the unit structure. The whole central assembly called the mount, was closely inspected to ensure proper alignment of all parts before the glass envelope was placed over the mount. The envelope was then heated and sealed on to the flared out section on the lower end of the stem.

The valve was connected to an exhaust pump and during exhaustion of the glass, the elements were heated to a high temperature by radio frequency currents induced by a surrounding coil. This drove out gas from metal parts. The operation also heated the getter material which vapourised and combined with any remaining gas to form a deposit on the relatively cool interior of the envelope. A number of getter materials were tried with early valves but magnesium was found to be the most effective. It left a silvery mirror-like deposit on the glass.

The valve was then sealed off to make it air tight, the base was fitted and the valve given suitable treatment to render the filament active. It was then subjected to a series of electrical tests and measurements and if results were within specification, it was packed in an appropriate carton for shipment.

Various types of bases were fitted to meet the demands of receiver designers. The UV base with short pins or stubs was followed in 1925 by the UX base with longer pins.

One of the early special types of USA valves was the UV200 which was a soft or gas detector as compared with the high vacuum of most other types. It operated on the extreme sensitivity produced by the gas at certain critical anode potentials.

The 201A valve was the most widely manufactured and distributed valve in the history of valve technology. Variants were produced over the years with such improvements as, tipless construction of the glass bulb, replacement of the brass/porcelain base with moulded bakelite base, magnesium getter replacing phosphorus getter, replacement of short pins with bayonet lug with longer pins with the filament pins being thicker than the grid and anode pins, changes in element materials and internal construction to improve performance and reliability.

Many hundreds of manufacturers throughout the world produced 201A valves, with some employing their own numbering schemes such as Cunningham types which were designated C300 and C301 released about the same time as RCA types. There were also badge engineered models with stampings, paper labels and cartons to specification, for sale by independent distributors. Valve historians estimate that there were hundreds of identifiable types available during 10 years from 1920 when it was first introduced for sale to the public.

Bill Rohde one of the original PMG's Department staff who took over the A Class station 4QG Brisbane when the Government acquired all A Class stations to establish the National Broadcasting Service had one of the best collections of 201A valves or their equivalents. Bill was friendly with several local Radio Servicemen who put aside 201A valves for Bill when they were removed from receivers brought into the shops for service. The collection was started about 1923 and by 1930 his collection included 36 different brands, 12 unnamed types but marked in a manner which indicated they were made by different manufacturers, and 19 different packaging cartons.

Bill was a member of the Wooloowin Radio Club for many of the seven years of its existence and showed the collection at one of the Club meetings. It was on display in the foyer of the 4QG studio in July 1932 when the station celebrated its 7th Anniversary. An office news sheet issued at the time indicated that the display included valves branded Radiotron, AWA, Supertron, Cleartron, Royaltron, Bluetron, Philips, Cunningham, de Forest, ERLA, Ce-Co, Stewart Warner, Star, Western Electric, QRS, Superairline, Ureco, Magnavox, Perryman, Marathon, Sonatron, Panama and others.

* **GREAT BRITAIN**

In Great Britain there were six major and several smaller valve manufacturers in 1922. By 1924, total production reached 2.5 million valves and the major manufacturers formed the Valve Manufacturers Association. This later became the British Radio Valve Manufacturers Association (BVA) whose purpose was 'to promote, encourage, develop and protect the interests of the public, the trade and the manufacturers of British made valves'.

Early valves produced which found their way to the Australian market included the AR series produced by Ediswan in 1922, the DE11 produced by Metropolitan Vickers Electrical in 1924, the P series manufactured by Cossor in 1922 and the ORA valve produced by Mullard.

The Marconi-Osram Valve Co., founded in 1919, was responsible for the development and production of many receiving valve types. These included standard R type with several variations, the V24 and Q types which were low capacity types with the electrode connections brought out to widely spread contact points mounted directly on the bulb surface. These valves were used with equipment in the first demonstration of broadcasting in Australia in 1919.

The MOV Company was the first British manufacturer to develop dull emitter valves. These carried the designations DE in the series. Captain H F Round of the Marconi Company was instrumental in the development of many valves including the screen grid S625 type which overcame the major problem in RF amplification with triodes. It was of unusual shape compared with most other valves. It was released in October 1927, and in 1928 the first factory built receivers incorporation screen grid valves were marketed. A book was published on the valve and its development.

Although the screen grid valve had a major impact on receiver design and performance, it did not enjoy a long life. Within seven years, it was replaced by another type — the RF pentode, also referred to as 'Penthode' in Philips publications.

The performance of American and British valves was much the same, but there was an important difference in construction of screen grid types throughout their production life. In America, the grid connection was taken to a top cap, whereas in both Britain and the Continent, an insulated screw terminal on the topof the bulb was used for anode connection.

* **EUROPEAN CONTINENT**

On the European Continent, manufacturers in The Netherlands, France and Germany were active in both the development and production of receiving valves. Philips in The Netherlands was one of the largest European manufacturers of electric lamps and produced their first valve in 1918. This was followed by the C type in 1920, the D types in 1921–22 and the first B type miniwatt triodes and tetrodes in 1924. The A series with filament voltages ranging from 1.1 to 6 volts were produced in the period 1924–28. The first miniwatt series used an early form of oxide coated filament and were the forerunners of a large range of battery powered valves. The company produced broadcast receivers which trialed these valves before being released to the public. Philips staff invented the pentode output valve in 1928 and produced many other innovative types including indirectly heated AC types in 1929, metallised coatings in 1933 with a gold coloured finish, the side contact base in 1934, metal valves in 1939, 8 pin loctal base and 1.4 volt battery valves in 1947.

Probably the best known valve to come out of the French valve business was the French Métal type. This French valve was manufactured by two companies under the brand names of Fotos and Métal and was known as type TM (Telegraphic Militaire). It was characterised by a horizontally mounted electrode assembly and four pin base which later became the post War European standard. The design was so successful that it formed the basis of many post War designs in Britain, The Netherlands and the USA. It was first manufactured in Britain in 1916 for military application and was known as the R type. Many of the valves were imported into Australia after the War and were used with Amateur equipment and early homemade broadcast receivers. It was still being sold in Radio Shops in 1927. Subsequent development of other designs using the R valve design features included Philips Z1, Mullard type K and Mullard ORA valves.

The German radio industry was one of the first to produce multiple valves inside the one envelope. The firm Loewe Radio AG produced the Loewe 3-in-1 in 1926 which was unique in that it contained, within the bulb, not only three separate electrode assemblies, but also all the necessary resistors and capacitors for a three stage broadcast receiver. Each resistor and capacitor was separately encapsulated in glass and it was an object lesson in economy of components to enable the single valve to be mounted in its six pin base. Many receivers using the 3NF valve were brought to Australia by German migrants and some have been preserved in Museums and private collections of vintage radio.

The valve was developed to minimise tax on receivers. In Germany, there was a tax on receivers with the tax rate being governed by the number of valves in the receiver.

Bill Gold an Engineer with the NBS in a magazine article referred to the valve as 'the world's first integrated circuit'.

Another valve produced in Germany and employed in Australian built receivers was the Te-Ka-De VT series. One of its earliest applications was in a one valve receiver manufactured by Oliver J Nilsen of Melbourne in 1927. The receiver was capable of loudspeaker operation when tuned to local stations. The set was low priced and sold well through the company outlets in Melbourne and Adelaide.

The valve was made by Süddeutsche Telefon-Apparate, Kabel und Drahtwerke AG of Nurnberg who had began producing valves for telephone carrier purposes in 1918. From 1920, they used the trademark Te-Ka-De with production continuing until

1956 except for a period during the Second World War when the factory was bombed and badly damaged.

Valves produced during the early 1920s included the Te-Ka-De VT16 with a tungsten filament requiring 3.5 volts at 0.52 amperes and anode voltage 20–60 volts, the Te-Ka-De VT105 with oxide coated filament requiring a filament voltage of 1 volt nominal at 0.15 amperes and anode voltage 20–90 volts and the Te-Ka-De VT107 with an oxide coated filament requiring a filament voltage of 1.65 volts nominal at 0.15 amperes and anode voltage of 20–100 volts.

Roy Cook a well-known Adelaide experimenter constructed three receivers each employing two Te-Ka-De valves for use by inmates of the Bedford Park Sanatorium about 1926 so that they could listen to 5CL and 5DN. The receivers were appreciated by the inmates and were in operation for many years. One was in the collection of an Adelaide enthusiast and exhibited at the Adelaide GPO during 19–23 November 1973 to commemorate the Golden Jubilee of Broadcasting in Australia.

* AUSTRALIA

- Amalgamated Wireless (A/Asia) Ltd.

The first receiving valves to be manufactured in Australia for commercial sale were produced during early 1921. They were manufactured by Amalgamated Wireless (A/Asia) Ltd and designated 'Expanse' valves. Expanse was the telegraphic and cable code of AWA and for several years, the word was a Trademark on apparatus they manufactured.

The company had began developmental work into the manufacture of a receiving valve shortly after the end of the First World War.

The first valve to carry the Expanse label was a double ended, double filament design manufactured in USA, and labelled in Australia by AWA. The valve had no end caps and was mounted in a cradle specially designed for the purpose. They were supplied to the Navy and also fitted in receiving equipment at Coast Radio Stations.

The first design produced locally was covered by an Australian Patent and was branded 'Expanse B'. It differed from imported designs mainly in the use of ebonite or hard rubber caps at each end, in order to protect the glass lead-in point of the envelope. Imported models used pitch to protect the glass.

A leaflet included in the carton with the Expanse B valve provided the following information:

'The Expanse B tube is not a luxury, but an inexpensive necessity. An electron discharge tube wonderfully made. Honestly guaranteed. Extremely sensitive as a detector, amplifier and oscillator. Two filaments. Operating life 2000 hours.'

It was claimed to be structurally superior to previous tubular types with the anode being well-fixed to one end by the lead-in wire and at the other by an indentation in the side of the valve. The grid and two filaments were mounted in a specially designed former which was moored at each end of the valve by two platinum wires embedded in glass. This held firmly, and prevented displacement by vibration which could result in microphonic noise.

Filament power requirements was 6 volts at 0.75 amperes. As there were two filaments, service life could be extended by switching to the second filament should the first fail. Anode requirement was 20 to 35 volts, with the exact value being determined by its use as detector, oscillator or amplifier.

The valve was a 'soft' type, i.e. it contained a small amount of gas as vacuum pump technology at the time was not capable of producing a better vacuum. Operators found that after the first filament had burned out, the performance of the valve improved due to the better vacuum. AWA Ship's Operators who had receivers fitted with 'soft' valves found it difficult to maintain the adjustment of the receiver. They had to continually readjust the receiver to compensate for changes due to movement of the operator's body, movement of nearby objects such as rotating cabin fans and whenever another person entered the radio cabin. George Apperley one of AWA's key marine experts who subsequently became AWA Manager of Communications, commented in later years, that 'the "hard" valve was probably one of the greatest gifts science has bestowed on civilisation'.

Engineer-in-Charge of the development and manufacture of the Expanse valve project was David Wyles.

David was educated in South Australia and served an Engineering Apprenticeship with Forward Down and Co., Ltd, Adelaide, a heavy engineering firm which had been established in 1873 by Walter Foreward and T D Down. The company manufactured mining and agricultural machinery and steelwork for bridges, some of which are still in service.

While visiting the Adelaide Exhibition Building in April 1910, David witnessed a demonstration of the operation of wireless telegraphy by Mr A W J McArdle, a well-known wireless experimenter. He showed a lot of interest in the equipment and at the suggestion of Mr McArdle assisted in setting up equipment three months later when a field trial was conducted using a powerful spark coil, six Leyden jars and chemical batteries. The receiver included galena obtained from a silver-lead mine at Glen Osmond which had been opened up about 50 years earlier.

Later, David was introduced to Lance Jones, another wireless experimenter. He was with Lance when the first signals were received in South Australia when the Sydney Coast Radio Station went to air in April 1912. About this time, news was received about the sinking of the 'Titanic' and there was a lot of discussion amongst local wireless enthusiasts of the role of wireless and Wireless Operators concerning the safety of ship's passengers at sea. David was caught up in this enthusiasm, and decided to change his career from heavy engineering to wireless.

When the Marconi School of Wireless opened in Sydney in 1913, he left Adelaide and enrolled in the School to be trained as a Ship's Wireless Operator and joined AWA as a member of its Marine staff.

After a long period at sea, which included visits to ports in the USA where he took an interest in the latest developments of wireless technology, particularly the new valves being introduced into ship's wireless equipment, he applied for a land based job with the company.

About 1919, he was offered a position to take charge of a project to develop a receiving valve for AWA designed ship's wireless receiving equipment.

A workshop was set up in the company building at 97 Clarence Street, Sydney and fitted out with glass blowing and vacuum pump facilities. In addition to David, the project group included Wallace McSkimming, a Chemist, and two expert female glass workers. It was many months before the first valves were released for use with ship's receivers. Because of the limited facilities, production was limited to about six valves per day.

During 1922–23, David visited Great Britain and the Continent to investigate Radio Engineering developments, particularly valve technology. He spent some time at the M-O Valve Company and bought back some samples of latest products.

In 1925, he left AWA to take an appointment as Chief Engineer with 2BL, and in 1929 transferred to Philips Lamps (A/Asia) Ltd as Technical Manager.

One of his major contributions to valve technology was the development of an insulating cap for which AWA was granted a Patent in 1921. The arrangement was adopted by valve manufacturers in a number of overseas countries.

From the initial staff of four at Clarence Street workshop, the number of workers employed on valve production rose to six and they were producing over 3000 valves a year. New premises were acquired in Knox Street but in mid 1923, the assembly line was temporarily closed down to allow installation of more modern manufacturing facilities. The new plant enabled the production of 'hard' valves, the first of which was the AWA type 99 (RCA type 199) which came off the production line in

February 1924. Production of the Expanse B which by that time had become outdated, was discontinued.

AWA had formed an agreement with RCA of the USA enabling AWA to manufacture selected RCA valve types in Australia.

Tooling and assembly jigs were developed for other designs and by 1927 types AWA33, AWA99X, AWA109X, AWA55, AWA101A and AWA101X were also being produced giving an output totalling some 60000 valves a year. These were being used in AWA manufactured receivers as well as being sold to other receiver manufacturers and the general public.

However, at this point, the assembly line was closed down pending the development of plans to set up a separate company equipped with the most modern valve making technology.

In 1931, AWA made an agreement with RCA, General Electric and Westinghouse of the USA to manufacture valves using the Radiotron label.

Ernest Fisk, the Managing Director was determined to establish a first-class valve manufacturing facility employing the latest machinery available. In late 1931, he arranged for Stan Grime, Assistant Manager to head a small party including William Baker and Gordon Bailey to visit the USA to study the latest practices and to select suitable manufacturing plant.

The company formed in April 1932 to manufacture valves was Amalgamated Wireless Valve Company Pty Ltd. The first valves which flowed from the assembly line were despatched in August 1933. Initially, output comprised American type valves but an increasing percentage of Australian designed valves were introduced to meet local demand of receiver manufacturers and the radio service industry. The factory at Ashfield had an area of about 1500 square metres.

To supply the large quantities of intricate wire parts, punchings and mica spacers, automatic machinery was employed to produce complete parts from separate pieces. Special machinery produced the wide range of grids which varied from being rectangular, circular or elliptical in cross section and in some cases of variable pitch.

Special gauges were developed to check grid dimensions to ensure uniform valve characteristics.

In the mounting or assembly operations, joints between metal parts were spot welded, with jigs being used to ensure rapid yet accurate assembly.

The sealing and exhaust process was carried out by using machines which were improvements on those used in earlier years. Known as Sealex, it was a combination of two separate machines. These were a bulb sealing machine and an exhaust machine. The exhaust pumps consisted of mercury condensation pumps backed by mechanical oil pumps in sufficient quantities to allow production of 400 to 600 valves per hour.

The principal functions of the Sealex machines included degassing of the envelope, burning-on of the monogram, sealing of the envelope stem, sealing-in of the top grid lead, degassing of electrodes by induction heating, reduction of carbonates of oxides in the cathode or filament, partial activation of the cathode, flashing of the getter and sealing-off.

The valves were then aged, and following that process, were subjected to a number of tests including shorts tests, two characteristics tests spaced a week apart with a percentage of each day's production being put through special laboratory tests including measurement of amplification factor, anode resistance and inter-electrode capacitance.

During 1934, some 350000 valves were produced in the factory including three new types that had been added to the list of local manufacture.

By 1937, production reached 750000 with octal base valves being a major development at the time.

Included among the Australian designed valves was a range of 2 volt battery types specially designed for local conditions. They were high efficiency types operating with low B battery drain and were an immediate success with production output of these types representing a high proportion of the total output.

In 1938, AWV prepared to introduce the manufacture of transmitting valves and sent engineering staff overseas to investigate the latest technology. On their return, a section was established to design and manufacture a range of valves. Jack Anderson was one of the key members of transmitter valve production.

Just before the outbreak of the Second World War, about 300 people were employed at AWV producing about 30 types of valves to meet the demand for manufacturing and servicing requirements. About one million valves were being manufactured and distributed.

During the War years when the factory geared up to meet the heavy demand of the Services, production output increased considerably.

By 1941, receiving valve output had increased 50% over pre-War figures. During that year 350000 transmitting valves comprising 17 types were produced for Service equipment and maintenance purposes.

During 1942, over two million valves including special types for radar application were produced and the work force had increased to 800. At that time more floor space was required and a new three storey building was erected on the Ashfield site.

The first Australian made miniature valves were released to the public in 1946 to meet the demand for post War receivers. These were followed by 6.3 volt AC miniatures in 1948, and 9 pin noval types in 1952.

In 1947, Colin Stockbridge one of AWA's trainees, graduated and was assigned to the Quality Control Department for receiving valves. A major problem in the Department at the time was associated with production of 1C7 and 1D8 type valves.

During Colin's time at AWV, magnetrons, klystrons and crystals were also produced for radar application. About a year before he left AWV to join EMI Research Laboratories in England he worked on the testing of 10 cm magnetrons. The Engineering Manager of these functions was Ron Aitchison who subsequently left AWV to become Professor Electrical Engineering Department, University of Sydney. Ron was Chairman of the First Session at the National Radio and Electronics Engineering Convention organised by The Institution of Radio and Electronics Engineers Australia in Sydney in 1967. Ron later served a period as President of The Institution 1969–70.

In 1956, a new factory of about 9300 square metres was erected at Rydalmere where output included TV picture tubes in 1957. Extension of the factory was undertaken in 1958 to cater for the production of transistors. It was the first factory in Australia to process and assemble transistors.

By 1960, employee members had exceeded 1100 with the factory output including receiving valves, transmitting valves, transistors, silicon diodes and picture tubes for TV.

At that stage AWV Manager was Dick Lambie who had joined AWV in January 1933. Prior to joining AWV, he had been educated at Dartford Technical College, England and served an apprenticeship as Toolmaker with Vickers Ltd. After coming to Australia, he worked at The Gramophone Co., Ltd, Sydney for six years before moving to AWV where he held the position of Production Engineer before being appointed Manager in 1951.

Factory Works Manager at the same time was Doug Sutherland who joined AWA Research Laboratories in 1935. Prior to that, he was engaged in research work in physics in Melbourne 1932–33 before transferring to the staff of Geelong Grammar School in 1934. In November 1937, he was appointed Engineer in the AWV Transmitting Valve Department and visited the USA to study developments in valve design and manufacturing techniques. He was subsequently appointed Works Manager of the Factory being responsible for both transmitter and receiver valve design and quality control.

Another AWA Engineer who made a major contribution to the design and application of radio valves was Fritz Langford-Smith, for many years Chief Applications Engineer.

Fritz developed an interest in radio while attending Trinity Grammar School constructing crystal sets and valve receivers for fellow students.

Shortly after graduation from University of Sydney with First Class Honours Degrees in Science and Engineering he went to the United Kingdom where he worked with Metropolitan Vickers and Co., England from 1928 to 1929 and then became factory and development Engineer for radio valves with Cosmos Lamps Works England until 1932.

Metropolitan Vickers and Cosmos had been originally involved in the manufacture of lamps. Metropolitan Vickers began producing the well-known R type valve in 1916 and after the War continued the development and manufacture of valves and added a range of receivers to its products. Both these items were marketed under the brand names Cosmos. By 1928–29, Cosmos designed and produced valves were amongst the most popular sought by receiver constructors of the period.

In 1932, Fritz left England and joined Amalgamated Wireless Valve Company Pty Ltd as Engineer-in-Charge. The company had only just commenced operation.

During 1934/35 he undertook an extended visit to the USA and Canada to study the latest technology in the development and manufacture of transmitting valves.

From 1935 until 1941, he was in charge of Sales-Engineering Service which later led to his appointment as Chief Applications Engineer.

At the same time, he was Editor of 'Radiotronics', a publication issued by AWV to publicise its customer support activities, as well as a range of miscellaneous data sheets, booklets, charts and bulletins.

He was also responsible for compilation of the 'Radiotron Designers Handbook', the Third Edition published in 1940 comprised a book of 350 pages. This was followed in mid 1952 by a very much larger book. By 1955, it was being published as the Fourth Impression of the Fourth Edition comprising some 1500 pages and 39 Chapters.

During the War years, he acted as Sales Manager during the absence on War service of Sales Manager Aub Hoskins. He was also a member of the Valve Production Advisory Panel of the Ministry of Munitions from 1943.

He was an active member of the Institution of Radio Engineers (Australia) and during 1938–39, was a Councillor of the Institution. During the World Radio Convention held in Sydney during 1938, he contributed a paper, 'The Relationship Between the Power Output Stage and Loudspeaker'.

In the 1950s, Fritz left AWV and took up a position with the English Electric Co., in UK as Technical Information Manager. However, due to health problems he left the company and returned to Australia in 1962.

The introduction of television in Australia increased the demand for receiving type valves in spite of the growing use of solid state diodes, then transistors and later integrated circuits. However, the advantages of solid state technology eventually resulted in the demise of the valve, and the production of receiving valves was phased out during the late 1970s.

However, there was still a high demand for transmitting valves and new type were being continually introduced. New AWV types introduced during the mid 1970s included high power ceramic-metal types 4CX10000D and 4CX5000A.

In the 1970s, the Transistor Section included a large work force of Engineers, Technicians and assembly staff. Included among the production staff were Dorothy Norquay, Valerie Visner, Dulcie Lonergan, Beryl Evans, Christine Graham, Margaret Wykes, Hazel Lambie, Joan Forwood and Kevin Ward.

- Philips.

After many years of planning, valve manufacture began in March 1937 at 100 Mallet Street, Camperdown, Sydney, by Philips Radio Works (Aust.) Pty Ltd.

One of the key people in the Philips valve manufacturing operations was Karel van Gessel who had some 18 years experience at Philips, Holland. He made a number of visits to the USA to study the latest developments in valve manufacture in that country, and used many of the ideas in setting up the facilities in the Camperdown factory.

Valve types produced were mainly American designs with a few Philips side connected base designs also being produced.

Even though valves were being produced by AWA and Philips in 1939 just before the outbreak of the Second World War, the total output fell far short of Australian needs for new receivers and for maintenance purposes. During 1939, over 640000 valves were imported from various countries including UK, USA, Austria, Germany, Canada, Japan and Holland. New South Wales received the greatest number, with a total import of over 545000 valves.

During the War years, Philips produced large quantities of receiving valves for the needs of the Services.

In 1946, the facilities were transferred to Hendon, Adelaide and by 1948, more than 70 types were being produced. By the 1950s, a range of 1.4 volt miniature type valves was added to the factory output.

Although valves were produced for PMG's Department carrier equipment, this was not enough to compensate for the falling demand of domestic receiver valves and the production of valves was phased out during the late 1970s.

- Standard Telephones and Cables Pty Ltd.

In 1938, the company decided to establish a manufacturing facility in Sydney for production of receiver type valves for line carrier and repeater equipment carrying telephone, telegraph and broadcast program traffic over PMG's Department cable and open wire routes and also for production of high power valves for STC range of transmitters.

Although such a facility involved the introduction of a range of advanced technologies including vacuum techniques, glass working and the metallurgy of rare metals, the plant was in operation and the first valves manufactured by early 1939.

The first receiving type valves produced were referred to as '1 ampere' and '¼ ampere' valves, taking their names from the filament ratings.

Later, repeater type pentodes made included 310, 328, 311 and 329 with oxide coated cathodes. Types 310/328 and 311/329 were identical except for cathode heater ratings.

Early in the War period, STC was approached by the Government to make valves for radar equipment. The first was the 200 MHz pulse triode type VT90. It employed thoriated tungsten filament with the anode being air blast cooled.

Subsequently, the multiple cavity magnetron type E1189, the strapped multiple cavity magnetron type CV56 and type CV35 a velocity modulated reflex klystron used in 10 cm radar were made at the factory.

After the War, the UHF disc sealed triode type 2C39A was produced. It was technologically advanced, requiring many new techniques in manufacture.

Production of valves continued until 1962.

Ken Brown was in charge when the factory began operation. Ken had extensive experience with General Electric Company and Standard Telephones and Cables in England before leaving in 1938 to take up a position with STC in Australia working on design and manufacture of telecommunications equipment and valves. In 1962, he was appointed Technical Director of STC occupying the position until 1977. In 1976, he became a member of the Board of Directors.

Ken became a Member of the Institution of Radio Engineers (Australia) in 1948 and a Fellow in 1957. He served as President 1957–58.

In 1942, Tom Basnett joined the valve manufacturing factory after transferring over from CSIR Radio Physics Laboratory. In 1956 he became a Member of the Institution of Radio Engineers (Australia). Tom remained with STC until 1964.

- G AND R COMPANY

  It is of interest, that design work on receiving valves was also undertaken in Australia prior to 1923 by A J Garrod and S Radcliff. Garrod during the First World War had worked in the Cavendish Laboratory at Cambridge under Professor J J Thompson producing detector and amplifier valves for the Defence Forces.

  Following his return to Australia after the War, he teamed up with Radcliffe an Industrial Research Chemist who had specialised in high vacua work with X-Ray tubes.

  A laboratory and manufacturing facility was established at a site just outside Sydney and the company negotiated with distributors in England and New Zealand to market the valve.

  The pair produced the GR valve after developing a range of novel apparatus for manufacturing purposes. The valve was a dual-purpose type being employed as detector with anode potential of 20 volts and as amplifier with 30 volts on the anode. It was 25 mm in diameter and 88 mm in length and fitted with four contact pins in the base. Unfortunately, production did not reach significant quantities for wide application.

  The Universal Electric Company exhibited a sample of the valve manufactured by the G & R Company on its stand at the Sydney Royal Easter Show in 1923 and it drew a lot of attention from an interested public.

THE TWIN GRID VALVE

A major disadvantage with early equipment employing a triode valve in a typical circuit was the need to provide a source of high voltage for the anode. This required an expensive, heavy and bulky B battery and during the First World War when wireless was being developed for use by the military, researchers set in train programs to develop a valve which could function without the need for the high voltage B battery, particularly for use with portable field units.

Scientists of the German company Siemens, Halske Co., came up with a solution of providing an additional grid positioned between the filament and the control grid. The valve performed satisfactorily with an anode voltage as low as 10 volts.

The twin grid valve, also called 'space-charge-grid-valve', was a tetrode in which the inner grid — the one nearest the filament — was held at a slightly positive potential with respect to the filament, with the outer grid serving as the control element. Under operational conditions, the positive potential on the inner grid had the effect of neutralising the space charge immediately surrounding the filament. This allowed a large cloud of electrons to collect near the outer or control grid forming a virtual cathode making possible a higher mutual conductance than in a conventional triode. However, the characteristic curves were not as straight as those of the conventional triode, and also, the current drawn by the twin grid valve was much greater.

After the War, when manufacturers began to produce for a growing civilian market, the Dutch firm Philips produced one of the early twin grid valves, designated Q type in 1923. The following year it was redesignated the type DV1 without altering the electrical or physical characteristics. About 1925, Lance Jones Manager of the Adelaide Radio Company in Rundle Street, Adelaide imported a quantity at the request of some local experimenters. Well-known experimenters who purchased the valve included Harry Kauper, later Chief Engineer 5CL, Fred Williamson later on the staff of 5AD, Bill Bland who established Bland Radio, and Roy Cook one of the first Adelaide experimenters to carry out a 'live' music broadcast. Roy built a receiver employing a Solodyne circuit.

The DV1 with a tungsten filament operated with a filament voltage of 3.5 volts and current of 0.5 amperes and operated satisfactorily as an amplifier, with an anode and space grid voltage of 10 volts and as a detector, with only 4 volts on each element. It had a pear shape bulb about 45 mm in diameter with short base pins with the space charge grid connected to a side screw terminal.

Roy Cook demonstrated the valve in a receiver at a meeting of the YMCA Radio Club where he was the Club's Instructor to a group of enthusiastic boys. Many years later, Roy donated the valve to the Adelaide Telecommunication Museum collection, together with a French Bigrille double grid valve.

About 1926, Philips produced a series of twin grid valves designed for operation with a range of filament voltages from 1 to 4 volts. One of the 1 volt version designated A141 was acquired by Bill Walker later on the staff of the PMG's Department National Broadcasting Service and the ABC. Like the DV1, the A141 was fitted with a side terminal to which the grid was connected.

Another brand of twin grid valve available in Australia was marketed under the Condor label. Philips had acquired the brand name and construction of Condor brands were identical with those produced in the Philips factory in Holland. Harris Scarfe Ltd, Adelaide were one of the Australian distributors of Condor valves and a PR16 type was purchased about 1927 by Cliff Moule later employed in the National Broadcasting Service. The valve was similar in appearance to the Philips DV1 and Cliff operated it with 4.5 volts on anode and space charge grid as a detector or 9 volts as an amplifier.

The DE7 manufactured by the MO Valve Co., Ltd, England was also readily available in Australia. Hugh Duncan of Duncan and Fraser, Franklin Street, Adelaide employed the DE7 in one of the range of valve receivers the company manufactured under the Dunfra label. One of the receivers was exhibited at the Radio Trade Exhibition in the Adelaide Town Hall in mid 1926. The valve was a dull emitter type using a filament supply of 1.8 volts at 0.4 amperes. Recommended anode voltage and inner grid voltages were 6–15 volts. The Dunfra receiver employed 6 volts for the detector stage and 10 volts for the following amplifier stage.

Twin grid valves were still being manufactured in the early 1930s for use as frequency changers in superheterodyne circuits until superseded by the heptode frequency changer valve.

A number of circuits were designed to make best use of the twin grid valve and included such names as Unidyne and Solodyne, both of which received considerable coverage in American magazines in the 1920s.

Bill Rohde, in Brisbane, constructed a receiver using the Solodyne circuit as described in the magazine 'Radio News' and demonstrated it at a meeting of the Wooloowin Radio Club about 1930. At the time, Bill had just commenced work at 4QG Brisbane which had been taken over by the Postmaster General's Department as part of the Government's plan to establish the National Broadcasting Service. The valve employed by Bill was a Mullard PM1DG which he purchased from Thomas Radio Co., in Adelaide Street, Brisbane. Parts in the receiver included a variocoupler and Philips audio transformer which were obtained from Edgar V Hudson Pty Ltd, a firm founded in the mid 1920s by Messrs Edgar Hudson and Fred Hoe.

The twin grid valve had the same shortcomings as a single grid valve in that it was a poor amplifier of high frequency signals even with neutralisation. The insertion of a grid termed screen grid between control grid and anode produced a valve designated as the 'screen grid tetrode' which gave good performance at the high frequencies.

The screen grid acted as an electrostatic shield between the anode and the other inner electrodes, and in this way, reduced the capacitance between anode and other elements by a factor of the order of 1000 compared with the triode. This prevented uncontrollable and undesirable coupling between the output and input circuits connected to the valve.

However, both screen grid and anode required high voltages for operation but with the introduction of mains powered receivers, there was no need to employ batteries.

AC HEATER VALVES

One of the major problems associated with early domestic receivers was the high cost of batteries for operation of the valves. Three different types of batteries were required and it soon became evident to designers that the use of the home electricity supply instead of batteries would be a boon to receiver owners. However, it took a lot of research and development effort before this was fully achieved. The change-over took place in two steps. The high tension or B battery was replaced by a device marketed as 'B Eliminator' or 'Battery Eliminator'. These units were basically a transformer and valve rectifier supplied initially as a separate unit, but later, built into the receiver.

The replacement of the A or filament battery took some time to solve. While valves designed to use AC on the filament were manufactured in the mid 1920s, they were far from satisfactory. Hum levels in the receiver were extremely high, even though loudspeaker response tended to attenuate the low frequency hum frequencies. The problem was caused by the electrostatic field produced across the filament wire, the electromagnetic field set up by the current passing through the filament and to temperature variations in the filament wire due to the rising and falling characteristic of the AC current. The result was the modulation of the receiver output signal by a frequency twice that of the frequency of the supply voltage.

Designers tackled the problem by producing indirectly heated valves. However, those early designs imported into Australia and sold at Radio Shops were not popular. They had a very long warm up time, and failure rate was high, due mainly to thermochemical action with the oxide coated ceramic tubes used, and deterioration of insulation between other electrodes.

About 1926, English designers eliminated the ceramic components and used instead, a helically coiled hairpin heater which was supported on an axial silica insulated rod, within an enclosing thimble shaped cathode tube. Unfortunately, a high heater voltage was required for successful performance. Further development led to the production of the KL1 valve which required only 3.5 volts and brought the cathode to emitting temperature in about 15 seconds.

In another British design, the heater was first coated with a thick paint material made up from an insulating substance mixed with a vehicle. The layer was baked on the heater and the insulated assembly inserted in the cathode tube. The process was referred to as 'slip coating' to distinguish it from the process involving enclosure in preformed insulating components. The structure so formed required only 1 ampere at 4 volts and gave long operational life. This design was adopted as standard rating for Cosmos AC valves, many of which soon appeared in Australian Radio Shops in the early 1930s, and in receivers imported from England.

Unfortunately, the manufacturers made no attempt to standardise base connections. With the K type, a Marconi-Osram product, the base was a standard four pin type with the heater connection being taken to the normal filament pins and the extra lead required for the cathode being taken to a terminal protruding from the side of the base. In the Cosmos design, a special base was provided in which one of the standard filament pins served for the cathode and the other replaced by a pair of short pins for the heater supply. These, of course, required special sockets. To encourage owners of battery receivers to convert to mains operation using Cosmos valves, the company produced a cheap adaptor.

One of the early AC valves produced in quantity in the USA, was the 5 pin RCA UY227. It employed a hairpin shaped heater insulated from a cathode by a twin bore ceramic tube. The oxide coated cathode was indirectly heated by the filament and although refinements took place, the principle became the standard construction arrangement for receiving valves until replaced by the slip coated heater about 1933.

By the early 1930s, most valve manufacturers throughout the world had adapted the AC cathode construction with some variations and the technology remained almost unchallenged right up to the time when receiving valves were replaced by transistor technology.

Early AC heater valves used a voltage of 2.5 or 4 volts but with the rapid expansion of radio receivers into the automobile industry, there existed a requirement to produce valves for operation with a filament voltage standardised at 6.3 volts.

Typical accumulators provided with automobiles were 3 cell or 6 cell formats. The EMF of a charged accumulator cell was about 2.1 volts although after completion of a full charge cycle it would rise above this value. For a three cell accumulator, the terminal voltage was 6.3 and for a six cell accumulator it was 12.6 volts. For the six cell accumulator two 6.3 volt valves were connected in series.

Valves designed with 6.3 volt filaments became available about 1931 and by 1932 were being widely employed in mains powered domestic receivers. Some rectifiers however, operated with 5 volts on the filament but there were exceptions including 7Y4 and 6X4 types which operated with 6.3 volts.

The 5 volt level was a carryover from early amplifier valves particularly the UV201 and was the standard voltage for battery powered triodes developed during the 1920s. It was determined on the basis of valve operation employing a 6 volt car type accumulator and allowing for reduced terminal voltage during the battery discharge process.

VALVE TYPES

The types of valves employed in broadcast receivers may be grouped into a number of types including diodes, triodes, tetrodes, pentodes, pentode power amplifiers, combined types and pentagrid converters.

Diodes were used as signal detectors and as power rectifiers for converting AC current to DC. It was the simplest radio valve consisting of two electrodes, the cathode and anode.

The triode, a three element valve comprising cathode, grid and anode was the foundation of all early broadcast receivers and experience gained with this type was the basis for subsequent development of many other types. Its major drawback was as a radio frequency amplifier due to feedback problems but circuit designs such as the neutrodyne did much to reduce the problem.

The tetrode had four electrodes with a screen grid being introduced between the grid and the anode. The function of the screen was to act as an electrostatic shield between grid and anode so reducing the grid to anode capacitance. This enabled stable operation as an RF amplifier.

The pentode had a suppressor grid introduced between the screen grid and the anode. It retarded the movement to the screen of secondary electrons dislodged when electrons struck the anode. Pentodes were commonly used as amplifiers and power amplifiers. Valves with sharp cut-off characteristics were used as AF voltage amplifiers and anode bend detectors while remote cut-off types were used as RF and IF amplifiers.

Pentode power amplifiers were used to produce AF power output above about one watt. They differed from RF amplifiers in that they were not screened. They used high anode and screen voltages. The beam power valve was an off-shoot.

The Dutch Philips Research Laboratories played a major role in the development of the pentode. Philips released the first pentode type B443 in September 1927 and incorporated it in their receiver Model 2502. It was company policy at the time to employ newly developed valves in its receivers before releasing the valves for public sale.

Mullard who had access to Philips designs produced the pentode in UK and marketed it under the 'Pentone' label for many years. Philips marketed their pentode valves under the 'Penthode' label until about 1936.

In 1932, five years after first release of the Penthode, Philips power valves included C243 (2 volt); D243 (2.5 volt); B443, C443, E443N and F443 (4 volt); and C643 (6 volt).

Many different combined valves were produced for various applications. These included twin diodes and twin triodes. One or more diodes were combined with triodes and pentodes to form second detectors. There were also combinations of triodes and pentodes and other forms as frequency changers.

The pentagrid converter had five grids. One group incorporated an oscillator grid and oscillator anode as part of the main cathode stream while another group had no separate oscillator anode, the screen grid serving a dual purpose.

Among the earliest mains power supply rectifiers used with Australian receivers was the American made UX281 type. Originally, only one valve was employed to provide a half wave rectification system, but later two valves were used to provide a full wave rectification system.

In 1927, the UX280 appeared on the market and it was to remain in the forefront of receiver designs for some 50 years. It was a full wave rectifier and was the first rectifier to make use of an oxide coated filament. The 80 had an input rating of 350V and in order to meet a demand for a valve with anode voltage of 450V, the 5Z3 was produced in 1933, an octal version type 5U4G was manufactured in 1937. When the 80 was produced as octal based versions, it was designated 5Y3G in 1936 and 5Y3GT in 1946.

English made rectifiers fitted to imported receivers included the Mullard D10 a half wave type, the Mullard DU5 a full wave type, and the Osram U5 a full wave type.

One of the first locally designed power supply units to employ the Osram U5 full wave rectifier was developed about 1928 by Peter Kennedy an Engineer in the South Australian Post Office and operator of station OA5AM.

In 1926, a friend had purchased a Silver Marshall Six from Adelaide Radio Company Ltd and asked Peter to convert it to AC mains operation. Peter designed a two section filter to limit the ripple to about 0.5% and used what later became known as a 'swinging' choke for the input choke. The final choke had an inductance of 18 Henries. He made the laminations and wound the two chokes and transformer in his home workshop. Two wax-filled paper capacitors were also part of the filter circuit. The valve was obtained from Harris Scarfe Ltd.

When the Second World War ended on 15 August 1945 it became evident to Australian valve manufacturers that they had to start gearing up to produce large quantities of valves for domestic receiver manufacture. It was important that the types to be employed be limited in number. The Australian market was estimated to require two to three million valves per annum but the minimum production necessary for a particular type to give reasonably economical manufacture was about 20000 per annum.

The valve manufacturers had to make a careful analysis of the position to ensure that their forecasts were soundly based and types selected for manufacture were those likely to continue for many years. Amalgamated Wireless Valve Co., Pty Ltd made a detailed examination of the situation employing a group under Fritz Langford-Smith and came to the conclusion that the most popular ranges were likely to include 1.4 volt battery range, 2 volt battery range and 6.3 volt AC range.

The 1.4 volt range was required for use with portable sets and receivers employed in the country where accumulator charging facilities were not readily available. The 2 volt range was required for operation with sets designed for 2, 4 or 6 volt accumulators with either B batteries or vibrator powered B supply. The 6.3 volt range was required for receivers designed to operate from the AC mains supply.

In the 1.4 volt range, there was a choice between the GT types being manufactured in Australia at the time and the miniature types used widely in USA. The miniature size had a number of advantages particularly for application with small portable receivers, so this design was adopted. Valve types 1R5 converter; 1S5 second detector; 1T4 RF and IF amplifier and 1S4 power amplifier for sets using 67.5 volt B batteries; and 3Q4 power amplifier for sets using 90 volt B batteries were selected for local manufacture.

The 2 volt types were not intended for use in small receivers so size was not an important consideration. Types selected for manufacture comprised 1M5G RF amplifier; 1K7G detector; 1L5G power pentode; and a new converter to be developed to replace the 1C7G and given a name.

The 6.3 volt AC range presented a problem owing to the wide diversity of characteristics and constructions. Two AWA officers were sent overseas to obtain the latest information on design and manufacturing techniques. It was subsequently resolved to cater for five single ended GT valves together with three existing valves in the GT range and a large rectifier. Types selected included 6SB7GT converter (a high slope version of 6SA7GT); 6SJ7GT; 6SK7GT; 6SF7GT diode super control RF pentode; and 6CQ7GT together with 6V6GT, 6X5GT and 5Y3GT, the latter being a GT version of 5Y3G.

By the early 1950s when valve technology had reached a high stage of development the large range of types available for receiver application included twin diodes, diode pentodes, duo diode pentodes, diode triodes, duo diode triodes, duo diode output pentodes, frequency converters, pentodes (voltage amplifiers), output pentodes, beam power amplifiers, single triodes (voltage amplifiers), twin triodes (voltage amplifiers), output triodes (pentodes and beam amplifiers triode connected), triode heptodes, rectifiers (vacuum), voltage regulators and magic eyes (tuning indicators).

For a comprehensive treatment on valve types the reader is referred to a series of excellent articles under the heading 'The Valve Box' by Fin Stewart in various issues of 'Radio Waves' published by the Historical Radio Society of Australia during 1997–98.

1.4 VOLT VALVES

Valves designed to operate with filaments powered from dry cells go back to the earliest days of broadcasting. The Radiotron series WD11, WD12 and WX12 all detector-amplifier valves produced prior to 1925 required 1.1. volts at the filament terminals and operated from a 1.5 volt dry cell. However, the current drain was nearly 0.25 amps. The Radiotron UV199 required 3 volts at the terminals and normally operated with a 4.5 volt dry cell battery. Current drain was about 60 Ma. An English valve, the DE3, available about the same time operated from a three cell dry battery and operated for up to 500 hours from special Radio dry cells then in use for receivers.

Radio valve technology received a boost about 1934 when miniature types were developed for hearing aid application. In the following year, a series under the brand HIVAC appeared suitable for portable broadcast receiver application. They required 1.5 volts for the filament. In 1938, the same company released a series with a filament rating of 1.4 volts at 70 Ma. AWA in Australia introduced a 1.4 volt series during 1938–39. RCA introduced in 1940, a design using the button base seal which set the pattern for miniaturisation in receiver valves. Thickened lead-out wires served as the contact pins. By 1939, the range included a pentagrid converter, RF pentode, output pentode and others. They operated on 1.4 volts at 50 milliamps.

In the design of those low consumption valves, the manufacturing requirement included the necessity to draw extremely fine tungsten wire, the application of a very thin emissive coating on the tungsten wire, and very small separation between filament and grid to maintain the mutual conductance. In Philips valves, the tungsten filaments were cataphoretically coated. In this process, the barium particles in the emitter paste were given a negative charge and with the filament wire maintained at a positive potential, the particles were drawn to the wire. This technique was still being used in the mid 1950s.

With the availability of 1.4 volt valves, technical magazines featured many portable designs employing these valves. The Radio Shops also marketed complete kits including a carrying case.

The most popular types featured in 1938–39 circuit designs included 1C5G, output pentode; 1H5G, diode triode detector amplifier; 1A7G, pentagrid converter; 1N5G, RF pentode; and 1A5G, output pentode. Of the two output pentodes available, the 1A5G operated with 1.4 volt at 0.05 ampere filament power, delivering 100 milliwatts of output, whereas the 1C5G operated with 1.4 volt at 0.1 ampere filament power, delivering 240 milliwatts of output.

Although the Ever-Ready Standard 1.5 volt battery could be employed with these valves, the company produced a special long life A battery type X250–1.5 volts for use as filament supply. Anode supply comprised two Ever-Ready Superdyne 45 volt B batteries in series.

METAL VALVES

When valves were developed for industrial purposes, such as switching, relay, voltage regulation, rectification and other purposes about 1930, it soon became evident that the major disadvantage in the employment of valves for such purposes was the fragile nature of the glass envelope. The manufacture of envelopes of valves had followed the practice of making incandescent electric lamps from the start, and valve designers were asked to find an alternative to glass, preferably steel, for valves manufactured for industrial purposes.

Experience had been gained in metal-to-glass seals since about 1922 when copper anode water cooled transmitting valves were developed, but the technique was not satisfactory for sealing steel to glass. It was not possible to eliminate glass entirely from the valve as it was required at the actual sealing points where the leads emerged from the container in order to provide insulation for the various element leads.

Following extensive investigations, a material known as Fernico proved to be satisfactory. It was an alloy of iron, nickel and cobalt and with the right proportions, had a coefficient of expansion almost equal to some types of glass. Sealing could then be carried at the temperature necessary to melt the glass and at the same time retain a tight vacuum when the seal cooled.

By 1932, the General Electric Co., in the USA, who had put a lot of resources into development work were in a position to produce all-metal valves for industrial use. The company also saw a number of advantages in all-metal valves for domestic receivers and produced trial runs of several types.

The valve was a winner from the start, and soon after its first public showing in 1935, valve manufacturers in the USA were producing 2 million valves a month to meet the demand. At least 70% of the domestic receiver manufacturers were using the valves in their latest models.

A major advantage in employment in domestic receivers was that the steel envelope acted as a shield and consequently eliminated the need for valve metal shields and their inherant problems. They were also physically smaller than their glass envelope counterpart and were more efficient as heat radiators. The internal construction was superior compared with the glass envelope types allowing more rigid mounting of elements and reducing considerably the problem of microphonics.

Also, by embedding the contact pins in a glass button, it was possible to eliminate the base which caused so much trouble in glass envelope designs. The base of these glass envelope types was cemented to the glass and frequently became loose. This created a problem in removing the valve for test purposes.

Many servicemen were not happy with the introduction of the octal base metal valves because it meant that if a valve had to be replaced and only a metal valve equivalent was available a new base had to be fitted to the receiver chassis. However, in the long run, the octal design proved to be one of the most successful in the long history of valve design. The principle was also adopted for other components such as coils, relays, crystal/oven units etc.

Although there were at least five major valve manufacturers in the USA producing metal valves to a number of designs in 1935, Australian valve manufacturers did not take up the challenge.

About 10 types were available in Australia from USA sources and included the 5Z4 rectifier, 6F6 output pentode, the 6H6 squat double diode and others.

Just before the outbreak of the Second World War the German Telefunken firm produced a range of metal tubes. The valves were of an unusual appearance being wider and shorter than their USA equivalent designs. They were used in Telefunken receivers and many can be seen in Australian owned Telefunken receivers in vintage radio collections.

Australian receiver manufacturers were quick to follow the lead taken by their counterparts in the USA in using metal valves in receiver construction.

Bill Bland of Bland Radio, Adelaide, manufacturers of Operatic radios, developed a prototype model in 1935 employing metal valves but did not proceed with production as he could not obtain sufficient quantities for assembly line requirements.

The first metal valve production chassis released in Australia was Briton Radio model 6CDM in 1935. Others in the same year included Lekmek model 615 which incorporated a 6E5 Magic Eye tuning indicator; Kriesler's High Fidelity 9MT, a nine valve receiver with 6F6's in push-pull in the output stage and 6E5 Magic Eye tuning indicator; and Astor's Ironclad Superhet Model 55.

Philips answer to the American metal valve range was a series of metal-clad or metal sprayed valves released about the same time. They were first used in Philips own receivers about 1933, and other valve manufacturers in Europe followed Philips lead. The The base and socket were much different from the American octal base and were known as the P universal base and socket. The P universal side contact base had been introduced with an earlier series of AC/DC valves and the availability of eight contacts in the base permitted separate earthing of the metal shield.

Australian receiver manufacturers saw the merits of the Philips metal-clad valves, particularly for those receivers designed for dual wave reception and sets produced in 1935 using those valves included a Calstan receiver manufactured by Slade's Radio, and a dual wave 4CD model made by Briton Radio. A special feature of the Briton receiver was the use of audio AVC and 'anti-phase' image suppression.

The original Philips metal-clad valves were grey in colour, but other series included gold and red colours. Most coated valves were of the screen grid types or octodes, but there were a few exceptions such as the gold coated E409 which was an indirectly heated triode.

VALVE BASES AND SOCKETS

Radio valves, like electric lamps, have a comparatively short life and it is necessary therefore to mount them in the equipment in such a manner that they can be easily replaced after failure.

The electric glow lamp had been manufactured for at least 15 years before the advent of the radio valve. The lamp comprised a glass bulb and a double contact male fitting known as the cap which was matched to a female fitting known as a socket or lamp holder wired to a power source. The most widely employed fittings were either bayonet or Edison screw types.

In the bayonet type, connection to the power source was made with two spring plunger terminals which pressed against the terminal plates in the cap of the lamp. With the Edison screw type, the brass case of the lampholder was provided with a coarse thread and the lamp cap similarly threaded. The cap of the lamp was screwed into the brass case of the lampholder which made one pole of the circuit. The insulated interior which was fitted in the brass case, was provided with a centre metal stud which made contact with a centre terminal plate in the top of the lamp cap, this connection making the other pole of the circuit.

In its normal operating vertical position the cap was above the glass bulb.

When the electric lamp manufacturers became involved in the production of radio valves, first during the development stage and later during mass production, they employed techniques already used with the manufacture of the electric lamp. When the Edison and Swan Electric Light Co., of London made diodes for John Ambrose Fleming circa 1905, the same brass bayonet lamp cap format was employed with side locking pins and the filament wires soldered to contacts at the base and insulated from the cylindrical brass sleeve. The connection to the anode was via a flexible lead passing through the side of the glass envelope for some models and via a screw terminal fixed to the glass wall with other models.

Other valve designs employed the Edison screw base rather than the bayonet format. The American de Forest Audio triode and the British Round N triode and others had the Edison screw arrangement.

In the case of the radio valve in situ, the glass bulb was above the stem end, referred to as the base. This was opposite to the electric lamp mounting arrangement.

However, not all valves were provided with a base type assembly. Some such as the Audiotron and the Australian made Expanse were provided with flexible wires passing through both ends of a cylindrical glass envelope. The wires were attached to terminal posts of a special holder.

The pin base format came into mass production during the early days of the First World War with French manufacturers being early leaders in the technology. British manufacturers soon followed the practice.

Manufacturers employed a number of different base designs up to and including the early 1920s. Designs included American, de Forest, Ediswan safety cap, English, European, Franco-British 4 pin bakelite, French 4 pin metal, Shaw 4 pin, UV, UX, UY, Western Electric, WD11 and many others.

From about 1932, many new valve bases were introduced by American, British and Continental manufacturers to meet developments in valve technology. By the mid 1950s, the most widely employed bases included Continental side contact; octal base with locating key; flat glass Key or Loctal base with locating pin; Rimlock with locating glass pip; miniature 7 contact button type base of octagon form providing an asymmetrical placement of the pins; Noval with 9 pins and providing an asymmetric pin arrangement by omitting the 10th pin; sub-miniature glass base valve, smaller than the Rimlock, and miniature types.

Base pins of miniature valves often became misaligned and Servicemen frequently employed a pin straightener prior to insertion of the valve in the socket.

Sockets or valve holders designed for holding the valve in position and for making electrical connection to the various power sources had to cater for a wide range of valve base configurations including valves with short pins; long pins; hollow, solid and spring type pins; and others. They were made employing various materials including bakelite, ebonite, porcelain, hard rubber, pyrex and various proprietary moulding materials. Some were made of one piece insulating material while others used an insulated bottom and a metal wall. Contact blades were usually made of phosphor bronze or brass with the outer ends being attached to binding posts with some of the early designs. This allowed circuit wiring without the need to employ solder on terminals. Some sockets incorporated shock or vibration absorbing characteristics to reduce valve microphonic problems.

Radio Shops stocked a wide range of models. In a lecture to the Southern Suburban Radio Club in Adelaide in 1926, Bill Bland, Proprietor of Harland Radio and Electrical Co., Adelaide described various types of sockets available in Adelaide Radio Shops at the time. They included All American; Athol reversible; Barkelew; Benjamin; CAV shock absorber; Cosmos anti vibration; Frost standard and shock absorber; Gecophone screwed legs and side mounts; GR standard and back panel mounting; Heath standard and sponge rubber shock absorber; Hi-Rad; Howard; HTC with side lugs; Igranic standard and 'non-mic'; Magnum standard and anti microphonic; Mullard ebonite; Muter; Na-Ald deluxe and cushion base; Rauland all bakelite; Samson; Signal; Silvertown ebonite with screw legs; Sterling standard and 'non-pong'; Tapa flush panel mounting; Transant with rubber mounts; Western Electric bayonet; Woodhall panel type; and others.

In lieu of a completely assembled socket, assemblers could purchase turned brass fittings known as valve lugs. They were supplied in packets of four complete with nuts, washers and a drilling template. They were turned from solid brass rod with a hole in one end of a size to suit typical valve pins. The other end was threaded to 4BA size. Many experimenters with lathes made this type for their sets. Len Sawford who worked for C M Lowe & Co., receiver manufacturers Port Adelaide, made many for use with receivers he assembled.

Another early South Australian company of the 1920s which made their own valve sockets for locally manufactured receivers was the Transatlantic Wireless Manufacturing Co., of Prospect. The company produced a range of receivers under the Newkrodyne label with sockets and other components being made under the supervision of Roy Buckerfield.

Adelaide Radio Shops which carried a wide range of valve sockets at the time, included D Green and Sons, J Craven and Co., Ltd; Louis Coen Wireless (SA) Ltd; Harringtons Ltd; United Distributors Ltd and Adelaide Radio Company.

In later years with the mass production of domestic receivers, many of the large companies produced their own valve sockets using their well equipped workshops. They included Amalgamated Wireless (A/Asia) Ltd, Electricity Meter Manufacturing Co., Ltd, Radio Corporation Pty Ltd and others. Ducon Condenser Pty Ltd was one of several component manufacturers which produced high quality valve sockets.

POWER SUPPLIES

With the exception of the crystal set which did not require a power supply, unless a biased carborundum crystal was employed, the power supply component of a broadcast receiver was of paramount importance.

A valve receiver required three types of batteries. They were costly to buy and because valves were relatively inefficient, the battery life was short, especially in multi valve sets. It was many years after the introduction of broadcasting that listeners could enjoy the pleasure of a batteryless receiver.

A typical receiver required batteries usually designated A, B and C supplies.

The origin of the letters A, B and C to describe battery supplies is not clear, but Lee de Forest, well-known as inventor of the triode, was one of the early pioneers to employ the A, B and C lettering format.

In his patent application of 25 October 1906 — granted on 15 January 1907 — for 'Device for Amplifying Feeble Electric Currents', an examination of the accompanying drawings shows the valve anode battery as designated B (B for battery) and the valve filament battery designated B', and referred to in the text as the A battery.

The designation C battery began to be used when the triode was used as an amplifier in telephone equipment when a negative grid bias battery was introduced.

* **A SUPPLY**

  The A supply was required to power the valve filament. It was obtained from either primary or secondary cells joined together to provide the necessary voltage.

  Filament requirements for the majority of valves ranged from 1.5 to 6.0 volts.

  Primary cells developed their power by chemical reaction and in the case of the standard dry cells, were discarded when they could no longer provide sufficient power for the filament operation.

The first type of primary cell developed to meet the specific requirements of a radio valve was the Carboncel, sometimes labelled Radio Battery. This cell could be reactivated by replacement of the electrolyte. A special porous carbon electrode allowed free circulation of air so that depolarisation was carried out by the oxygen of the atmosphere allowing a steady current flow over a long period of time. The Carboncel battery had a useful life of about 1000 hours per charge with an average drain of 0.5 amperes. The terminal voltage was a little over 1.0 volt so that two cells in series with a rheostat were required for a 2 volt filament.

Other carbon cell brands included AD Carbon Cells type 222 and 229, and Bleeck Radio A Battery made in Brisbane by W A Bleeck.

Another type of primary cell was the Eveready Air Cell. In appearance it was like an accumulator. It used a sodium hydroxide solution as its electrolyte and was not refillable. The electrodes were so proportioned that they disintegrated at the same rate as the weakening of the electrolyte. The cell was supplied sealed and in a dry condition so that all the purchaser had to do was to break the seal and pour in 3.5 litres of water in the cell. The Air Cell had two cells connected together internally and produced about 2.45 volts with a service life of about 1000 hours, provided the drain was kept to about 0.5 amperes. The positive electrode of the cell consisted of porous carbon with the top being in contact with the atmosphere which provided oxygen for depolarisation. The negatives of each cell were a pair of thick zinc plates.

Air Cell operated receivers were on view to the public for the first time at the 1937 Royal Agricultural Show in Sydney. With the availability of this unique power source, manufacturers were quick off the mark to produce receivers designed specifically for this battery. By late 1937, well-known brands employing Air Cell power source included STC, Tasma, Stromberg-Carlson, Briton (Rational Radio), Symfona, Paramount, Eclipse, Kriesler, Zenith, Genalex, Aristocrat (ESM), Kingsley, Lekmek, Weldon, Velco, Breville and others.

To obtain the guaranteed 1000 service hours from the battery, the receivers had to be designed to use 2 volt filament valves with a combination requiring a total drain not exceeding 0.65 amps, including the receiver dial lamps. Because of the constant voltage from the battery, there was no requirement for a rheostat to adjust the filament voltage, but it was standard practice to put a series resistor permanently in one lead of the supply. Correctly proportioned, the resistor kept the voltage applied to the filaments within the rated limits throughout the life of the battery.

About 1923, the Alklum storage battery became available in Australian Radio shops. It was manufactured in Great Britain and was a nickel-iron type with insoluble electrodes and alkaline electrolyte.

The outside container as well as the plates were made of nickelled steel in rigid construction. The battery provided a voltage of 1.4 volts per cell and could be charged in about six hours. It had capability of discharge at 2.5 amperes when employed as a radio A battery.

The most widely used and popular A supply was the lead acid accumulator as it gave long service and could be recharged. With the later introduction of vibrators to provide anode high tension, the accumulator became more popular. Various brands were available, both of local manufacture and imported with a range of capacities. For example, the Exide battery in 1926, for 6 volt supply, was available in capacities of 20, 30, 40, 50, 60, 75, 90, 105 and 120 ampere hours (Ahr) with normal charge rate varying from 1½ amperes for the 20 Ahr unit to 9 amperes for the 120 Ahr unit. Other brands available about the same period included Fuller; Hart; Ediswan; Cable; Burndept; Cosmos; HAH; Lithanode; Oldham; CAV; Peto & Radford; Rotax; Masse; Siemens; Perlin; United; Clyde; Titan; Yale; USL; Greeco; and Star, a locally produced unit; and others.

Included among the popular locally made accumulators were those sold under the brand name Radiola. In 1926, they were available in voltages of 2 volts with capacities 25, 40 and 55 ampere hour ratings; 4 volts at 25 ampere hours and 6 volts capacities 25, 40 and 55 ampere hour ratings. All four volt and six volt models were supplied with a polished crate. The company provided a charging service at the rate of 15 pence (30 cents) per accumulator.

The majority of early receivers employed valves requiring 2 volt supply but later with the introduction of 4 volt and 6 volt filament valves, many receivers were fitted with valves requiring different filament voltages. The 6 volt accumulator was ideal for this, as combinations could be easily wired to be satisfied from the 6 volt source, such as three 2 volt valves in series, or one 4 volt and one 2 volt valve in series, or one 6 volt valve, and so on.

With the gradual availability of valves with filaments which could be powered from the 50 Hz mains, the need for accumulators declined. However, they remained in service for many years as extension of mains power, particularly to country areas, took a long time.

Although the accumulator had the advantage that it could be recharged by the owner or taken to the local garage, it often deteriorated due to bad maintenance. Sulphation of the plates was often a problem. Many Radio Shops had the answer to this problem. For instance, in 1928, Harveys in Capitol House, Melbourne, advertised 'The Monkey Gland Remedy' at four shillings and sixpence per bottle. It was claimed that the solution renewed old batteries and defeated sulphation. The instructions read, 'Just pour it in'.

One accumulator of unusual design produced by Fuller's United Electric Works in England, and distributed in Australia by Loch and Gerber Ltd, of York Street, Sydney in the early 1930s, was the Block Plate-less Accumulator. It was cylindrical in shape and instead of having oxide pasted into heavy lead grids, the Block accumulator cylinder itself was, apart from its external bakelite case, the negative electrode which employed a special process to hold the paste onto the interior surface with no need for a grid structure. The positive electrode was a simple core inside the cylinder.

The manufacturer maintained that the new design gave twice the ampere hour capacity of a conventional accumulator of the same volume. They explained that the reason for the superior performance was that in a conventional accumulator, part of the current flowed direct from lead grid to lead grid resulting in uneven action on the paste enclosed by each grid. In their plate-less design there was steady and uniform action from electrode to electrode through the entire homogeneous paste.

One of these accumulators was donated to the radio collection of the Adelaide Telecommunications Museum by Jack Trembath who acquired it from a colleague while a member of the Wayville Radio Club in Adelaide. The Club had been active since September 1924 and regularly conducted broadcast experiments in the 200 metre band with its transmitter 5WB. The transmitter was located at the home of the President Bert Wilson, a member of the 5AD technical staff.

* B SUPPLY

High tension for the anode of the valve was provided by primary batteries made up of banks of dry cells connected in series, secondary batteries of the rechargeable type, vibrators or motor generators powered from accumulators.

High tension dry batteries were made up typically to provide 22½ or 45 volts by employing 1.5 volt cells using jelly type electrolyte connected in series. For higher voltages such as 67½, 90, 135, 180 etc, a number of 22½ volt or 45 volt units would be connected in series.

When these batteries became exhausted they were discarded. They were usually available in light duty, heavy duty or super power ratings with the super power unit being suitable for a receiver requiring up to 25 Ma current drain. Brands available in the 1920s included Eveready (Ever-Ready), Ediswan, Hellesen, Burgess, Columbia, Armax, Deal, Ray-o-Vac, Volta, Diamond, Voltron, Dutho, Darimont, Siemens, Saxon, Harkel, Pertrix, Elatax, Bright Star, Hercules, Yale and others.

The lead acid B battery was popular because it could be recharged and gave a reasonably high drain capacity. However, they were much more expensive than the throw-away types using dry cells. For example in 1926, a Dutho storage type giving 45 volts output was three times more expensive than a heavy duty Volton brand dry cell battery of the same voltage.

The lead acid models were basically miniature accumulators connected in series. A typical home made unit comprised simply strips of lead hanging in a glass test tube, with standard battery acid as the electrolyte. Commercial units were assembled using small rectangular or square jars sealed at the top to prevent spillage of the acid electrolyte. A typical 60 volt Exide battery had a capacity of 3 ampere hours at the 20 hour discharge rate. Another popular type was the Peto and Radford model distributed by A G Healing Ltd in 1927. It was sold as 20 volt units with multiple units being linked together to obtain higher voltage. Each unit was complete with compact crate 14 inches (350 mm) long by 2 5/8 inch (66 mm) wide with completely sealed cells. Capacity was 2.5 ampere hours at a low discharge rate. Other brands available from Radio Shops in the late 1920s included Eveready, Hart, CAV, Varta, Standard, Eusco, Dutho, Willard and others.

Mr R Rhodes an Electrical Engineer who lived at Kadina in South Australia and who operated Amateur station OA5HR in the 1920s manufactured high tension lead acid type batteries for transmitter application as well as for receivers. They comprised glass test tubes 25 mm diameter each with lead plates and electrolyte and assembled in block format. For transmitter supply, five blocks each of 100 volts were connected in series to provide 500 volts DC while units made for receivers comprised blocks of 60 volts. For 120/180 volts, two/three blocks were connected in series. Only materials of highest quality were used and the batteries were considered to be equal to the best of imported types.

Another Kadina experimenter who built lead acid high tension batteries for transmitters and receivers was Darcy Hancock who operated station OA5RJ about 1927–28.

At the time, Kadina public power supply was 200 volts DC but this was well below the voltage required for transmitter high tension. Darcy constructed a lead acid battery of 100 cells using pickle bottles and concentric lead plates to provide 200 volts. A test showed the battery had an ampere hour capacity of 7.5. By connecting the battery with correct polarity across the town supply he was able to produce 400 volts for the transmitter valve anodes. A smaller version using vaseline jars donated by a local chemist was built for his receiver. It provided about 100 volts at 3.5 Ahr capacity.

Another B supply receiver type was built up with a number of Edison or similar alkali accumulator cells in series. These types featured a number of advantages not possessed by lead acid accumulators but were not as widely used. One popular model marketed by Taylor and Spacey Pty Ltd, Melbourne in 1927 was called 'Alkaline' and was claimed to be no more efficient than a lead acid accumulator. It used nickel and steel plates in an alkali solution. The battery was assembled in a polished cabinet with external tappings mounted on an ebonite panel. Provision was made for charging the unit.

The vibrator unit was widely employed in the mid 1930s for providing high tension supply. The vibrator-interrupter unit consisted basically of a transformer connected across a low voltage supply and having the primary circuit interrupted to provide magnetic flux variations for transformation. Rectification was effected by means of copper oxide or valve rectifier or an extra set of contacts on the interrupter. This latter unit was known as a synchronous vibrator.

The B battery eliminator was an early attempt to make use of the AC mains supply to provide high tension for the receiver valves. By 1926–27. the range of units available from Radio Shops included:

- Philips Eliminator
  Made in Holland by Philips, the transformer, filter choke and capacitors were housed in a black finished metal case. The valve, 373 type was a half wave rectifier with 40 Ma output. Three taps were provided — one a common negative, one for detector anode supply and the other for amplifier anode supply. The total output of the eliminator was controlled by a rheostat while the detector voltage was variable in three stages by means of a control knob moving over three studs connected to a tapped wire wound resistance. The unit was known as type 372. Models imported from England were fitted with Mullard DV10 half wave rectifier, Mullard DU5 or Osram U5 full wave rectifier.
  Over the years, the company produced a range of models including type 3002 in blue metal case and full wave rectifier valve type 506; type 3003; type 3005 for DC mains; and type 3009 with maximum B voltage of 150 volts.
- Balkite Eliminator
  This USA manufactured unit differed from most other types in that the rectifier was a patented Tantalum cell unit. The eliminator was housed in an enamelled metal box with four positive taps. Model W was designed with output capability to cater for receivers up to five valves while Model X had capacity to provide for eight valve receivers.
- Radiokes-Mayolian Eliminator.
  Developed in the Mayolian Laboratory in USA, the Model 610 had a variable output from zero to 200 volts DC using B-H type Raytheon rectifier and capable of output up to 80 Ma. The unit was fitted with taps providing separate variable voltages for RF, detector and AF valves.
- Emmco Eliminator.
  Manufactured in Australia by Electricity Meter Manufacturing Co., Ltd, the unit was housed in a metal case with bakelite top. Five terminals were provided, one earth, one B minus, one detector positive adjustable by knob from 20 to 45 volts, one RF positive adjustable up to 100 volts and one AF positive fixed at 135 volts.
- Valley Eliminator.
  Available as Model 40 or Model 50. They were fitted with Raytheon rectifier valves. The Model 40 was designed for receivers with up to six valves while the Model 50 would handle receivers employing up to twelve valves. They were manufactured in USA by Valley Electric Co.
- Stromberg-Carlson Eliminator.
  Rectifier employed was a Radiotron UX213 full wave rectifier type. It catered for AC line voltages of 200 to 260 volts using an adjustable switch. Output voltages were maintained constant by using glazite type resistance units which were unaffected by changes in humidity and had good heat dissipation properties.
- Jansen Eliminator.
  The factory operated by Jansen Bros., at Eudunda in the South Australian northern region was hard pressed to meet the demand for the high quality reliable units it produced. Seven models were manufactured and included units which operated from a range of home lighting power plants to provide HT outputs of 100 and 150 volts DC.
- Don Eliminator.
  The Don Electrical Company, Camperdown in 1933, manufactured a combined B and C eliminator. All together, the company produced 12 models. There were car receiver models capable of operating from 6 and 12 volt inputs, and 10 home receiver units designed for DC input voltages of 2, 4, 6, 12, 24, 36, 50, 60, 70 and 110 volts. They produced HT voltages up to 200 volts at 40 Ma and C bias voltages up to negative 30 volts.
- Apco Rectodyne Eliminator.
  The Apco Rectodyne brand was distributed by AWA. One

model was designed to operate from 200–230 volts. Both gave a variable output of 0 to 135 volts DC. Under load conditions of 20 to 25 milliamps, which was considered to be normal for 5 to 6 valve receivers, the eliminator would provide 135 volts maximum using type 201A valves, but with one UX213 Rectron valve, it would deliver 135 volts under load of 50 to 60 milliamps or 150 volts under 25 milliamp load conditions.

It is of interest that the UX213 Rectron was the first full wave rectifier announced by RCA. It eventually led to the elimination of the practice of using two half wave rectifiers in receiver power supplies.

The power supply unit developed by designers for the fully mains-powered receiver changed very little over the years from systems employed from about 1930. The basic unit accommodated on the same chassis as the receiver proper, comprised four main parts. These were power transformer, rectifier, filter and voltage divider.

The power transformer contained the primary winding and several secondary windings all on a laminated steel core. Taps were provided on the primary for various input AC voltages. In addition to the high voltage winding for the rectifier anodes, low voltage windings were provided to heat the rectifier power valve filament and the receiver valve filaments as well as providing power for dial lamps.

Typical of transformers of the mid 1930s were three Essanay models available with secondary currents of 80, 90 and 110 Ma. All three were designed for operation with primary voltages of 200, 230 or 250 volts and secondary voltages 385/385 volts. Filament windings were 80 Ma transformer (1) 2.5 V at 3 amperes (2) 5 V at 3 amperes; 90 Ma transformer (1) 2.5 V at 8 amperes (2) 2.5 V at 3 ampere; (3) 5 V at 3 amperes; and 110 Ma transformer (1) 2.5 V at 8 amperes (2) 2.5 V at 3 amperes (3) 5 V at 3 amperes. The transformers were vacuum impregnated and had good voltage regulations characteristics.

Although some early circuits employed two half wave rectifier valves to form a full wave rectifier, these soon gave way to a single full wave rectifier type valve. Two general types of valves were used initially. They were cold cathode and hot cathode types. The cold cathode was a gaseous type using valve types similar to the American 'Raytheon Tube' employing helium gas. The hot cathode type included the common vacuum type widely used, and also mercury vapour types used for a while with some imported receivers.

Two configurations of low pass filter circuits were used. They were the input capacitor filter and the choke input filter. The input capacitor system employed a choke and two capacitors with one capacitor at the input to the choke and the other on the output side. The choke input system employed choke input and a capacitor on the output side.

A disadvantage of the input capacitor circuit was that it caused large peak currents to be drawn from the rectifier resulting in excessive heating.

The choke input circuit provided less smoothing than the capacitor input arrangement, and in some high quality receivers, the choke was followed by a second choke and capacitor.

With the development of the electromagnetic loudspeaker, designers used the speaker field coil as the choke, so reducing cost and space requirements on the chassis. Capacitors were usually tin foil paper type or electrolytic type with the electrolytic type being the most popular because it was relatively cheap and had self-healing properties of the dielectric.

Various methods were used with voltage dividing circuits to provide other DC voltages, but the most widely used was the bleeder-resister type. This was simply a tapped resistor across the high tension circuit following the filter network. Typical resistors were wire wound or solid compressed carbon types.

Another method of providing high tension supply was by use of a motor/generator set. This technique was widely employed with car radio systems and where home lighting battery systems were in use.

One system known as 'Pines B Eliminator' (magmotor) produced by Pyrox Pty Ltd, Melbourne operated from 6, 12 or 32 volt batteries to drive the motor. It provided a range of high tension voltages, well filtered to eliminate any ripple problems. It was in use during the 1930s but Bill Smith a Radio Dealer and Serviceman at Wallaroo in South Australia said that performance was affected if the DC power source dropped in level due to high drain by other household appliances. He fitted a regulator for some customers to minimise the problem where power was provided by a home lighting system.

The ML Anode Converter distributed in 1930 by Edgar V Hudson in Brisbane was available in a range of models with inputs of 12 or 32 volts DC and outputs of 150 to 1000 volts filtered DC. Each unit was totally enclosed together with smoothing circuit and regulator accessories in an aluminium casing with mounted bakelite controls. It was supported on rubber blocks and made very little noise during operation.

A W Kemp and Co., Sydney manufactured a range of rotary converters so people with 32 volt and 110 volt DC home lighting outfits could operate radio receivers designed to be powered from 240 volt AC power supplies. Many popular deluxe models with gramophone replay facilities were not readily available for operation with 32/110 volt DC supplies. The company also produced a converter to cater for listeners connected to 230 volt DC mains supplies.

There was also a 32 volt powered device called a rotary transformer which not only provided high tension from one set of dynamo brushes but low tension from another set of brushes mounted on the other end of the shaft for filament voltage.

The Healing Model 55D manufactured in the mid 1930s was one such receiver fitted with a rotary transformer. It was a five valve superheterodyne type using valve types 6D6 RF amplifier, 6F7 oscillator modulator, 6D6 IF amplifier, 75 diode demodulator and AF amplifier, and a 41 power pentode. The receiver incorporated AVC, and controls comprised volume control, on/off switch, tone and static control, and station selector. Measured high tension voltages were 225 volts on the anodes of 6D6 RF, 6F7 and 6D6 IF; 105 volts on 6F7 oscillator anode; 82 volts on anode of 75; 210 volts on the 41; 225 volts on the screen of the 41, and 82 volts on the screen grids of 6D6 RF, 6F7 and 6D6 IF valves. Measured filament voltages ranged from 6.1 to 6.7 volts. The electrodynamic loudspeaker was matched to the output valve and had a field resistance of 135 ohms. Intermediate frequency was 180 kHz.

Mr and Mrs Kennedy who had a property out from Murray Bridge in South Australia purchased one of these models from Healings in Adelaide about 12 months after local broadcasting station 5MU Murray Bridge began operation. Frank Miller who built and owned 5MU was a friend of the Kennedy family and he helped them install the receiver using a long stranded copper wire tied to the top of the windmill tower as an aerial. When the receiver was first switched on, there was a high noise level almost as loud as the station signal. Frank traced the problem to a faulty capacitor in the high tension ripple filter circuit. He returned the following day to replace the faulty component. No further trouble was experienced and the receiver provided reliable service for some five years before being traded in for a new model.

* C SUPPLY

The C supply was required to provide bias for control grids of selected valves in the receiver. As current drain was very small, dry cells were quite suitable. The battery usually had taps brought out at each cell to provide a range of negative voltages. One problem with the use of a C battery to provide a negative bias voltage, was that the bias voltage remained constant at top voltage for almost the entire shelf life period of the battery, whereas the voltage applied to the anode by the B battery decreased with the increased use of the receiver. This aggravated signal distortion and noise problems.

The need for the bias battery disappeared with the introduction of automatic biasing techniques in receiver designs.

Battery charging and testing facilities were important features associated with battery operated radio receivers. Where battery charging facilities were not readily available locally, many set owners purchased their own units. Units were available which would enable charging using the AC or DC mains supply, a wind driven generator or a small motor generator set. Popular battery chargers in 1926 included BGE, Colmovox and BTH Tungar chargers using a special bulb with a graphite anode for rectification and a Philips rectifier using a half wave valve. Most Radio Shops and garages had a range of battery chargers available to meet requirements, with Philips Models 327 and 366 being amongst the most popular in 1926. The 327 had capacity for charging 1 to 6 cells (2–12 volts) at 1.3 amperes, and the 366 had capacity for charging either 1 to 4 cells (2–8 volts) at 6 amperes or 5 to 7 cells (10–14 volts) with 3 amperes. A number of battery manufacturers operated a battery exchange system whereby a charged A battery could be obtained as replacement for a discharged battery at a small cost. The P and B Battery Co., Ltd in Adelaide was one such company which provided this service during 1926.

Of the motor generator types, the Chaseway model was popular, providing facilities for charging accumulators of 2, 4, 6 and 12 volts.

Wind driven generators were widely employed by country listeners remote from mains power sources. The system cost nothing to run except for some minor maintenance from time to time. As they were employed to charge the battery, and not to directly power the receiver, the intermittent nature of wind was of no concern. One model available in 1936 and available through the various branches and distributors of International Radio Co., Ltd was the Pioneer Air Flow Charger manufactured in the USA by Pioneer Gen-E-Motor Corporation. The unit provided an output of 6 volts at 5 amperes DC. The electrical unit was completely weatherproof and was provided with a cut-out device to operate when the battery was fully charged. The propeller was scientifically curved to operate at extremely low wind velocity. Although the charger could be mounted directly on top of a standard windmill steel tower, a four leg steel frame about 2 metres high was available to enable the unit to be mounted on top of a barn or the house.

Wind driven generators were also widely used for charging 32 volt home lighting systems and some radio manufacturers produced receivers which could operate directly off the 32 volt supply without the need for vibrator of motor generator units. In the early 1950s, a grazier living west of Quilpie wrote to the ABC in Brisbane describing an Astor QN model which he operated from his 32 volt system. The set was an eight valve type with RF stage and push-pull output stage. The 32 volt supply was connected direct to the anodes of the valves serving as the HT supply. The listener used the receiver to listen to short wave station VLM at Bald Hills out from Brisbane as there were no MF stations within reception range. The 32 volt generator was mounted on top of an old windmill tower which had become surplus when a new bore was sunk at another site.

Trickle chargers were widely employed with many home installations. They were usually installed in the receiver cabinet or nearby, whereas full chargers were usually located out of the house in the garage or workshop and the battery was taken there for charging. The Philips 1017 Rectifier unit was one trickle charger available for charging A batteries. It employed a mercury vapour type rectifier. Because of hum and noise problems, the trickle charger was switched off when the receiver was in operation.

A trickle charger which employed a copper oxide rectifier was the Rec-Tox unit manufactured by Westinghouse and distributed in Australia by AWA. It had capacity to charge a 4 or 6 volt accumulator at a rate of 0.8 to 1 ampere continuously. The unit was enclosed in a cast aluminium case finished in maroon colour enamel.

In addition to commercially made battery chargers employing thermionic vacuum valves, gas filled Tungar rectifiers with their bright purple glow or copper oxide metal rectifiers, many set owners made their own chargers in the form of chemical or electrolytic rectifiers. These rectifiers functioned because of the property of certain metals when immersed in various electrolytes of permitting currents to pass in one direction only. This allowed the battery to be charged by a pulsating direct current.

A typical home made rectifier used an ordinary pint glass jar with a hard rubber or insulated top. Sheet metal electrodes about 25 mm wide of aluminium and lead were immersed in the electrolyte of ammonium phosphate. Before service, the aluminium electrode had to be formed. This was done by connecting the aluminium electrode to the positive side of a DC source, such as a heavy duty B battery. The rectifier was usually connected to the mains in series with the accumulator being charged, and an electric light bulb.

This type of electrolytic rectifier was commonly referred to as a 'slop jar' and other versions used electrodes of carbon and tantalum. There was also a range of electrolytes and in addition to ammonium phosphate, substances such as sodium phosphate, borax, sodium bicarbonate, and others were used with varying degrees of success. A typical cell could handle up to 50 volts with the current handling capacity being determined by the surface area of the electrodes.

The use of a range of batteries with the receiver required that the owners possess a means of measuring the condition of the various batteries, if they wanted to reduce dependence on a Radio Serviceman. Meters were, of course, essential in a Serviceman's kit. The most widely used instrument was a pocket type of voltmeter with two ranges. The actual scales varied with different models and manufacture, but a typical two range instrument would cover the range 0 to 8 volts on one scale, and 0 to 150 volts on another. The small range allowed the measurement of voltage of the A or C battery, while the larger range allowed measurement of the B battery voltage. Milliammeters were also available for measuring the current drain, but the use of these required some knowledge of the technical side of the receiver.

Typical pocket types available included Pifco with range 0–8V, 0–16V, 0–24V and 0–4 Ma, all available on the one instrument; Capitol with different models covering ranges 0–8 and 0–16V; 0–12, 0–120 and 0–240V; and 0–8, 0–16 and 0–32 Ma; and dual reading J T pocket meters in heavy nickel cases with models covering the ranges 0–6 and 0–30V, 0–10 and 0–50V, and 0–6 and 0–12V.

It was important that the voltage measurements be carried out with the battery in operation, i.e. on load.

An instrument specially designed for testing accumulators was the cell tester. It had an in-built low resistance across pointed probes so that a heavy current was drawn from the cell under test. A hydrometer was also a necessary test instrument when checking accumulators.

With the introduction of solid state technology and the high efficiency it brought with it, the power supply requirements of broadcast receivers has been very much simplified. Gone are the days of separate A, B and C batteries and the problems and expense associated with them. Only a few dry cells are required with modern day portable receivers and coupled with improvements in battery technology, long operating life of the battery can be expected. In addition to the standard AA, C and D sizes, there are special Radio sizes on 9 volts in the General Purpose Heavy Duty carbon zinc type, as well as in the Alkaline type.

A receiver of recent design called Baygen Freeplay operates without any batteries or external electrical power source. The receiver manufactured in South Africa and distributed in Australia by Dick Smith Electronics stores is a three band transistor superheterodyne model powered by a wind-up clockwork spring motor which supplies 3 volts for 40 minutes duration. It covers the AM and FM broadcast bands and the short wave band 5.8 to 18 MHz.

Demand for the receiver is so great that in 1997 the company in Cape Town was producing 500000 sets a year.

REPAIR AND REACTIVATION

Rebuilding receiving type valves was never undertaken on a commercial basis in Australia, but some work was done by individuals who had access to apparatus for providing a vacuum inside the valve envelope. In the early days of broadcasting, valves were expensive and difficult to obtain. Generally, they had a short life.

One enterprising Radio Shop manager in Adelaide in 1925, placed an R type valve in the window and as a publicity stunt, conducted a guessing competition on the number of hours the valve would remain alight. The valve operated for 297 hours which was typical for this type at the time. However, some experimenters claimed that the valve could operate for over 3000 hours if operated with 3.75 volts on the filament and 75 volts on the anode.

The R valve was developed by the French Military during the First World War and was manufactured in great numbers by factories in France and England for military application. After the War, there were hundreds of thousands released as surplus material and importers and individuals in Australia brought in great numbers to meet the demand. It also arrived in Australia in broadcast receivers manufactured in England. These included the Re-Echo two and three valve reflex model, Durham long range single valve receiver, two valve Wootophone model and four and five valve models of the RI brand. All these receivers had the R valve mounted on the outside of the cabinets and when powered, the room would be lit up just like a battery of electric lamps. The R valve had a large glass envelope in the shape of a typical electric light globe and the filament, grid and anode elements were mounted horizontally in the envelope.

Professor Kerr Grant of the University of Adelaide, developed a technique and tools for replacing burnt out filaments of R valves in the early 1920s. The glass of the valve was annealed using a small blow pipe at points nearest to the two ends of the horizontal filament. Holes were drilled in the glass using a piece of tubing in a hand drill liberally coated with cutting material and turpentine. After drilling the holes, a small tool would then be inserted through the hole to lift up the bent over clamp holding the filament wire and repeated at the other end. If no replacement tungsten wire was available, thin platinum wire would be used and the clamps bent back to hold the wire in place. The Professor had ample stocks of the platinum wire, as he had been using it to develop an improved electrolytic detector before valves were readily available.

After being satisfied that the work was complete, the two holes would then be sealed with glass. The original pip on the envelope would be gently removed with a pair of pliers, and the exhaust pump applied. If a first class repair job was required, the filament would be heated after the correct pressure had been reached as indicated on the pump meters. The envelope would be 'pipped off' at the end of the exhausting operation.

The major problem with undertaking repair work of this nature was obtaining suitable air exhausting equipment. However, there were a number of enterprising experimenters around at the time, and at least one in Melbourne constructed his own equipment. It was a mercurial pump type which he used to repair 201A valves as well as R types for his friends.

A method of repairing the filament of a 201A valve without puncturing the envelope and destroying the vacuum was to remove the glass envelope and its element leads from the base and by means of a drill to make a small hole in the base of the glass support to gain access to the sealing wire of the filament support arm. This support arm had a small piece of sealing off material which was embedded in the glass support and in essence was electrically connected to the centre of the filament. After drilling the hole with the aid of the drill and cutting compound made of carborundum paste, the hole was cleaned out, a lead inserted and the hole filled with amalgam and left to dry for a day or so. A continuity test would indicate which side of the two original filament leads could be used to complete the filament circuit. Tom Elliott well-known Brisbane Radio Engineer used this method in the 1920s and he found that short application of 6 volts would provide a good weld of the filament to the support wire and ensure good contact for a long time.

Once active Amateur who was involved in experimental broadcasting during 1920s was Roy Cook with his station 5AC in Adelaide. Roy acquired many R type valves through Ship's Wireless Operator friends who would purchase bulk quantities when their ships visited England. The valves were widely distributed to Amateur friends in Adelaide. At one time, Roy recovered over 20 valves with burnt out filaments and in 1924 despatched them to Radions Ltd in England who were manufacturers of Radion valves and also conducted a repair business on valves manufactured by other companies. The company would replace filaments and repair glass envelopes but would not replace grids or anodes. The average cost of replacing a filament was five shillings compared with twenty-five shillings for a new R valve in Australia at the time.

The reason why there were so many valves with burnt out filaments was that some Amateurs, including Roy, used the R valve as a transmitting valve and to obtain a high output they would increase the filament voltage and also raise the anode voltage, frequently to the point where the valve anode was operating at a cherry red condition.

One noteworthy broadcast by Roy Cook using a transmitter with several R type valves was the broadcast of the Adelaide Tramways Band during the Annual Smoko Social in 1923. It was one of the first live broadcasts of a band in the State. Two of the R valves used in the transmitter had previously been sent to Radions Ltd, to have replacement filaments fitted.

In early battery operated receivers, the B battery was often blamed for a deterioration in performance of the receiver if filaments were alight or the envelope felt hot, in cases where the filament could not be seen because of gettering material on the inside of the glass. However, B battery exhaustion was frequently confused with loss of sensitivity of the valve due to fall off in emission. Valves made with thoriated tungsten filaments could sometimes be rejuvenated by a simple process, so improving performance. Thoriated tungsten filaments contained the oxide thorium throughout the whole diameter of the filament wire. One of the reasons for use of the oxide was to keep the fine wire from being too fragile. In the manufacturing process, a layer of atoms of thorium was formed on the surface of the tungsten. The thorium emitted electrons much more copiously than pure tungsten. After a period of service, the layer of thorium atoms evaporated, and so emission fell off sharply, so affecting the valve's performance.

By using a reactivation process which boiled additional thorium atoms out of the interior of the tungsten filament, a new layer of thorium atoms was formed on the surface of the filament wire.

The reactivation process was developed by the General Electric Co., in the USA which also developed units to carry out the process. These were manufactured by various firms with many units being imported into Australia in the early 1920s. They included such brands as Reactivator, Vitaliser and Rejuvenator.

One Radio Serviceman, who conducted a business in Glenelg in South Australia, made his own unit as well as most of his other test equipment.

The process of reactivation involved flashing the filament with a specified high voltage for a short period of time followed by ageing the filament at a lower voltage for a longer period. The anode and grid elements were disconnected from any voltage source during the process.

The flashing reduced some of the thorium oxide in the wire to thorium and the ageing formed the required surface layer.

Two of the most widely used valves imported from the USA in the early days of broadcasting, were the UX and UV 199 and the UX and UV 201A types and recommended reactivation procedures for these were as follows:

- UX and UV 199.
  Flash by applying filament voltage of 10 volts for 30 seconds and age by reducing the voltage to 4½ volts for 10 minutes.

- UX and UV 201A.
  Flash by applying a filament voltage of 15 volts for 60 seconds and age by reducing the voltage to 7½ volts for 10 minutes.
  Either AC or DC voltage could be used, but an accurate voltmeter and a stop watch were essential for good results.
  The process was suitable only for thoriated tungsten filament valves. The WD 11 and WD 12 also imported from the USA, could not be reactivated. These tubes employed a coating of certain oxides on the filament wire and when this had been used up, no reactivation process could renew it.

Extreme care had to be taken that the filament did not fuse, and a good deal of experience was necessary to reduce catastrophic failure to a minimum. Some Servicemen with stocks of valves removed from receivers, often placed batches in the kitchen oven and baked the valves up to two hours in a hot oven. Although this was safer than applying a high voltage to the filament, it often resulted in many of the valves becoming 'gassy'.

VALVE TEST INSTRUMENTS

Instruments for carrying out simple tests on valves became available soon after the mass production of valves for broadcast receivers began. In the USA, the UV200 and UV201 were released late in 1920 and UV199 followed in mid 1923. These valves were imported into Australia in large numbers for sale by Radio Shops as loose valves, or supplied with USA assembled receivers. About the same time, a valve tester arrived with capability of testing only a UV199 valve. It was soon followed by units capable of testing several different types of valves then widely employed in home receivers.

One of the most popular valve testing instruments which became available early in 1927, was produced by the Jewell Electrical Instrument Co., in Chicago. The unit had five meters mounted on a panel, together with a single valve socket, a number of terminal posts, and two rheostats. The meters measured separately, filament volts, filament current, grid volts, anode volts, and anode current. The filament voltmeter had a scale 0 to 6 volts, the filament current meter a scale 0 to 1.2 amperes, the anode voltmeter a scale 0 to 120 volts, the anode current meter a scale 0 to 10 Ma and the grid meter which had the pointer at centre scale, had a scale 0 to 10 volts.

For valves which required a different socket from that provided on the instrument, an adaptor was used, or alternatively, short pieces of wire could be run from the valve pins to binding posts around the socket. The instrument required external batteries for A, B and C supplies to be connected to appropriate terminals. The current from the A battery passed through the ammeter and then through a 60 ohm rheostat which had the right amount of resistance for UV199 valves with 6 volts applied. The rheostat allowed the correct filament voltage to be set for other valves with different requirements. Two 10 volt batteries were provided for the grid circuit to enable either negative or positive voltage to be applied. A rheostat enabled the pointer to be positioned exactly on centre scale.

The instrument allowed measurements to be made to determine the ratio of the change in anode current to the change in grid voltage (mutual conductance), after applying the appropriate filament and anode voltages as recommended by the manufacturer. Normal practice was for the Serviceman to plot a rough graph, but many Servicemen soon became sufficiently skilled to determine the mutual conductance after making a couple of spot measurements.

Other measurements which could be carried out with this Jewell instrument were amplification constant and anode resistance. The values obtained were compared with those recommended by the valve manufacturer for use of the valve in different applications such as detector, audio amplifier, or radio frequency amplifier.

Station 4QG Brisbane had one of these instruments in its test equipment cabinet when the station was taken over by the Government in 1929. It was not replaced until about 1937.

Valve testers later became part of an instrument called an analyser which, in addition to testing valves allowed testing of other receiver components, as well as voltages, currents and resistance in different parts of the circuit.

In 1927, AWA produced the Radiola Servicing Set. The instrument was enclosed in a globite waterproof case 16 inches (400 mm) by 12 inches (300 mm) by 6 inches (150 mm) and incorporated testing apparatus for measuring normal anode current and emission of valves, testing apparatus for checking the continuity of circuits, testing apparatus for measuring the voltage of A, B and C batteries and a calibrated modulated oscillator enabling receivers to be tested without relying on a transmitting station, most of which only broadcast for short periods during the day.

Commercially manufactured instruments were expensive and during the Depression years, so many enterprising Radio Servicemen built their own units. Bill Smith, a Dealer and Serviceman at Wallaroo in South Australia built one for use in his business. It was donated to the radio collection of the Adelaide Telecommunications Museum.

By the mid 1930s, there were a number of commercially made Australian instruments available, and included brand names Arion, Calstan, Cragg, Palec and University. Imported models seen in many radio service businesses included Capitol, Confidence, Dependable, Elgin, Franklin, Hickok, Jewell, Radio City, Readrite, Superior, Supreme, Triplett, Weston and others.

With the increasing number of valve types becoming available, valve checkers soon became out of date. Adaptors were a solution to the problem. Some Servicemen made their own, but commercially made units were readily available. They included a button type, a wafer type, moulded bases which could be obtained with any number of pins and a Na-aid adaptor which made it possible to test 7 pin valves in a 6 hole tester. Some had a flexible lead and clip for connecting to the control grid cap on the valve. For testing valves which operated with high filament voltages, there was a Na-aid adaptor with a self-contained step-up transformer in the adaptor.

THE TRANSISTOR AND THE DEMISE OF THE VALVE

The basic concept of the thermionic valve was amongst the most important inventions in the development of Radio Engineering technology. Without it, radio broadcasting, television and the many offshoots involving transmission and reception would have been almost impossible. In its hey day, there seemed to be no end to the variety of uses for this marvel of metal, glass, insulation and empty space.

The number of valves produced throughout the world reached billions and types ran into many hundreds. Immediately after the Second World War, sales of receiving valves in the USA alone exceeded 200 million annually. In 1930, a well-known USA Handbook listed about 60 valve types and 20 years later the number had increased to nearly 700.

In the mid 1930s, Australian valve data publications listed nine main classes. They included variable-mu valves, screen grid valves, miscellaneous triodes, special purpose valves, output triodes, output pentodes, Class B valves, rectifiers and transmitting types. In order to identify the type of base employed, the data sheets used an arrangement of letters and figures such as X-UX base, Y-UY base, 6-standard 6 pin base, 7-standard 7 pin base, 3-English 3 pin base, E-English 4 pin base, 0-English 5 pin base, 7P-English 7 pin base, M-metallised, G-metallised golden series and others. Valve brand names in wide use at the time included Apex, Arturus, Cleartron, Cossor, Ediswan, Ken-Rad, Mullard, National Union, Osram, Philips, Radiotron, Sylvania, Tung-Sol, and others. Filament voltages for receiving type valves covered a great range. Typical voltages were 1.1, 1.5, 2.0, 2.5, 3.3, 4.0, 5.0, 6.0, 6.3, 7.5, 12.6, 14.0, 16.0, 25.0 and 30.0.

In later years, other classes of valves and base types were introduced, adding to the problems of circuit designers, servicemen, manufacturers and distributors. Designers of valve testers also had to cater for an ever increasing range.

Although the valve was invented about the same time that the semi-conductor in the form of a crystal and its cat's whisker was first used as a detector in radio receivers, valve technology made tremendous advances in the 50 years of its reign, while the solid state device remained dormant over most of that period.

However, science marches on, and with a major breakthrough in the discovery of the transistor in 1947, and the subsequent rapid advances and refinement in solid state technology, the valve was rapidly replaced, not only in broadcast receivers, but in nearly all areas of electronics. By the early 1970s, solid state devices had completely replaced the valve in broadcast receivers and by the 1980s was firmly entrenched in transmitters.

There are a number of reasons why the transistor replaced the valve. These include greater reliability, long life, lower cost, less heating, smaller size and low voltage requirements. The fragile nature and large physical dimensions were frequently a problem with the use of valves in equipment subject to heavy vibration such as in motor cars, aeroplanes etc. An examination of some equipment shows the use of spring loaded clamps and stocking-type net material being used to hold the valves in position and to dampen vibration.

The transistor consists essentially of a piece of prepared semi-conductor to which three leads are attached, so physically it differs in conception from the thermionic valve. Whereas the valve requires the passage of electrons from a heated cathode to the anode within an evacuated envelope, in the case of the transistor, the electronic action occurs within a solid substance.

Although there are a number of other important differences between the valve and the transistor, the fact that the transistor does not require a heater, the saving in power requirements as a result is probably the greatest boon resulting from its employment in electronic apparatus.

The name transistor was derived from 'transresistor' for 'transfer resistor'. It is made from silicon or germanium crystals that are usually formed into a junction or sandwich. A significant difference between the valve and the transistor technology is that the valve amplifies voltage, while the transistor amplifies current.

One of the first successful receivers employing all transistors was assembled by staff of USA company Texas Instruments during 1952. It was an experimental model but it proved that the technology could be applied to radio receivers. However, it was some time before companies throughout the world were in a position to begin commercial production. In 1955, a Japanese manufacturer released the first model under the Sony label, and two years later, with the help of miniaturised components, produced a so-called 'pocket radio'.

The first all transistor produced commercially in the UK was Model 710 an eight transistor receiver manufactured in 1956 by a subsidiary of the large company Pye Radio Ltd. Although costly compared with a valve portable battery operated set, one Adelaide importer ordered six to 'test the market'. None reached the public. They were all sold while 'on the water' to academics.

Because many manufacturing problems were encountered with the production of silicon, early mass produced transistors employed germanium.

By the end of the 1960s, germanium and silicon transistors were being produced concurrently with each being used for a particular application. Silicon devices could operate at temperatures about 50° higher than germanium types but germanium transistors had a number of advantages for AF output stage working and they could be easily matched in complementary pairs for complementary pair push-pull output stages. Silicon planar transistors had wide application in radio receiver RF stages.

It is of interest that silicon which played such a significant role in the development of the transistor was one of the earliest crystals employed for detection of wireless telegraphy signals. Among well-known detectors used in 1910 when the valve was born, was the Ferron detector used on some ships which visited Australia during the period, even though there were no stations in full-time operation. The Ferron was the trade name for a silicon crystal mounted in a nickel plated cup mounted on the base.

Historical records reveal that a Ship's Operator in Port Arthur, Texas, copied spark signals from a ship in New York, more than 1000 miles (1600 km) away using a Ferron silicon detector. A Ferron detector was on display in the Adelaide Tele-communications Museum prior to closure of the Museum in late 1992.

Just as there was a variety of types of valves in service such as diodes, triodes, tetrodes, pentodes etc, there are a range of transistors including bipolar transistor, field effect transistor (FET), junction FET and metal oxide silicon FET (MOSFET). Transistors can also accommodate large amounts of power and by combining many power transistors, it is theoretically possible to build a transmitter of unlimited power. The commissioning of the 50 kW fully solid state transmitter for 3WV during 1988 bears witness to the rapid progress made in building high power transmitters with transistors. Other 50 kW valve transmitters in the NBS were progressively replaced by solid state units. With valves, various means are employed to remove heat, but with the transistor heat sinks are used where necessary. Most heat sinks are made from extruded aluminium and come in a variety of shapes and sizes. Whereas a power valve requires a high voltage and draws low current, a power transistor requires low voltage but draws high current. The input and output impedances of high power transistors are very low, whereas valves are high and this is another area requiring a different approach in circuit design.

Receiver manufacturers used imported transistors in the late 1950s, but a number of companies soon established facilities in Australia to take advantage of the anticipated demand for the new technology. They include Philips, AWA, STC, Fairchild and National Semiconductor who established facilities for either making and assembling germanium transistors or assembling silicon transistors from imported chips. However, production costs were too high to compete with imported products and output steadily declined until by 1975, only STC and Philips were still carrying out local assembly. Within a few years they also closed down operations.

STC was the first major Australian company to become involved in the manufacture of the new solid state devices. In 1955, the company commenced process design and development for the manufacture of germanium devices and began manufacture of germanium transistors in 1956. This manufacture involved every step from zone-refining the basic material and drawing the single crystal ingots to sealing the finished devices in their cases, and required a high degree of scientific know-how and technical skill.

Notwithstanding the great advantages of the semi-conductor, public demand for the device was well below expectation. Even large organisations with considerable investment in the electronics industry were slow to take up the new technology.

In order to create an interest amongst radio and electronics enthusiasts, STC developed circuits and provided them to technical magazines for publication. Kit sets were produced for a simple broadcast receiver and these met with good demand.

Because of certain limitations with devices based on germanium, particularly transistors and their poor performance at high frequencies, overseas manufacturers switched to the use of silicon. However, this involved a totally different approach to manufacturing techniques. The changeover cost was expected to be very high, so STC made a decision to close down its germanium plant in 1962.

A few years later, in order to meet a requirement for high performance silicon transistors for radio and carrier equipment, STC set up a manufacturing plant at the Liverpool site using technology developed by the ITT company in USA. The facility produced metal can silicon transistors and plastic encapsulated low power silicon diodes. Production equipment was installed during 1966 with product output commencing the following year. Output catered not only for STC requirements but for a number of major Australian customers as well as some overseas customers.

AWA and Philips were also active in the semi-conductor business with both planning to be involved in integrated circuit operations. AWA was the first to produce an Australian made integrated circuit when a unit was produced in 1967. The company had formed AWA Micro-electronics Pty Ltd (AWM) in 1965 in anticipation of becoming involved in microcircuit technology.

In 1967, AWM was awarded a major contract by the then Australian Department of Supply. This contract ensured there would be a local source of microelectronic design and manufacturing expertise to serve the special needs of Defence and other Government electronic requirements. Over the period of the contract, AWM was able to develop to the stage of economic commercial production.

In 1968, Graham Rigby was appointed to head the IC design and development group. He also maintained a part-time position of Lecturer at the University of New South Wales.

Graham received the Degree of B.Sc. (Physics) in 1961 and M.Sc. (Electrical Engineering) in 1963 from the University of Melbourne. During 1963–64 he as an Assistant Lecturer in Electrical Engineering at the University. He then went to USA where he received his Ph.D. from the University of California at Berkeley and was Assistant Professor in Electrical Engineering there from 1966 to 1968. During this period he held temporary and consultant positions with a number of major firms including Westinghouse Corporation, Bell Telephone Laboratories, Fairchild Instrumentation and Signetics Group. He returned to Australia in 1968 to take up a position with AWA.

For the next twenty years, AWA continued to operate a micro-electronics fabrication facility at its plant at Rydalmere where customers requiring silicon chips to meet their specific needs were able to arrange for the design and production of such custom design devices. In that period, more than two hundred designs were produced by AWA including integrated circuits for Defence, cardiac pacemakers and digital telephones.

In 1985, AWA acquired rights to design software developed by RCA in the United States and invested in computer systems to speed up the custom design process. The Company also took over from CSIRO the highly successful Australian multi-project silicon chip system whereby Engineers were able to design a chip to meet their own concept and requirements, using AWA's tools. This ensured the continued supply of high quality, special purpose silicon chips for prototype purposes at a fraction of the normal production cost.

It became apparent however, that although the expanded design centre operated well, its capability was not matched by the manufacturing facility. In 1987, AWA's Board approved a major investment to replace the microelectronics manufacturing facility with a new facility, to be located in the Technology Park at the Australia Centre in the Sydney suburb of Homebush. This was a joint venture with AWA as the senior partner, the other parties being British Aerospace (Australia) Ltd and the New South Wales Government through the NSW Investment Corporation. The Company was incorporated in July 1987 as AWA Micro-electronics Pty Ltd. The facility became operational in 1988 and was officially opened by Prime Minister Bob Hawke in March 1989.

The new facility was the first in Australia to be able to design and manufacture Application Specific Integrated Circuits (ASIC's). One of the key features of the plant was the highly sophisticated clean room where the silicon wafers were made. Cost of the clean room and associated services was $3 million.

In 1991, AWA reduced its equity interest to 46.2 % and Intaq Microelectronics Pty Ltd acquired the shareholding of British Aerospace (Australia) Ltd.

The AWAM facility offered a complete service covering design, mask manufacture, wafer fabrication, assembly and test of ASIC's. It was highly specialised and unique in Australia with the yields and quality attained from the plant being comparable to world leaders in this field. The facility serviced the needs of Australian and international customers for the design and manufacture of computer chips, with particular focus on medical technology such as pacemaker and bionic ear implant technology.

By 1992, AWA Microelectronics had reached the stage where it could hold its own with overseas groups when it produced its five millionth chip and was supplying companies in the USA Silicon Valley. The factory production line was working three shifts a day, five days a week and was planning for seven day operation.

In 1994, it was reported that a long range strategic and financial plan indicated that the business would achieve a positive cash flow and an operating profit within two years.

Unfortunately, the plan did not produce the returns predicted and losses increased rapidly. Before the end of 1995, decision was taken to sell the operations to the USA based chip designer, Quality Semiconductor Inc. AWA entered into an agreement with the new owner for the joint development of products and technologies.

Another company associated with semi-conductor application in Australia was Rutherford Electronics, Australian Agent for USA firm National Semiconductor. In 1971, the company operating as NS Electronics Pty Ltd established a factory at Bayswater near Melbourne and began the manufacture of transistors in April of that year with plans to commence IC production employing imported wafers after fabrication.

By 1973, two Australian based companies had silicon IC diffusion plants, four had IC assembly lines and at least six were developing or had established hybrid microcircuit facilities.

The introduction of the transistor in the 1960s did not bring with it the same enthusiasm amongst 'do-it-yourself' home constructors as the valve did in the 1920–30s.

In Adelaide alone, in the mid 1920s there were more than 100 licensed Radio Dealers selling receivers and radio components to meet the needs of a relatively small population at the time, but today, the number of radio component suppliers with large stocks would be less than a dozen, even though the population is now very much greater. Very few Amateur station operators today construct their own transmitters and receivers from basics.

When transistors became widely available from about 1960 many radio enthusiasts started off in a small way to try out the new technology. Typical early designs included the addition of an AF stage to a crystal set by feeding the output of the crystal set via an 8MFD capacitor to a Mullard OC71 transistor. An additional AF stage with an OC72 or OC71 enabled sufficient output under some circumstances, to operate a small loudspeaker.

The more adventureful experimenters undertook design of receivers with a reflex circuit employing one or two transistors and a crystal diode. Typical transistors imported from England at the time included OC44, OC45, OC71, XA102 and XA101. The GEC GEX 34 was a widely used crystal diode.

Other simple designs included a single transistor receiver with OC44 or OC45 transistor and a three transistor TRF design employing GEX 34 crystal diode, one OC45 transistor and two OC71 types. Coils were wound on ferrite rods.

After successfully constructing these simple designs many enthusiasts soon graduated to the assembly of superheterodyne designs. Kit sets were readily available from a number of sources.

The development of printed circuits soon led to the assembly of receivers on printed circuit boards rather than a wired up chassis format. The printed circuit incorporated much of the wiring printed in copper on a flat insulated board. The laminated plastic panel acted as a chassis or component mounting panel as well as carrying the circuit as copper lands.

One of the interesting aspects of broadcast engineering has been for some features of the technology to wax and wane over long periodic cycles. Many components, devices and equipment were developed before their time, only to reappear in later years as the technology advanced.

Some technological transitions took place gradually, with the pace and the phase-in process in most cases being governed by how improved the new technology was compared with the earlier method, particularly in terms of performance and cost effectiveness. Noteworthy cases include condenser microphone replacing the carbon granule type, electric recording replacing acoustic method, superheterodyne circuit replacing TRF and others, magnetic recording replacing mechanical transcription, stereo replacing mono, vertical radiator replacing T and other type aerials, compact disc technology eliminating the need for electro-mechanical pick-up, vapour phase cooling replacing high velocity water for transmitting valves, solid state device replacing the thermionic valve and now digital technology has appeared on the scene to challenge analog technology.

The solid state transition is not yet complete. Designers of high power valves have not thrown in the towel. Although solid state transmitters of 50 kW power output have now replaced 50 kW valve types in the MF NBS network, the high power short wave transmitters in the Radio Australia and HF Inland Services still employ high power valves, mainly on the basis of cost-effectiveness.

Although electronics education courses these days concentrate on solid state technology with only passing reference to thermionic valves, it is not certain by any means, that valve technology will be all but a memory in a year or two. One overseas designer had predicted that high power valve transmitters will remain competitive into the 21st century.

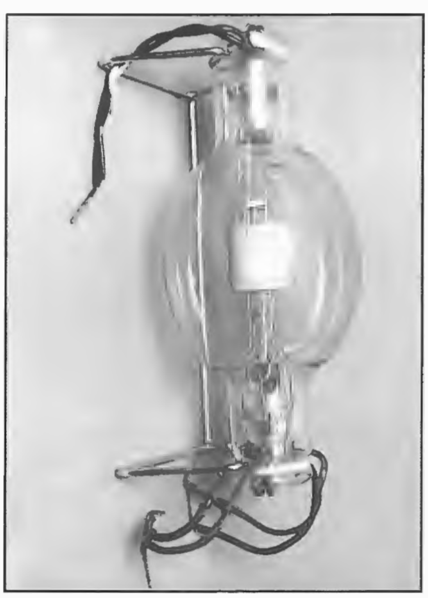
Techno-sparring between the two camps of designers enhances incentive towards excellence on both products and application, and Broadcast Engineering benefits from it all.

In the hi fi audio equipment field, several overseas manufacturers have been developing top performance units employing valves. During 1995, many models appeared on the market including some very highly priced to meet an increasing demand for this type of equipment.

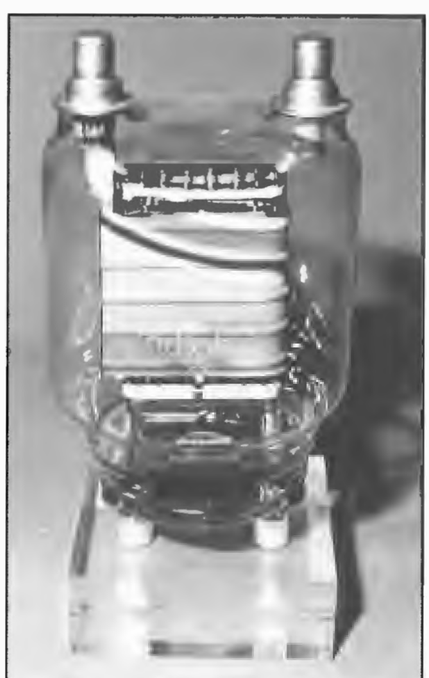
Philips QB2/75 screen grid transmitting valve with oxide coated filament and maximum anode voltage of 2000 volts. Anode dissipation was 75 watts. Commercial station 3BA employed one of these in the final stage of the transmitter when it was commissioned on 31 July 1930. The transmitter produced 50 watts into the aerial. Manager and Station Engineer Warne Wilson, Operating Engineer, Alf Kerr.

Philips TC04/10 valve widely employed in low power Commercial transmitters in the early 1930s, and known as a 'horn' valve due to its appearance. This valve was used in the crystal oscillator buffer stage at 3WR when the station went on air in January 1931, producing 50 watts into the aerial. Station 3WR originally went to air on 25 February 1925 but closed down on 22 December of the same year as a public broadcasting station. It began again on 5 January 1931 with new studio and transmitting facilities designed by Les Glew and manufactured in the Melbourne workshops of Oliver J Nilsen.

The 866/866A hot cathode mercury vapour rectifier was one of the most widely used rectifier type valves in Commercial and National transmitters from the early 1930s. It was rated at 1 ampere peak anode current and 10000 volt inverse peak. This valve was employed in the medium voltage rectifier circuit of VLQ short wave transmitter STC type A880A commissioned at Bald Hills on 17 February 1943. Officer-in-Charge of installation, Arthur Clark.



Typical radiation cooled transmitting valve used in the early 1920-30's known as 'football' valves. The valve was mounted vertically in a cushioned bracket keeper and the flexible leads were inserted in standard brass clamping terminals.



The Radiotron 833/833A valve was one of the most widely employed valves in AWA transmitters for many years going back to the late 1930s. The valve was a power triode with all four terminals protruding out of a specially designed envelope. For Class C telephony it provided a power output up to 630 watts. This valve was used in the 3CS transmitter installed in 1952 by Chief Engineer, Roy Streeter.

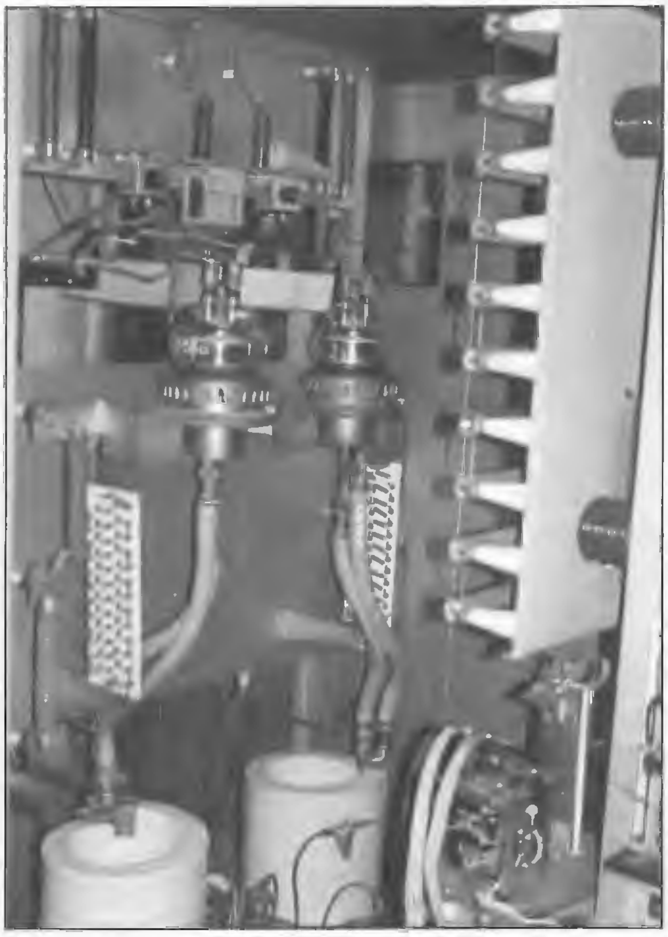
The 4030C water cooled modulator valves used in the original 100 kW transmitters at Radio Australia, Shepparton commissioned 1946. Two valves were in service with a spare pair on standby with filaments and grids being switched into circuit by means of mechanically operated and electrically interlocked change-over switches.

Construction of the two 100 kW transmitters was a joint STC/AWA effort with AWA constructing the modulator with Joe Reed as Project Engineer.

Final stage of 4QN Clevedon STC 6.25/7 kW transmitter commissioned in 1936. The stage employed a pair of 4220B water cooled valves with two on standby in spare sockets. The stage was a Class C amplifier with a pi type circuit terminated in a 600 ohm transmission line. The 12 kV EHT supply for the valves was supplied by a rectifier system employing three 4222A water cooled rectifiers.

Installation Foreman Mechanic, Reg Baker. First station Officer-in-Charge, Les McDonald.

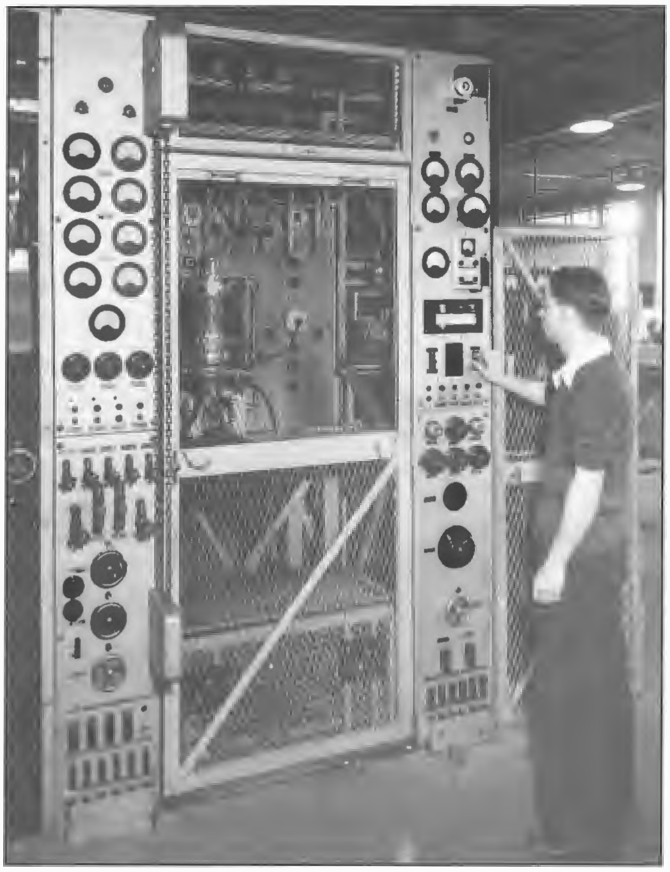
Federal/ITT power triode transmitting valve type F124A used in the power amplifier stage of the two original 100 kW transmitters at Radio Australia, Shepparton in 1945. Each transmitter used four F124A valves in push-pull parallel configuration. The filament of these water cooled valves was pure tungsten and valves had an average life of 6500 hours of operation. Commissioning Engineer, Tony Brettingham-Moore.



Modulator stage of RCA 50 kW transmitter installed Radio Australia, Shepparton 1944. The Class B modulator stage employed two water cooled 880 type valves capable of producing approximately 40 kW of audio output. Cooling water was circulated by duplicate pumps and cooled by an air blast heat exchanger. Isolating ceramic helics were used to isolate the valve anodes from ground. The transmitter remained in service until 1991. First Officer-in-Charge, Jack Hargreaves.

Typical large forced air cooled transmitting valves. (L to R): Ediswan ESA5000, 3J/261E and ML899RA. The Ediswan ESA5000 was a direct replacement for the American ML899RA and both were used with 10 kW transmitters installed at Radio Australia in 1945. The 3J/261E was used in the modulator and power amplifier stages of STC 55 kW MF transmitters installed at many National stations.

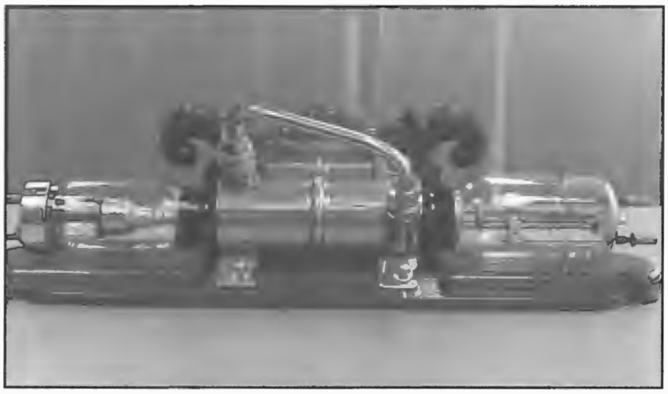
Water cooled transmitting amplifier and rectifier valves used with National transmitters. (L to R): Philips DA12/15, STC 4220C, Federal/ITT 124A, STC 4222A and (front) STC 3Q213E. The double ended valve 3Q213E replaced SS1971 types in 4QR and VLQ transmitters when SS1971 types were no longer manufactured. The first National transmitter provided with water cooled valves was 2NC Newcastle commissioned on 19 December 1930 by Engineer Harry Weir.



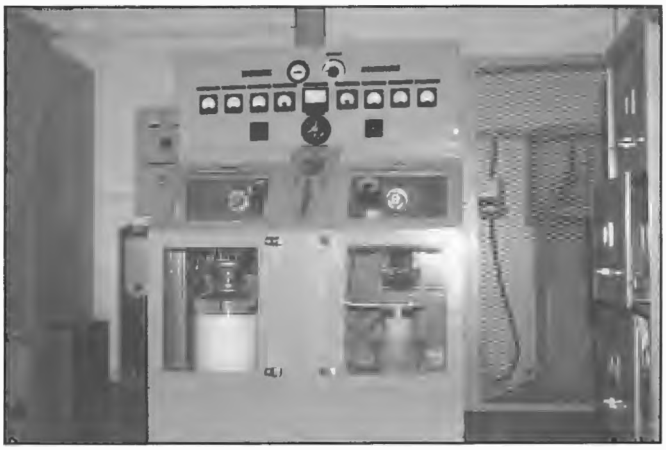
Standard Telephones and Cables Ltd manufactured many of the large valves used in its broadcasting and communications transmitters. The photograph shows the exhaust station for a radiation cooled valve rated at 1250 watts anode dissipation.

One of the company's senior staff associated with valve design and manufacture was Tom Basnett who joined STC in 1942 and left in 1964, two years after closure of the valve manufacturing facility.

A 4279Z valve being examined by Ray King alongside one of two STC 2 kW type 4-SU-14 transmitters installed at NBS station 4QY Cairns. When commissioned on 20 January 1950 the power amplifier and modulator stages were each equipped with a pair of 4279A type valves. The valves were subsequently replaced by 4279Z types manufactured by STC in their Sydney valve factory. The station was closed down during April 1997. First Officer-in-Charge, Eric Gough.



A mounted double ended water cooled valve 3Q213E as employed with early STC 10 kW 4QR/VLQ Brisbane transmitters as replacement for original SS1971 type valves and presented to Doug Sanderson on the occasion of his retirement in 1989. Doug was an Engineer with Postmaster General's Department/Telecom and spent most of his career extending over 48 years with the National Broadcasting Service.



Valve conditioner designed by Bill Gold and installed at NBS Metropolitan Transmitting Centre 5CL/5AN Pimpala shortly after the station was commissioned in 1961. It was designed to condition valve types 3J/261E and 3J/192E used in the STC 55 and 10 kW transmitters. Altogether there were five 3J/261E and eight 3J/192E types in a working 55/10 kW combination. Although these valve types were replaced with Philips types in later years, the valve conditioner continued to be used as originally intended with only minor changes. It continued operation until the STC transmitters were replaced by solid state types in late 1994.

Large hot cathode mercury vapour (HMCV) rectifiers were employed with transmitters 10 kW and above for many years. Types included 857B with 50/100 kW units at Radio Australia, Shepparton, 2V/561E in STC 50 kW units and 4078A in 10 kW units. They were usually installed in groups of six, frequently with one or two spares to enable rapid connection into circuit in the event of a working valve failure. They were first employed in the late 1930s but from the mid 1960s HCMV rectifiers were gradually phased out in favour of semi conductor units.

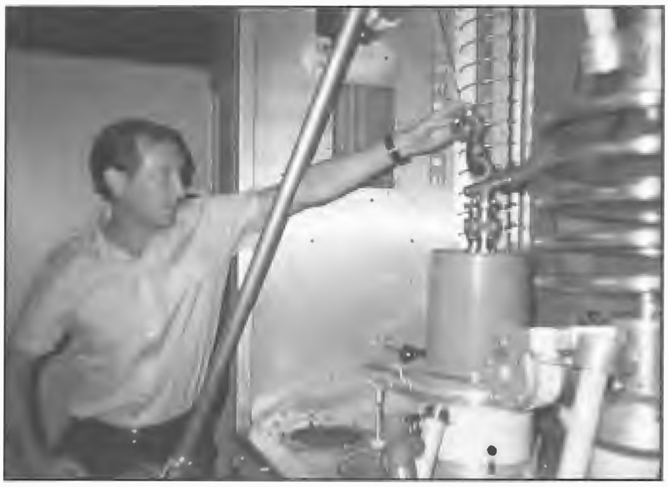
Machlett ML6427 forced air cooled valve employed in modulator and power amplifier stages of short wave station VLW Hamersley, WA with STC 50 kW HF_transmitter. A total of four were used in the transmitter. Filament power 8 volts at 200 amperes and EHT 9 kV. The mounting of cooling fins horizontally was unusual in air cooled valve technology. Normal service life about 15000 operational hours. STC Engineers associated with development and manufacture of the transmitter included Phil Humphries and Clive Pickup.

Eimac 4CV100000C vapour phase cooled tetrode valve, first employed at Radio Australia, Cox Peninsula in 1961 but now used at other high power short wave stations in Australia. In the transmitter, the valve sits in a boiler unit.

Above right: Display set-up of 4CV100000C vapour phase cooled valve and boiler unit employed with Collins 250 kW transmitters Radio Australia, Cox Peninsula. Two valves were used in the PA stage and two in the modulator stage. Water entered the boiler at the bottom and steam resulting from the water being boiled by heat transfer from the valve anode passed out via an insulated tube to a condenser unit mounted outside the building where the steam condensed back to water and returned to the water supply reservoir. Regular transmissions introduced December 1969. Collins on site Engineer, Charlie Pierce.

Right: Type CQS200 vapour cooled ceramic tetrode used in final stage of 250 kW Brown Boveri short wave transmitter installed at Radio Australia, Carnarvon in 1976. The station was established to provide service to South East Asia following severe damage to the Cox Peninsula station from Cyclone Tracy. The Carnarvon station was closed down in July 1996. First Officer-in-Charge, Jack Clugston.

Valve type CQS50 ceramic tetrodes in push-pull in the modulator stage of the 250 kW Brown Boveri transmitter at Radio Australia, Carnarvon. The modulator employed conventional high level modulation with modulation transformer and choke. Transmissions commenced 20 December 1975. Murray Little and Trevor Chapman were members of the installation team.



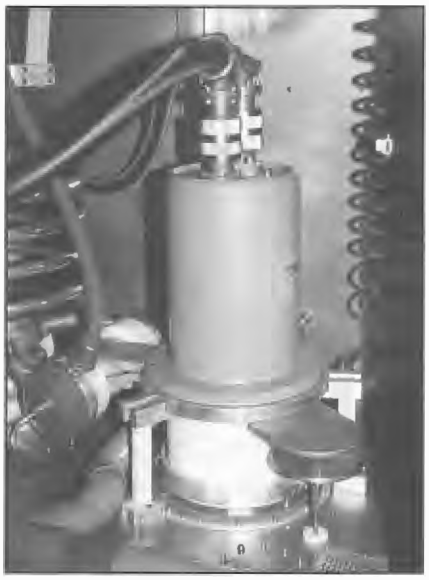
The replacement of bulky and heavy transmitting valves has been a problem with maintenance staff for many years. However, today only high power HF transmitters in Australia use large valves for radio broadcasting purposes. All stations were equipped with lifting facilities to enable replacement of a valve by a single operator. Photograph shows Phil Leaney operating a lifting device for replacement of a Thomson TH573 valve in a 300 kW Thomson transmitter at Radio Australia, Carnarvon before closure of the station in 1996.

Water cooling equipment for valves and capacitors with the 300 kW Thomson-CSE TRE2320 transmitter installed at Radio Australia, Carnarvon in April 1984. Prior to closure of the station in mid 1996, the transmitter was the most powerful in the Radio Australia service. Officer-in-Charge at close down, Les Fancote.

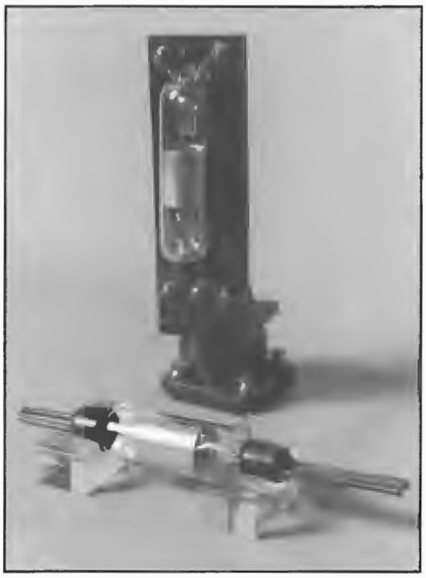
The GEC BR189 air blast triode which replaced the water cooled 4030C modulator valves in the Radio Australia, Shepparton 100 kW transmitters. The original transmitters were taken out of operational service in 1984 when Bruce Wilson was Officer-in-Charge.

Carburising the filament during rebuilding of a transmitting valve at AWA works, Sydney 1987. The filament was flashed in a hydrocarbon vapour bell. The process ensured correct hot filament resistance and electron emission level and stability during service life. The company operated a rebuild service for some types of transmitting valves.

As part of a valve rebuild operation, grids were concentrically lined up with respect to the filament strands to ensure correct electrical characteristics. Rebuilt valves gave comparable operating life at less than half the cost of a new valve.

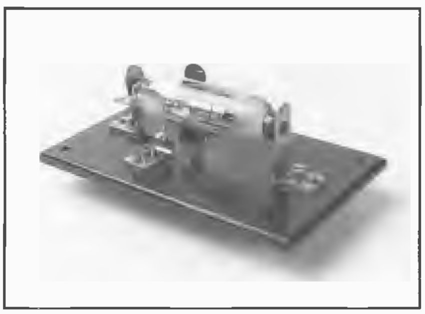


Valve type TH558 employed in two 250 kW HF Thomson-CSF TRE 2326 transmitters installed at Radio Australia, Cox Peninsula in 1993. It was the only valve employed in the transmitter and was a ceramic-metal tetrode of coaxial structure employing patented Hypervapotron anode cooling technology. The valve had a maximum anode dissipation of 500 kW. Water jacket inlet and outlet connections were on the top of the valve. Project Engineer, Ralph Baker. Transmissions ceased on 30 July 1997 and the station placed on a caretaker mode with maintenance staff.



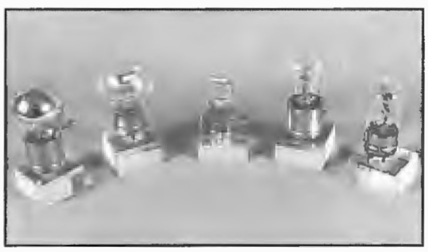
The first Australian designed receiving valves were manufactured by AWA in early 1921 and designated Expanse B. They were employed in ship's wireless equipment and at Coast Radio Station receiving systems. The valves were double ended with twin filaments. End caps provided protection for the glass at lead exit points. A note found with the valve on the vertical mount indicated it was one of a consignment imported by AWA from a USA manufacturer in 1920 and designated Expanse A using a paper label glued on the valve.

A collection of double ended receiving type valves used in Adelaide by Bill Bland circa 1923 with his experimental station 5AG. Notes found with his papers indicated he had at various times acquired valves manufactured by Lee de Forest, Elmer Cunningham, Harry Roome and Otis Moorhead in USA; Expanse from AWA and an Annaka brand valve from a Japanese ship's wireless operator during a visit to Adelaide. Bill Bland was involved in experiments with broadcasting technology from about 1920 and in 1927 established Bland Radio, a major receiver manufacturing company in Adelaide.



The Marconi Q valve was a companion of the V24 developed by Captain H J Round of the Marconi Co., in 1916. To overcome the high inter-electrode capacity problems of valves then in use, he used a cylindrical bulb bringing out the axial filament leads at opposite ends, while anode and grid were brought out to small caps at opposite ends of a diameter. The Q valve was employed in an AWA transmitter in Sydney providing the first public demonstration of broadcasting in Australia on 13 August 1919.

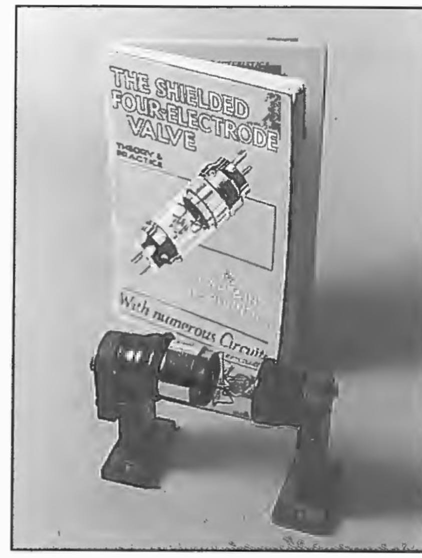
The transmitter had been developed by AWA staff George Apperley, Bill Bostock and Eric Burbury for earlier ship-to-shore telephony tests.



Philips receiving valves early 1920s manufactured in Holland. Although some valves had been made as early as 1918, it was not until 1922 that large numbers were produced. Nine new types were made in that year. Popular valves of the period included E type, BII type, DIV type, DVI type and BVI type. Philips valves were sold by many Australian Radio Shops.

These two valves manufactured in France were employed by Roy Cook an Adelaide experimenter with his station A5AC on the occasion of one of the first 'live' music broadcasts in South Australia. It was the broadcast of a concert by the Tramways Band in 1923 with the band being assembled in Roy's home for the broadcast. The clear glass valve Metal TM (L) was employed in the transmitter with filament voltage 6 volts and anode voltage 350 volts. The cobalt blue glass valve Fotos TM (R) was used in a one valve AF amplifier which followed a crystal receiver circuit. The receiver was set up in the home of a friend and fellow experimenter Ern Stanton in another suburb to monitor the broadcast.

The Loewe valves made in Germany in 1926 were unique in that they contained within the evacuated bulb, not only three separate valve electrode assemblies but also the resistors and capacitors required for a three valve receiver. Each capacitor and resistor was individually sealed inside a glass phial. Many of the receivers with the valves were brought to South Australia by German migrants who came to work in the vineyards of the Barossa Valley.



The screen grid valve type S625 was developed by Captain H J Round of the Marconi Company in England. It overcame a major problem being experienced at the time with triodes in RF amplifier circuits. It was released in 1927. By 1928 factories began to manufacture receivers incorporating the valve. A book was published describing the theory and practice of the valve and provided recommended circuits. Hartleys of Melbourne was one Radio Shop which stocked the valve.

The valve shown was used in a five valve receiver made by James Cook a member of the Malvern Radio Club in Melbourne.

Left: One side of a display cabinet housing a selection of receiving and small transmitting valve (tube) cardboard cartons. To minimise damage during transit from the manufacturer, the valve was usually wrapped in several layers of soft paper, suspended in a small support frame made from corrugated cardboard or the carton stuffed with coarse animal hair, shredded paper or cotton wool.

Typical batteries provided for battery powered receivers. Two or three 45 volt B batteries were usually required to provide high tension for anodes. The C battery provided negative bias and the Masse accumulator provided filament power for valves requiring 2 volts. Masse accumulators were available from all Harringtons Ltd Radio Shops.

Hellesens 60 volt dry cell B battery imported from Denmark and purchased December 1925 from Norwood Radio Depot, Adelaide as a Christmas present. The 60 volt unit was available as 'ordinary' or 'oversize' models with the oversize model costing twice as much as the ordinary model.

This 6 volt CAV accumulator in carrying case was purchased from a Melbourne Radio Shop in 1927. It had been imported from England and comprised three 2 volt cells with screw type terminals so that it could be used to provide 2, 4 or 6 volts depending on filament requirements of the valves in the receiver.

It was used by a Port Melbourne listener with a five valve Stromberg-Carlson receiver purchased from M Brash and Co.

GE tungar battery charger used to charge A or B lead acid batteries. They were available in 2 and 5 ampere capacities. Tungar was a trade name for a two electrode valve specially designed for rectifying purposes. They were made in USA by General Electric Company and distributed in Australia by Australian General Electric. The agents claimed that 70000 units were distributed to Radio Shops and garages in Australia in 1926. At the time there were 128000 licensed receivers.

Pocket voltmeters and ammeters were widely used in the early 1920s for servicing receivers and particularly for testing batteries. Some measured voltage only while others were combined voltmeters/ammeters. Many were double scale types. They could be used for testing continuity of coils or transformers with the aid of a battery but most servicemen preferred to use a buzzer for this work at the time. These instruments used in workshop of Harris Scarfe Ltd, Adelaide.

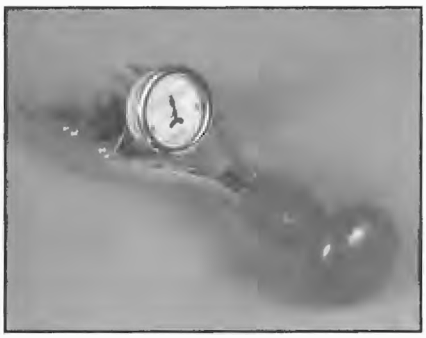
Philips High Tension Supply Unit Type 3003, 1930, commonly known as B & C battery eliminator. It employed 506 type valve as full wave rectifier and 3006 type valve as half wave grid bias rectifier, protected by removable steel cover. Anode voltage adjustable from 150 to 210 volts and grid bias voltage adjustable from 0 to –40 volts.

Jewell Tube Tester No 107 imported from USA 1925. It had limited application, testing for mutual conductance only. A chart under the base was used to assess the condition of the valve. Adaptors were available for testing more than one type of valve.

Instrument purchased from Home Radio Service Ltd, Brisbane, the Queensland distributors of Jewell radio instruments and meters.

The Jewell analyser was typical of a number of test instruments employed by radio servicemen in the early 1930s. Compactness was made possible by calibrating one AC and one DC meter for several scales. Push buttons changed the connections to set up automatically, any of the numerous circuit arrangements possible.

This analyser was one of the many test instruments in the laboratory of Melton and Co., Brisbane in 1930, manufacturers of Crammond brand receivers.



The Boss cell tester was designed to test individual cells of lead acid A batteries. It placed a low resistance across the cell terminals and the meter indicated the voltage drop. It provided a more accurate assessment of the condition of the cell than a normal high resistance voltmeter.

Left: The Calstan valve tester was manufactured by Slades Precision Test Equipment, Croydon. The company, set up by Charles Slade commenced manufacturing precision test equipment in 1931. The word Calstan was derived from CALibrated to STANdard. Separate valve testers gradually gave way to multitesters so that radio servicemen could carry out measurements and tests, including valve tests, with one instrument.

This instrument used for instruction purposes at Marconi School of Wireless.

Chapter Six

Broadcast Receivers

Development

Broadcasting Requirements

Although the radio receiver is no longer the centre of entertainment in the home, having been replaced by television, home videos, compact discs and the like, it held that position for about 40 years. Nevertheless, it is still king at those times when this restless society demands entertainment while on the move such as travelling in the car, working the harvester in the vast paddocks, gardening outdoors, jogging in the park, or for talk-back to voice an opinion etc. The number of receivers outnumbers the population by about 9 million. About 71 % of people live in households with at least four radios.

Even before broadcasting began officially in 1923, home radio receivers, either in kit form or fully assembled, were readily available. However, those sophisticated products of technology did not spring up overnight. Like transmitters, they were the result of considerable development and research over a long period of time going back even before 1896 when Guglielmo Marconi received his patent for a practical system of wireless telegraphy.

The concept of broadcasting as we know it today, was the brainchild of David Sarnoff in the USA in 1915 and when it became a practical reality about five years later, the receiver developed for the home took on a different format from that used in the commercial fields of wireless telegraphy and radio telephony. The design had to cater for the fact that the home receiver was to be operated by a person without any knowledge of the technical aspects of radio, it had to be simple to operate, be safe, be powered by a simple arrangement of batteries and most importantly, its appearance had to harmonise with other items in the home, particularly the lounge room furniture. However, the major technical challenge to the designer was that the receiver had to be capable of reproducing music of high quality and that the program be heard by a group of people. This contrasted with the wireless telegraphy situation which required the reproduction of a single tone or at the most, a narrow band of frequencies to be heard by a single person using headphones.

As part of its plan for the introduction of broadcasting, the Government placed restrictions on the type of receivers which could be employed in the home for reception of the station programs. The receivers had to be so constructed that they could operate only on fixed predetermined wavelengths. A fee had to be paid for each wavelength that the unit could receive. The arrangement became known as the Sealed Set Scheme, and meeting the technical specifications required by the PMG's Department was a difficult task for manufacturers and importers. In fact, within about six months of the commencement of broadcasting, only 61 designs out of 154 submitted had been approved by Departmental inspectors. To add to the problem of Australian receiver manufacturers, high royalties demanded by AWA who held many important patents, meant that in order to reduce the cost of producing a receiver, the number of valve sockets had to be kept to an absolute minimum. The result was that the majority of the designs were crystal sets, crystal set plus one valve, single valve, two valve and three valve models. They performed poorly, gave low output and were expensive. Little wonder then, that by mid 1924, only 1206 Broadcast Listeners Licences had been issued throughout Australia. Because of the low income from their share of the licence fees, the operators of the broadcasting stations were soon in financial difficulties.

The receiver designer's job was not an easy one. Solutions were not easy to come by. Economics was a major consideration and often compromise followed compromise. Noise was tolerated at first because of the novelty aspect of broadcasting and the magic of it all. However, listeners soon demanded improvement in receivers to give better quality. They had grown up with the gramophone and expected quality at least as good.

There was a great number of radio magazines in production during the 1920s and each had favourite receiver circuits which were improved with every issue. Such was the demand for knowledge in the new science that some magazines came out on a weekly basis. Typical, was 'The South Australian Wireless and Radio Weekly' published in Adelaide in 1925–26. In addition to magazines published in Australia, many were imported from England and USA.

Typical of circuits which appeared in magazines was the Type 103 Triple Magnifying Valve Receiver described by George Apperley in a 1924 issue of 'Radio'. The receiver had been designed and manufactured by AWA as a successor to their P1 receiver and used with ships wireless installations but even though no longer in commercial production when broadcasting began, the circuit was ideal for broadcast reception purposes and many receivers using a slightly modified version of the circuit were constructed by enthusiasts. About five members of the Brisbane YMCA Wireless Club built receivers as a Club project under the guidance of one of the Club's experienced Engineers. The boys found it ideal for reception of 4QG and for listening to Amateur broadcasts on the 200 metre band. One of those who constructed a receiver at the Club was Bill Rohde who later joined the staff of 4QG and in subsequent years became Supervising Engineer Radio in the Postmaster General's Department responsible for National Broadcasting Service stations throughout Queensland.

Such was the demand for information on the many circuit designs and 'do-it-yourself' construction details that in 12 issues of 'The South Australian Wireless and Radio Weekly' between mid 1925 and mid 1926, over 50 designs were described. Most were contributed by local Engineers and technical experts using their names, or various pen names, but interstate experts were also involved. They included the following:

Four Valve Super Reflex (Hal Austin); Reinartz Circuit (Clem Ames); Two Valve Receiver (A E Williams); The P1 Circuit; Reinartz Single Valve (Rupert Baker); Two Valve Reflex (Hal Austin); Three Valve Reflex (Lance Jones); Three Tube Regenerative for All Waves (A E Williams); Four Valve Tuned Anode (Arthur Cotton); Neutrodyne; Two Valve Selective (E Compson Daw); Four Tube Tuned Anode (E Compson Daw); Four Valve Receiver (Joe Reed); Three Coil Three Valve Receiver (Joe Reed); Four Valve Receiver Without Plug-in Coils (Hal Austin); Secret of the Superheterodyne (Fred Oldfield); Two Valve Loop Aerial Receiver (Colin Orrock); One Valve Receiver (Fred Oldfield); Three Tube Selector Circuit (E Compson Daw); Modified Superhet; Autoplex Single Valve

Receiver ('Audion'); Interplex Circuit (E Compson Daw); Modified Flewelling Receiver ('Audion'); Locally Built Superhet (Fred Oldfield); Superselective Single Valve Receiver ('Audion'); Three Valve Neutrodyne ('Audion'); Two Valve Low Loss Receiver (Roy Buckerfield); Five Valve Receiver (Lance Jones); Five Valve Receiver for Long and Short Waves (Colin Orrock); Cheap Two Valver ('Busbar'); Portable Four Valve Receiver (Hal Austin); Three Valve Receiver (George Luxon); Aperiodyne (Fred Oldfield); The Superheterodyne (Bill Bland); Neutrodyne Standard (A Jarrett); Three Valve Low Loss Receiver (Arthur Cotton); Tuned RF Receiver (A F Harper); Good One Valve Receiver (Southern Suburban Radio Club); Neutrodyne Single Control (Harrington); Selective Two Valver (A F Harper); Superselective Four Valve Receiver (Southern Suburban Radio Club); Two Dial Five Tube Receiver (Hal Austin); Neutrodyne Dual Set (R W Brisbane); Toroidal Four (Southern Suburban Radio Club); Selective Three Valve Receiver ('Oscillator'); Conversion of Tuned Anode Receiver (Fred Oldfield); Four Valve Browning-Drake Circuit (Hal Austin); Sharp Four Valve Receiver (Frank Miller); Heteroplex Circuit (E Compson Daw); Unique Receiver (Jack Ferry); and others.

Magazines in other States, particularly in Victoria and New South Wales, were just as active in the publication of data and information on receivers.

Although one valve receivers were popular with the 'do-it-yourself' fans, and could also be purchased as kit sets or fully assembled by many Radio Shops, only a very few of the Australian major manufacturers produced one valve models but they were soon taken off the assembly line. One model made on a commercial scale was Type D1 MAK one valve receiver produced by Newton, McLaren Ltd, Adelaide. A brochure supplied with the unit indicated 'it had a range 50–100 miles (80–160 km) with headphones and if properly handled, concerts could be picked up as far as 200 miles (320 km)'.

One of the major problems designers of receivers for broadcast reception in the home by unskilled people had was to develop a circuit which would provide simple and effective control of the receiver gain.

Receivers produced for radiocommunications purposes prior to the introduction of broadcasting, were usually designed with multiple RF stages which in some models were independent stages coupled together by bridging straps or stages permanently built on a common chassis. To vary the gain of the receiver, and so control the level of the output signal, RF stages were cut in or out as desired, either by switching or with some designs, withdrawal of one or more valves from the sockets. Other designs employed variometer or reaction coils to vary gain. One English manufactured receiver had a switch which rotated over brass studs to cut in or out, up to seven RF stages. Designations above the studs indicated the receiver range. The calibrations were 20, 50, 100, 150, 200, 250 and 300 nautical miles.

The next development was the provision of a rheostat in each filament battery supply lead or a common rheostat to control the current through several valves.

With the introduction of valves which operated with AC powered filaments, rheostats in the filament leads were no longer appropriate. Circuits were developed to vary grid bias on the RF stage valve but this was not entirely satisfactory. One receiver developed by the Marconi Company had seven RF stages with a single potentiometer controlling grid bias to all valves. Other methods employed included variation of the screen voltage when screen grid type valves became available. However, the problem was not satisfactorily solved until 1930 when the variable-mu tetrode became available with a control grid with wire spacing that varied in pitch over its length. It soon became the standard approach for receiver gain control circuitry.

Although battery receivers were available for reception of the early program transmissions, the crystal set was a very popular type. It was relatively cheap to make or even to buy fully assembled, and program quality was reasonably good. To overcome the problem of using headphones and to allow a group of listeners to be entertained, an audio frequency valve amplifier and speaker were added to the crystal set. Unfortunately, the program was badly distorted as a result of deficiencies in the loudspeaker for the reproduction of the signals and the high distortion characteristics of the amplifier. Valves were easily overloaded and transformers used in the amplifier were not suitable for handling a wide band of audio frequencies. Those available initially, had been designed for single frequency operation for reception of wireless telegraphy tone signals or for the restricted bandwidth of the telephone service.

When first marketed, receivers were rarely sold as a complete unit — this even applied to crystal sets. The purchaser bought the receiver, loudspeaker or headphones, complete set of batteries and the aerial kit separately. They were installed according to an installation sheet supplied free by the Radio Shop. These ancillary items could cost as much as the receiver proper. Having a factory built receiver with a large bold nameplate such as Superdyne etc, was often a mark of distinction but it did not necessarily perform any better than one put together from a local technical magazine description or from a kit set.

Many ingenious circuit designs were developed, including so-called straight receivers and regenerative types, but quality remained poor. The superheterodyne circuit made a brief appearance but the high cost was not appreciated by the buying public. To overcome oscillation problems with cascade amplifiers with a number of radio frequency stages, Hazeltine's neutrodyne circuit was trialled and was an immediate success. It held centre stage with the buying public right up to about the early 1930s when the superheterodyne made a comeback and all other circuits in popular use with 'dyne' in their name such as Autodyne, Capacidyne, Cocodyne, Deresnadyne, Filadyne, Homodyne, Islodyne, Neutrodyne, Radiodyne, Solodyne, Tropadyne, Ultradyne, Unidyne and others, many developed to avoid infringement on the Armstrong patent which controlled the use of the superheterodyne circuit, quickly disappeared from the scene. The introduction of improved valves and components did much to consolidate the hold of the superheterodyne circuit for home receivers. The standard eight valve model of the early 1920s could be reduced to three or four valves and result in a receiver of compact size and high performance, not only for the home but also for the car or as a battery operated portable.

Although early receiver cabinets were made from wood with the front panel being usually bakelite, some manufacturers in the USA notably Atwater Kent in 1926, found it to be cheaper to stamp out cabinets of steel and to disguise the material with a two-colour crinkle finish and gold trimmings. When samples arrived in Australia some manufacturers, particularly Stromberg-Carlson and Radio Corporation followed suit. However, the metal cabinets did not prove popular with the Australian buying public and after about 1930, except for car radios, very few metal cabinets appear to have been produced commercially. It has been suggested that consumers perceived wood as having value and warmth. However, it is interesting to note that with modern modular hi-fi systems incorporating radio receivers, that consumers have now accepted metal as an aesthetically pleasing design material in the home environment.

BADGE ENGINEERING

As a result of the introduction of import restrictions at the start of the 1930s by the Government, there was an upsurge in interest by financiers in backing the establishment of domestic receiver manufacturing businesses. Although some of the businesses manufactured components for their own needs, and for sale through distributors and Radio Shops, many were set up to specialise in the manufacture of components only. Some were small organisations while others were very large employing staffs of hundreds of people. The small organisations generally tended to specialise in the manufacture of single components types.

Transformers, chassis, coil cans, resistors, mica capacitors, terminals, aerial wire were some of the components made by small businesses.

The manufacture of kit sets was a growing business right up to the outbreak of the Second World War. It catered for the large number of do-it-yourself constructors and at the same time it enabled possible receiver patent infringements to be bypassed, as the kit set was a collection of components and not a complete receiver.

Many manufacturers set up for mass production catered not only for receivers with their own brand name, but also for large distribution organisations who required chassis or complete receivers to their own badge name and specifications. Some large Department stores employed a small group of technical people to construct or assemble receivers in the 1920s but by the 1930s, they changed to sets badge engineered by the large producers. Well-known receivers such as Mullard, Seyon, Genalex, Hotpoint Bandmaster, Westinghouse, Gulbransen, Philco, Serenada, Prelude, Air Player, Cremona, Vogue, Masterpiece, Sonora, Rexanola, Challenge were badge engineered.

Even some small businesses profited from badge engineering. D Harris and Co., of 140 Rundle Street, Adelaide, ran an agency business and manufactured a small number of receivers, mainly to suit customer requirements. At one stage during the 1930s, business was very slack, and it appeared that some of the staff would have to be dismissed. A representative of the largest Department store walked into Dave Harris' office and asked for a price of a five valve receiver, as the store was considering adding radio receivers to its stock range as a trial. A quick mental calculation was made, and the representative suggested five shillings less than what Dave quoted. Dave agreed, and when the store representative said he wanted 100 receivers delivered over a specified period with their own brand name, the jobs of the staff were saved. One member of the technical staff at the time was John Allan who became a Squadron Leader in the RAAF's Radar organisation during the War. After the War he conducted a small specialist Radio Engineering business.

One company which was involved in badge engineering as its major activity of manufacture was Invincible Radio Company, with Head Office at 12 Castlereagh Street, Sydney and branch office in Brisbane. Standard range of chassis supplied in bulk to Dealers and Department stores included 3–4 chassis, 4–5 chassis and 5–6 chassis. They also manufactured chassis to any specification with an order for eight valve chassis being undertaken for one of the large Pitt Street Radio Shops, followed by an order for six nine valve chassis using a standard Kriesler superheterodyne kit with valve types 46, 56, 57, 58 and 80. Output stage included a pair of 46 valves with the screen tied to the anode at the socket. In this condition, the valve worked after the style of the usual 45 type except that less anode current was drawn, yet the undistorted output was maintained. The aluminium chassis was 18 inches by 12 inches by 3 inches. During the 1933 Christmas period, the entire floor stock of the Radio Shop was sold.

Another aspect of badge engineering was the use of well-known company brands by others when the company ceased manufacturing receivers. The HMV label is typical. When EMI (Australia) Ltd, formerly The Gramophone Co., Ltd closed down its receiver production facilities, Rank Arena was licensed to use the HMV label.

Noise

Although noise is not a major problem with modern receivers, it was of great concern in receivers constructed prior to the early 1930s. Efficient radio frequency amplifiers had not been developed, so that the minimum signal strength on which the receiver could operate was influenced by the efficiency of the aerial system being used, and to the extent of the low frequency amplification produced by the receiver.

Contributors to the overall noise included microphonics, dry solder joints, bad contacts, run down batteries, shot noise, thermal agitation, atmospherics and man-made electrical noise. Microphonics was particularly bad, as it caused an irritating ringing sound. Although vibrating plates of tuning capacitors contributed, valve element movements especially filament wires, were the most troublesome. Many novel valve sockets or holders were developed to minimise the movement of the valve. They were marketed with claims such as anti-pong, anti-vibration, anti-microphonic, pneumatic action and others.

Well-known brands in use included Benjamin Vibroholder, Redfern Pneumatic Action Valve Holder, CAV Helical Spring Socket, Bowyer-Lowe Anti-pong Socket, Security with in-built shock absorbent material, Barries Anti-vibrator, Igranic Anti-microphonic, Cosmos Anti-vibrator, Sterling Non-pong, Emmco Radion Socket with rubber cushioned feet and screws, and others.

In 1935, Stromberg-Carlson announced the development of gang capacitor Type F which reduced microphonic problems encountered in receivers which incorporated short wave bands by at least 90%. It was covered by Australian Patent No 23624/35. The capacitor differed from other types in that the end plates of both rotor and stator were made from much thicker aluminium sheet than that used with the other plates. It was found that 22 gauge gave the best performance for end plates.

The performance of a receiver can also be affected by radiation from external electrical or electronic equipment. Most electrical and electronic equipment, including radio receivers, has capacity to generate unwanted disturbances in the form of Electromagnetic Interference (EMI).

In January 1996, Australian Government legislation introduced the Electromagnetic Compatibility (EMC) Framework, a regime to ensure the satisfactory co-existence of electrical and electronic equipment. Implementation of the EMC Framework regulations was placed with the Spectrum Management Agency. The Framework involves a set of standards and compliance arrangements aimed at minimising the problems of electro-magnetic interference and their effects. From 1 January 1997, new products have to comply with the regulations.

An important part of the EMC Framework is the appointment of Competent Bodies by the SMA to fill a defined role which includes the assessment of Technical Construction Files (TCF's) and if appropriate, to certify equipment as compliant with the EMC Framework.

As at mid 1997, there were two appointed Australian Competent Bodies. They were EMC Assessors Pty Ltd with offices in Melbourne and Sydney, and EMCSI Pty Ltd with an office in Melbourne.

Sound and television receivers and associated equipment were covered under Standards AS/NZS1053 and AS/NZS4053.

The minimum field strength level provided by an MF broadcasting service in order to overcome interference from man-made noise varies with the local environment. Three different environmental situations are taken into account when determining suitable field strength levels. They are rural with towns of populations typically 2000 or less, suburban for populations 2000–10000 and city for populations above 10000. The aim is to provide a protected field strength in the presence of man-made radio noise alone, of 0.5 mV/m for rural, 2.5 mV/m for suburban and 10 mV/m for urban environments. The figures are used as a guide by planners but are not to be taken as absolute criteria.

Screening

Screening of components was practised even with some early model receivers, but with the introduction of the screen grid valve and others which followed, enabling high gain receivers to be produced, screening became essential, and was a major input factor in any receiver layout design.

Many early audio frequency transformers, particularly the cheap varieties were not enclosed with a pressed metal cover and receivers in vintage collections today show some receivers with metal plates placed between transformers and other components in order to reduce a coupling problem. Aluminium sheeting was the most popular screening material followed by copper, brass and tin plate. One model produced in Adelaide, the Reactodyne by Bullock Cycle and Radio Stores in 1926, featured sheets of nickel plated brass in semi-circular shape to shield each audio valve from nearby transformers.

The effect of hand capacity on tuning was another problem with many designs of the 1920s. To overcome the problem, many ingenious practices were adopted. Some builders covered the inside of the panel with sheet tin or tin foil. Newkradyne receivers built by the Transatlantic Wireless Company in Adelaide used a glass mirror front panel with components mounted on the glass, and the silver of the mirror being wired to the set earth terminal. Initially, receivers had a clear glass front panel and a mirror at the rear, but this did not reduce the hand capacity factor so the front panel was changed to a mirror and advantage taken of the conducting property of the silver which formed the mirror. The entire glass drilling operation was done by staff who assembled the receiver.

By the early 1930s, with high gain receiver stages, the introduction of the superheterodyne circuit and hum problems with mains-operated receivers, designers had to be more scientific than earlier workers in producing trouble-free receivers for the domestic market. They had to deal with the fact that electric energy can be transferred by means of an electric field, a magnetic field or through current-carrying wires with their electric and magnetic fields.

Whilst a totally enclosed metal box will result in a zero electric field outside the box, good performance will result if the box contains small slots or is drilled for heat ventilation purposes. This is true for either AF or RF sources provided the resistivity of the metal is very small, such as for aluminium or copper.

As the electric screening effect of metal sheet is not greatly influenced by slots or drilled holes, some designers incorporated parallel wires or strips of tin foil insulated from each other at one side only, in receivers. This enabled screening from electric fields to be provided with the device being called a 'static screen' indicating that no magnetic screening was involved. The principle was also applied to some coupling circuits in transmitters and aerial coupling units.

In the case of magnetic fields, an AC field produces a circular electric field surrounding the magnetic field proportional to the rate of change of the magnetic flux. At radio frequencies, the currents flow on the surface of the aluminium or copper and do not penetrate through the metal, so that if for example, an oscillator operating at RF is surrounded by a solid metal can, no electric or magnetic field will occur outside the box. However, if the can has slots at the top or bottom to cater for wiring leads and the slots are parallel to the magnetic lines of force, problems can occur. Similar troubles were experienced with some coil cans with press-on type lids when the lids developed bad contact with the can due to aluminium oxide. In some receivers, where coils were mounted horizontally or parallel to the metal chassis, and there was poor contact between the can and the chassis, a slot effect was created resulting in RF leakage to nearby components.

Because aluminium and copper are not perfect conductors, the current penetrates the material according to an exponential law. For frequencies at the low end of the broadcast band, i.e. 500 kHz, the current decreases to about 1% of its surface value at 0.4 mm depth, but at audio frequencies, the depth of penetration is such that very little screening occurs. In fact, a copper shield would need to be about 10 mm thick to attenuate audio currents to 1% of the surface value.

To screen audio frequencies, designers surrounded coils with a material possessing high magnetic conductivity causing the magnetic lines of force to remain almost entirely within the material. Although the laminated iron cores of AF transformers had some screening effect, well-designed transformers were surrounded by a pressed metal cover of high permeability material.

Even though containers were effective in shielding single or groups of components, the designer had to take account of interference which could occur by currents passing out of the shield via wiring. Sometimes decoupling techniques had to be applied.

Although Goat shields could be used to protect valves, manufacturers assisted by providing built-in screening in the form of metal envelopes or spraying a coat of zinc on the outside of the bulb. Valves with metal envelopes were imported by Australian manufacturers in the mid 1930s, and soon incorporated in locally produced receivers. Philips were the main producers of metal sprayed valves. Colours used included grey, red and gold.

The Goat split shield was produced by Goat Radio Parts in the USA and during 1935–36 more than one million receivers produced in the USA employed Goat shields. Most Australian manufacturers also employed them.

In the early days of broadcasting, many transmitting stations were commissioned in residential areas where listeners were located close to the station. This caused a particular problem when the local station employed a high power transmitter and the listener wished to tune in to a distant station. The high level local signal caused severe interference in the receiver circuitry and in some cases it was almost impossible to completely tune out the program.

Some manufacturers produced receivers suitable for operation under such circumstances but they were relatively expensive.

When 4QG was commissioned in Brisbane in 1925, it operated from the roof top of an inner city building and caused a reception problem for the owner of a hotel not far from the transmitter. In 1938, the publican came from Ipswich to take over the Brisbane hotel and his wife wished to listen to 4IP Ipswich some 40 km away from time to time to keep abreast of local news there.

Because of the close proximity of 4QG which at the time had an aerial power of about 2500 watts on 800 kHz, the publican found it impossible to tune out 4QG and receive the low level signal from 4IP which had a 100 watt transmitter on 1440 kHz. He called in a city Radio Serviceman who tackled the problem on four fronts.

- The receiver was an AC powered 5 valve Philips Radioplayer and a Line Filter unit was fitted into the AC feeder line with the output from the filter being taken to the set via a shielded cable.
- The entire receiver chassis was placed inside an aluminium case provided with ventilation holes for heat removal and holes for cables from aerial and line filter and cable to the loudspeaker unit. The braid of all these cables was securely clamped to the aluminium case which itself was connected to a nearby water pipe by a copper strap.
- A wave trap was inserted between the aerial and the receiver aerial terminal. The wave trap was designed to tune out the 4QG 800 kHz carrier with all components being mounted inside an aluminium box and screwed to the aluminium chassis shield case.
- The loudspeaker lead from the receiver chassis was enclosed in copper braid shield, the loudspeaker metal frame earthed and one side of the voice coil earthed so grounding the outer winding of the transformer.

The Serviceman took great care to ensure all external leads were short and well-earthed to prevent any chance of signal pick up.

The publican's wife was well-pleased with the modification.

UNDESIRABLE FEEDBACK

Feedback in Radio Engineering has been the subject of study since the development of the valve. In some circuit designs, feedback is intentional, while in others, feedback can be a major problem. Feedback can be positive, in which case, the circuit will oscillate if the amount of feedback reaches a critical value, while if it is negative, the circuit gain will be reduced, but so will some undesirable factors such as distortion. In early regenerative receivers, some positive feedback was essential for their operation.

Undesired feedback has different effects at audio frequencies and at radio frequencies. It can also lead to combined AF and RF oscillation. Some early receiver designers had difficulties in coming to grips on how to counteract undesired feedback at audio frequencies. Trouble could result from a number of situations including inductive coupling between improperly screened transformers and chokes, coupling through impedance in a common path such as batteries, acoustic feedback and others.

Interstage transformers were widely employed, and a good design would keep them well apart and placed at right angles in a symmetrical position. Magnetic vertical screens were sometimes applied. Acoustic feedback was caused by sound waves from the loudspeaker impinging on an AF valve causing vibration of the valve elements. The oscillation produced a hollow sound of rising and falling nature.

Undesired feedback at radio frequencies could result from capacitive coupling inside and outside the valve, inductive coupling between coils, coupling between leads, coupling via impedances in a common path and others.

Feedback trouble due to grid-anode capacitance of triode valves was a common problem. Although a number of neutralising circuits were developed, the problem was not really overcome until the introduction of valves with additional grids which acted as screens.

External capacitive coupling was often a difficult problem to resolve in receivers built on open chassis or breadboards without partitions. The use of screened leads and metal cans over valves, were frequently used. When screen grid valves became available with high gain characteristics, many designers resorted to the use of metal compartments to house the valve and critical stage components.

When manufacturers introduced cast or sheet metal housings for ganged capacitors they unwittingly set up a situation which caused inductive coupling through untuned loops. The common ganged capacitor spindle which was earthed at both ends formed a loop which gave coupling between all coils in the enclosure. Improperly earthed rotors of variable capacitors was also an area which often resulted in undesirable coupling. It was important that the contact fork making contact with the rotor shaft be of low resistance, and if the stator was mounted on metal studs or posts above the chassis, that the studs or posts be solidly earthed and short so as to keep any inductance as small as possible. Some well-designed receivers employed a wide, low inductance strap to ensure low impedance between the capacitor and the chassis.

A five valve Rodaphone battery receiver designed and manufactured by A M Rodda, Currie Street, Adelaide in the mid 1920s, employed a brass shim strip about 1 cm wide to ensure good contact between capacitor frame and earth.

John Allan of National Radio Corporation, Adelaide made a major contribution in this area following investigations into problems being experienced with receivers being produced to a new design and chassis layout.

HUM

With the introduction of mains powered receivers, hum became a problem due to pure AF action or to modulation of the received carrier. Insufficient HT filtering of the power supply unit produced hum of frequencies 50 Hz in the case of half wave rectification, and 100 Hz for a full wave rectifier. The problem could often be cured by increasing the common HT filtering or alternatively, as was practice with many designs, to add small RC filters to individual valves. This was often cheaper. The use of the loudspeaker field coil as a filter choke and a hum neutralising coil or hum bucker were widely employed by manufacturers.

To minimise hum transfer due to coupling between the mains transformer and an interstage transformer it was standard practice to mount the power supply inductors away from the AF section of the receiver. In small mantle models where space was limited, it was not unusual to find interstage transformers mounted behind a screen or in a metal can.

In some early self-biased triode circuits, leakage between cathode and heater resulted in an AC current through the bias resistor. A large capacitor across the resistor fixed the problem.

A power transformer fitted with a static screen between primary and secondary wirings was sometimes fitted to give protection against self-modulation by the receiver. The RF carrier passed via the power transformer through the capacitance between the two windings, and thence through the rectifier where it became modulated because of the change of coupling caused by the varying rectifier resistance.

THE 1930 DECADE

The decade of the 1930s was a period of exciting development in home radio receivers. Manufacturers were hard-pressed to meet the demands of the public. Some buyers wanted simple-to-operate and cheap receivers; some wanted a model which looked like a piece of furniture in the lounge room; battery receivers were not wanted by people who had a mains supply connected to the house and some wanted the best money could buy with autodyne/superheterodyne circuitry, automatic tuning, bandspread, two speed tuning, all-wave set, tone expander, direct coupling, automatic volume control, magic eye tuning, brilliantly lit and coloured dial, and so the list went on.

Above all, city listeners wanted receivers that could be operated without the need for those ugly and often dangerous aerials in the backyard which too often collapsed during high wind causing damage to the owner's property, or worse still, to the neighbour's house or fence.

One of the most popular low cost designs capable of operating from the AC mains at the beginning of the decade was the 2/3 or as more commonly known, the 'two plus R' receiver comprising two valves plus a rectifier valve. A typical circuit employed a screened grid detector valve as the input regenerative stage followed by an audio amplifier stage. Choke capacity coupling between the stages was a feature of some designs. Although the chassis was small enough for enclosure in a table type cabinet many were built into console type cabinets.

A small manufacturing firm which build considerable numbers of receivers using 'two plus R' circuit was D Harris and Co., Rundle Street, Adelaide. The firm supplied the Radio Departments of some of Adelaide's leading Department Stores during the early 1930s. The firm's own brand name was 'Radion' but receivers provided for the Department Stores were provided with names to suit the customer's requirements.

A major problem at the time was that the selling of domestic receivers was a very competitive business, and Sales Managers exerted considerable pressure of Engineers and designers to produce features which could be used to advantage as 'sales plugs' or 'talking points' with prospective purchasers or in press advertisements. They also wanted the price to be as low as possible. The price was composed of design, development, overhead and manufacturing costs plus distribution and advertising expenses, and in the hard economic climate at the time, the policy with many companies was 'the cheaper the receiver the better'.

Pressure on Engineers for incorporation of novel features to satisfy the sales people was often a difficult matter to handle. The production of a simple, reliable and easy-to-operate receiver of reasonable quality was not a problem for a competent designer. Features such as automatic tuning, interstation muting, automatic volume control, all-wave operation, band spreading, visual 'tune-by-light' and many other features, did little to improve quality of reproduction, added to overall cost and if not carefully designed and adjusted, could degrade the reproduction quality and reliability of the receiver. However, if well-engineered and produced, some could enhance the simplicity of operation and the total enjoyment of the listener.

The range of receivers available in the middle of the decade included miniature models which could be mounted on a shelf in the kitchen providing entertainment and information for the busy housewife, and also, receivers capable of reception of short wave stations. These latter types were an immediate success due mainly by the popularity of cricket Test Matches being played overseas. Licences jumped 163000 during 1934.

To take advantage of the availability of these new designs, the marketing people in the radio manufacturing industry adopted a slogan 'A Second Set in Every Home'. During 1933–34 over 150000 receivers were made and sold within 12 months. By 1937, the number produced in local factories was estimated to have exceeded 280000 sets with about 180000 of these being sold to people already possessing one receiver.

One popular model was the Astor Mickey Mouse receiver, a five valve AC powered superheterodyne model introduced in 1933 and produced in various models until about 1939.

Australia became independent of overseas suppliers for the supply of components including valves. The bulbous-shaped glass valves which had been standard for years gave way to a new stepped dome-shaped design and improved internal construction overcame annoying microphonics. Metal envelope valves also became available and were snapped up by designers of car radios as well as the home receivers.

Plastic cabinets were introduced for mantle models giving the cabinet designer greater freedom in producing a wider range of designs than was possible with wood.

The designers of dial mechanisms were given free rein to enhance the appearance of the radio receiver. Horizontally-mounted full vision tuning scales with cord-driven cursors were soon in widespread use. Other designs included semi-circular full vision dials with pivoted cursors. However, the early small escutcheoned window dials were still in use.

The EFCO Manufacturing Co., of Arncliffe, one of Australia's largest producers of dials, featured at least 20 different models in its 1934 catalogue using such names as Beam, Gondola, Moderne, Aero, Cameo, Lylic, Bedford, Avon, Gothic, Efco and others.

At the end of the decade, and the time of the start of the Second World War, the manufacturing of home receivers had reached a stage of consolidation with the number of licensed listeners being close to 1.2 million. These listeners were being well-served by 24 National and 98 Commercial transmitting stations. The sales of home receivers was estimated to be between 120000 and 150000 for the year War was declared.

During the decade commencing 1930, the domestic radio receiver reached a level of performance really never outstripped in later years during the period of valve technology. This was due principally to improved circuit designs, development of new valve types, improved component reliability and performance, high performance dynamic loudspeakers, adoption of the superheterodyne as the basic circuit, the incorporation of record playing facilities in radiogram models and the introduction of Dual-Wave receivers enabling direct short wave reception from overseas countries.

However, some designs were well before their time, for example, direct coupling (d.c.) in the audio frequency stages incorporated in some receivers of the early 1930s. In the design, the anode of one stage was connected to the grid of the next stage directly, or through a biasing battery or equivalent. It came into vogue following the publication of a paper in the Proceeding of the IRE in USA in 1928. The authors were Edward Loftin and S Young White and the paper was titled, 'Direct-coupled Detector and Amplifier with Automatic Grid Bias'. It was commonly known as the Loftin-White circuit. One design which incorporated the Loftin-White circuit was a five valve TRF Univox receiver manufactured by Eclipse about 1930. In theory, the d.c. stage promised flat amplification from zero to infinity Hertz. However, equipment at the time, particularly microphones, pick-ups, and loudspeakers all had poor frequency response characteristics and valve characteristics were far from ideal for application with d.c. amplifier circuits. Also, it suffered from a drift problem. A change in the supply potential for any valve caused currents and potentials of all succeeding valves to vary. Sometimes a balanced amplifier was employed to reduce the drift problem.

In more recent times, d.c. amplifiers found application in computers, d.c. voltmeters using valves, oscilloscope deflection amplifiers and high fidelity valve amplifiers. Today, direct coupling is widely employed in integrated circuit technology.

THE POST WAR YEARS

The War years were difficult ones for the listening public. New models were not readily available after about 1941, but the Government ensured that sufficient parts and components were available to keep sets working. Every major manufacturer of home receivers was heavily engaged in producing equipment for the Services and plans for producing new receiver designs had to be deferred however, small numbers of current designs were produced.

Much development work had occurred during the War period with service equipment, and some of the technology soon found its way into the home receiver when manufacturing was resumed from about late 1945.

Some manufacturers produced mammoth luxury type receivers with large numbers of valves. Reliance Radio Pty Ltd, Sydney was one company which followed this path by producing 16 valve and 32 valve models in 1949. The company had been involved in the manufacture of large chassis since the 1930s with some of the popular models being nine valve Reliance-York, 1933; ten valve Reliance-York, 1934; twelve valve Reliance-York, 1936; and twenty valve York-Royal, 1937.

The 16 valve model, designated Super Sky Master, features included variable selectivity control; automatic frequency control; double push-pull parallel audio system with 807 type valves operated as triodes; two deluxe built chassis incorporating RF stage plus seven type EF50 valves; new type auditorium loudspeaker; Garrard automatic record changer; moving iron pick-up; record compartment at each end of the cabinet; craftsman constructed double lid cabinet by Andersen and Frantzen, and finished in butt grained Italian walnut veneer wood.

The 36 valve receiver provided facilities for AM dual wave and FM reception plus disc home recording. The design was such that the AM and FM sections were constructed as separate tuners feeding into a common audio channel. Other features included variable selectivity; automatic frequency control; voltage regulated oscillator, extensive IF channel system in the FM tuner; preliminary AF stages feeding into push-pull 6V6GT valves followed by push-pull parallel 807 valves; AF stage could be fed from either of the radio tuners, a pick-up or a crystal microphone; output of AF stages could be fed to loudspeaker system or cutting head for recording purposes; 12 inch (30 cm) loudspeaker in vented enclosure; receiver housed in a single large cabinet with fully closing doors.

About 1948, two developments were announced which were to have a major impact on receiver design. These were the printed circuit board and the transistor.

New plastics were also available and by 1960 the all-transistor battery-operated portable gave a new lease of life to the broadcasting industry.

The announcement of the availability of germanium crystal diodes brought a temporary interest in crystal sets particularly by those old enough to remember their early involvement with the crystal set and its cat's whisker. However, it was short lived.

Although transistors were initially imported, manufacturing soon followed in Australia. However, in due course with rapid changes in solid state technology and the importation of cheap receivers from other sources, the manufacture of broadcast receivers in Australia was wound down and ceased during the 1960s. Australia is now almost totally dependent on outside sources for domestic broadcast receiver requirements.

When transistor radio receivers were first introduced, they were not the compact, versatile and high performance models of today. Many early receivers employed the same basic construction as miniature battery models then in use except that the valves were replaced by transistors. The same steel chassis format with large tuning capacitors, audio and output transformers were used. Until printed circuit boards became available, all wiring was connected to tag strips including the transistors with their long leads.

The hobbyist was introduced to the new technology when Neville Williams described the construction of a simple transistor receiver employing OC70/71/72 series of PNP germanium devices in May/August 1955 issues of 'Radio and Hobbies'.

Other designs of small sets followed with the Transporta Six being described in August 1958. It was a superheterodyne circuit employing transistor types 2N252 in the converter stage, 2N308 as IF amplifier, GD4 diode as detector, TS1 and TS2 as AF amplifiers and a pair of 2N185 types as a transformer coupled Class B output stage. The TS1 and TS2 were locally produced transistors while the others were imported. Two PCBs were used in the assembly and the whole unit including a 5 inch (125 mm) loudspeaker was housed in a wooden cabinet 150 mm by 280 mm by 75 mm in size and covered with leatherette.

Improved designs of MF band receivers followed in subsequent years including car radio sets with a hybrid design of valves and transistors in 1959 and fully solid state designs in 1961–63.

CABINETS

Construction techniques of early broadcast receivers followed practices then in vogue with receivers made for wireless telegraphy reception, and by Amateur radio experimenters. Basically, they comprised a wooden baseboard and a vertical front panel usually of bakelite on which controls were mounted. For the experimenter, a control panel with a large number of knobs, terminals, meters etc, was a status symbol. The more congested the panel, the greater the status of the operator. After all, he was a Technical expert.

When this philosophy spread to the home broadcast receiver, people without a technical background in radio would have none of it. Sales were only a trickle, and it took some time for manufacturers to appreciate that the goal for operation of a receiver had to be simplicity. The fewer the controls, the better the chance of a sale.

Also, the exposed components and wiring did not impress the lady of the house. The unit was placed inside a wooden box but some English manufacturers insisted on mounting valves outside. That practice soon stopped when shelves were loaded with unsold receivers. The shape and finish of the cabinet had a lot to do with sales numbers, so more effort was put into this area of design. Exposed batteries and wiring were another drawback, and designers solved the problem by putting wings on the cabinet to house the batteries, while others built a freestanding cabinet to sit on the floor. The floor cabinet or console as it was called, had other uses. It allowed the loudspeaker to be hidden away as well as the batteries.

When it became evident that the appearance of the cabinet had as much influence on sales figures as technical features, manufacturers called in furniture makers to design and build cabinets for their receivers. For many, it soon became a full-time business just making radio cabinets, such was the demand. The cabinet designers let their heads go, and Radio Shops were soon stocked with ornate veneered designs and combination forms such as book case/cabinet, writing bureau/cabinet, liquor bar/cabinet and others.

In the USA, all the major receiver manufacturers had console models in their range by 1925 and some of these were imported into Australia. The number which were available here was not great. The receivers were in the top price range and also shipping costs were higher than for table models.

Consoles were made in Australia from the early days of broadcasting. At the Radio and Electrical Exhibition in Adelaide in December 1925, two manufacturers displayed ornate consoles. Behrens-Thiem and Co., displayed a five valve receiver in a beautiful French polished blackwood cabinet with Queen Anne period legs. The cabinet which housed the batteries was 1.3 metres high. The company also had a smaller model called the Serenade. Mr L Whibley whose design was built by a well-known Port Adelaide furniture manufacturer, exhibited a five valve receiver housed in an Elizabethan period cabinet of generous proportions intended to add distinction to any room.

One of the largest designers and manufacturers of radio furniture in Australia, particularly during the 1930 decade when the popularity of consoles were at their peak, was F Dickin Pty Ltd, Sydney. The firm had been in the furniture business before the turn of the century and during the Second World War years manufactured laminated spars for Mosquito bombers and transit cases for radio and radar equipment.

Other major radio cabinet manufacturers included Beale and Co., Ltd, Annandale who also made Beale brand receivers, and H C Whibley, Woolloongabba who made Queenstate brand radio cabinets.

One of the advantages of a floor console was that in good designs, it enabled superior sound reproduction, compared with a small table model of the period. However, designers had to be careful in designing the layout and construction of the cabinet section which housed the loudspeaker. Small changes in materials and dimensions, particularly volume, could make a considerable difference to performance. Bad designs frequently resulted in a cavity resonance causing a 'boomy' effect in reproduction.

Some manufacturers highlighted their loudspeaker performance characteristics. For example, Thomson Radio Ltd, Sydney, paid a lot of attention to this in their five valve superheterodyne Theatle receiver produced in 1934. They emphasised the advantages of the floating loudspeaker and its velona soundboard. Cabinet resonance was eliminated by mounting the chassis and loudspeaker on a thick soundboard which floated on rubber at all edges. It was recessed some distance in from the front side panel mountings of the cabinet to form a baffle. The company claimed 'the vibrating soundboard enlarged the sound so that a clear velvet tone with deep mellow bass is produced'. Cabinets were also made with acoustical labyrinths. Air from the rear of the cone passed through a winding path lined with sound absorbing material with the sound emerging at the bottom front of the cabinet below the loudspeaker.

The standard open back cabinet had a resonance in the enclosure to the rear of the cone. This resonance, resulted in a peak in response at one or more frequencies, which was mainly a function of the cabinet design, although the loudspeaker had some influence. Peak responses in the range 120 to 180 Hz were often found. A radio cabinet with an open back did not allow production of high fidelity sound, particularly models which had wide sides. Manufacturers recommended that the back of the cabinet stand at least 6 inches (15 cm) from the wall.

The more expensive receiver cabinets employed an enclosed loudspeaker with absorbent material lining to improve fidelity. It prevented interference between front and back of the cone. A cabinet with a large volume was preferred, as it reduced the rise in resonant frequency above that provided by a large flat baffle.

Seyon consoles produced in the mid 1930s for Noyes Bros, were fitted with a patented sound chamber. Celotex boards were arranged in the form of a 30 cm long square horn tapering sharply to the rear of the cabinet. A baffle on which was mounted an 8 inch (200 mm) loudspeaker was fixed midway in the horn throat. It was assumed that, by setting the loudspeaker back from the front cabinet grille and employing the horn design, the searchlight or beam effect of high frequencies usually experienced with designs with loudspeaker and baffle placed against the grille, a much better balance between low and high audio frequencies was obtained, and also prevented undesirable cabinet resonance problems.

Construction techniques employed in the manufacture of cabinets for Associated General Electric Industries, Hotpoint Band-Master receivers were typical of those used by companies producing high quality cabinets during 1935:

- Nails were not employed. All principal parts forming the structure were tongued together producing one solid unit of the complete cabinet. Although more costly than other methods, it produced a superior cabinet, many of which can be seen today in vintage radio collections.
- End panels and the top board were made from heavy laminated timber faced with Queensland walnut for most designs. The front panels were prepared using selected figured Queensland walnut on laminated timber. Shelves and bustle boards were cut from heavy plywood and all moulds machine or handmade from solid well-seasoned top quality timber.
- All woodwork visible from the front, if not made from walnut or selected timber, was either stained to match the natural walnut or treated in an approved finish such as gloss or satin black in accordance with specifications.
- The cabinet was finished with a recently introduced high gloss lacquer, hand-rubbed to give top quality piano finish to bring out the natural beauty of the wood and to provide a hard and durable finish.

AWA also, produced some magnificent cabinets for its console receivers during this period. The Radiola Model 140 an AC powered seven valve superheterodyne set with a full vision rotovision tuning dial with open finely graduated scale, was installed in a cabinet 41 inches (1025 mm) high, 25 inches (625 mm) wide and 14.5 inches (362.5 mm) deep. The cabinet expressed the best in modern furniture design at the time. The front was faced with selected Queensland walnut ribbed veneer in the latest herringbone pattern while the remainder of the cabinet was faced with high grade walnut veneers. It was finished with a rich walnut shade with hand-rubbed high gloss lacquer. The cabinet provided for the battery version, Model 139, was faced with a veneer patterned with Macassar Ebony bandings and finished in a deep walnut tone in hand-rubbed high gloss lacquer. Many of these cabinets are held in vintage radio collections today, and even after 60 years, the finish is in surprisingly good order. Cabinets used for AWA receivers were designed and manufactured by the company in its own workshops.

In 1938, when Weldon Radio, Sydney introduced a range of five new models they were advertised as 'housed in imposing and ultra modern cabinets' and were 'an education in radio craftsmanship'.

In the mid 1930s with the widespread employment of the superheterodyne circuit by manufacturers, and the development of miniature components, opportunity existed for the production of receivers of the mantle and table types so allowing greater flexibility in home use of the radio. For example, the radio moved into the kitchen where the housewife could listen while she went about her normal chores in the kitchen. It also meant increased sales as the console was still popular as a receiver in the lounge room. The price of receivers fell as mass production rose and cheaper small cabinets including plastic types became available. Even after the War, console models were produced by some manufacturers but they eventually disappeared from the scene, together with table models as the Australian manufacturers folded up businesses with the importation of cheap transistor receivers produced overseas.

The fixed receiver, whether console or mantle model transformed the room in which it was installed into a listening booth becoming the focus of the family's aural space.

With the availability of the portable receiver, the aural space was no longer fixed. It moved with the listener while walking, driving in a car or a tractor, or sitting outdoors with a group of people. The personal receiver in the form of the Walkman with dual capability of cassette and radio has further transformed the aural space to an individual one, resulting in complete privatisation of sound.

Sheetmetal workers also became involved in the manufacture of early radio cabinets. Metal cabinets were popular with some USA manufacturers in the 1920s. Atwater Kent was one of the first to introduce metal cabinets because of large cost savings. It was much cheaper to stamp out sheetmetal cabinets with machines, than to hand manufacture wooden types. Although labelled 'tin cans' when first introduced, they were disguised with a two-colour crinkle finish and gold trimmings. Many were imported into Australia with both table and floor models being in the Adelaide Telecommunications Museum radio collection. The Model 52 was on display for some years and drew a lot of attention from vintage radio collectors. It was floor mounted, 30 inches (750 mm) high and 18 inches (450 mm) wide, and accommodated an all-electric seven valve receiver. The cabinet had a black ripple satin finish.

Australian manufacturers also produced receivers with metal cabinets. Crinkle gold and copper finishes were popular. Many Stromberg-Carlson and Astor models are in vintage radio collections today.

In 1927, Messrs Saville and Co., of Charleville in Western Queensland produced receivers with metal cabinets. Although the nearest broadcasting stations at the time were in far away Toowoomba, Brisbane, Adelaide and Sydney, the company had a thriving business manufacturing and installing receivers under the brand name 'Eureka'.

Company staff travelled extensively throughout Western Queensland, and it soon became evident that the standard method of accommodating receivers in wooden cabinets, open at the back, was totally unsuitable to the environmental condition in the area, and the rough treatment receivers were subjected to during cartage to the listener's premises. The hot dry and dusty climate caused the wood in wooden cabinets to shrink and warp, and dust accumulated across the variable capacitor blades, and across contacts of valve sockets, jacks and switches.

The company contracted with a Brisbane sheetmetal firm to provide an all-metal dustproof cabinet to suit their range of three, four, five and eight valve receivers.

The entire cabinet was made of oxidised copper sheet allowing space for receiver in the centre, and batteries in left and right compartment wings. The back, top and front of the cabinet was stamped out to form a lidless type housing. The baseboard of the receiver was reversed and suspended from beneath the top of the cabinet. The valves were held in place by the use of spring-loaded anti-microphonic sockets. Access to the interior of the cabinet was gained by pulling out a tight fitting copper tray which formed the bottom of the cabinet. Protruding shafts of tuning capacitors and rheostats were sealed with rubber grommets. During transport in the company van, receivers were placed on a wool-filled mattress in the back of the van. To complement the receiver using the same philosophy, a Radiolux Amplion loudspeaker Model RS2 was used. It had a metal cabinet and copper finished grill.

In late 1931, Edward Hirst, Managing Director of British General Electric Co., had two console radio cabinets covered with skins to gauge public reaction on potential sales for such a feature. One cabinet was covered with shark skin while the other was covered with crocodile skin. It was assumed that as pieces of furniture the cabinets would lend distinction to any room.

Mr Hirst developed the idea from an early Victorian era practice when papier mache furniture created a craze.

The two cabinets were displayed in the company Showroom for a considerable period but there are no details available on the public reaction. However, no other models were produced.

PORTABLE RECEIVERS

The introduction of broadcasting in the 1920s had a great impact on home entertainment, and it soon became evident that a home broadcast receiver could be adapted to enable it to be taken outdoors on a picnic, to the seaside, or in the park.

Many of the early portable receivers were extremely cumbersome. They were in fact simply scaled down versions of the home receiver still using a bulky horn loudspeaker and heavy batteries.

Manufacturers in the UK and USA saw a market for portables and were quick to tool up for mass production.

One of the earliest UK models seen in Australia was the Pye 555 made by W G Pye & Co., in 1925. It was a five valve receiver with an Amplion horn type loudspeaker mounted inside the case, together with the batteries. The set sold in large numbers and remained unaltered until 1927 when it appeared with a modified cabinet and cone type loudspeaker. In 1927, the company released four other portables and large numbers were exported to Australia to be sold by local Radio Shops. One of these, the Selector Five, used a superheterodyne circuit. It had an oscillator-detector, intermediate frequency amplifier, second detector, and two audio frequency amplifying stages. Loudspeaker reception was guaranteed up to 70 miles (112 km) from the transmitter.

Harris Scarfe Ltd Wireless Department of Adelaide sold a Selector Five to Len Potts, a farmer at Kadina, north of Adelaide just before Christmas 1927, and a few months later, sold one to his neighbour who erected an aerial extending from a windmill to the house.

One of the earliest American portables available in Australia was the TRAV-LER, a five valve receiver manufactured in 1925. It was still being sold in Radio Shops as late as 1931. Another was the Kemper Portable also made in 1925. It featured a collapsible loop aerial.

An early Australian made model was the PORTA made in Melbourne by Astor about 1928. It had a loop aerial concealed in the lid and employed a French Sferovox cone loudspeaker, also mounted in the lid.

The aerial provided with most early portables was very inefficient and many sets had provision for connection of an external aerial. It was not unusual at a picnic outing for a weighted wire to be thrown up to the branch of a nearby tree, and this used as the external aerial to improve reception. Some receivers were provided with a push-in spike to give a good ground connection.

The introduction of 1.4 V valves in 1938–39 was a landmark in the development of portable receivers. It meant that the filament could be powered from a 1.5 V dry cell instead of a heavy 2 V accumulator. Not only were the valves smaller than the 2 V types, but filament and high tension power drains were less.

One of the first commercially manufactured receivers employing the new 1.4 volt valves was produced by Tasma in late 1938, under Chief Engineer Eric Fanker.

It was a five valve superheterodyne design powered by a single 1.5 volt Ever-Ready Standard dry cell and two 45 volt Superdyne batteries in series, for anode voltage. Measured filament current was 0.3 ampere and anode current 11 milliamperes.

A receiver from the production line was given to Don Knock, Radio Engineer of 'The Bulletin' who put the receiver through a series of field trials during a trip from Sydney to Toowoomba in Queensland in December 1938. It performed well on both MF and short wave bands. Radio dealers from Brisbane visited Toowoomba to witness the trials.

Kit sets employing various circuits soon became available. One kit set called 'One-four Portable Five' was marketed in January 1939 as Foxradio kit by Fox and MacGillycuddy Ltd, Sydney. Valve types were 1N5G, RF amplifier; 1A7G, mixer oscillator; 1N5G, IF amplifier with 465 kHz iron core IF transformer; 1H5G, second detector and AF amplifier; and 1C5G, output stage. The AVC voltage was taken from the negative end of a 0.5 megohm volume control which formed the diode load resistor. Batteries comprised two 45 volt light duty B batteries type Ever-Ready WP45 in series, one 9 volt C battery type Ever-Ready W9S to bias the output pentode, and one 1.5 volt Ever-Ready Standard dry cell for filaments. Loudspeaker was Rola type 5–6 permag type. A leatherette covered cabinet manufactured by Western Manufacturing Co., Sydney was supplied as part of the kit. The aerial consisted of a sheet of copper gauze lining the lid, with connections from the gauze to the receiver being made via the top metal hinge attaching the lid to the cabinet.

In 1940, a year before Japan became involved in the Second World War, resulting in production of domestic receivers in Australia being reduced to a trickle, there was a wide range of portable models available from Radio Shops. Popular models included:

- Airzone model 5085, a five valve dual wave receiver with tuning, volume, tone and battery switch controls. Battery types comprised 1–PR8 and 2–PR45 providing 200 hours operation. A 6 inch loudspeaker was employed.
  Model 457 was a four valve receiver covering the MF band and provided with tuning and volume/battery switch controls. Batteries were 1–PR8 and 2–PR45 providing 220 hours of reception. A 5 inch loudspeaker was used.
- Aristocrat model 1058S, a five valve receiver designed for MF band reception and provided with tuning, volume and selector switch controls. Batteries comprised 1–PR8 and 2–PR45 providing 225 hours of operation. An AC power unit was also available.
  Model 1059S, was a five valve receiver capable of dual wave reception. Controls comprised tuning, volume, wave change and selector switch controls. Batteries were 1–PR8 and 2–PR45 providing 225 hours of operation.
  Model 1058P was a five valve receiver designed for MF band reception. Controls were tuning, tone, volume and battery switch. Batteries were 1–PR8 and 2–PR45 providing 225 hours of reception. A 6 inch loudspeaker was fitted.
- Astor model 'Porta', a five valve receiver designed for MF band working with tuning and volume controls plus automatic aerial and battery switch control. Power supply comprised one combined AB battery pack providing 225 hours of operation. A Rola 6 inch loudspeaker was employed. An AC power pack version was also available. Cabinet was provided with aeroplane linen finish.
- Breville model 268, a five valve MF band receiver with tuning, volume and power on/off switch. Batteries were 1–PR8 and 2–PR45 providing 250 hours of reception.
  Model 269, a six valve MF band receiver with tuning, volume and power on/off switch controls. Battery types were 1–PR8 and 2–PR45 providing 220 hours of reception.
  Model 256, a four valve broadcast band receiver with tuning, volume and battery switch controls and employing 1–PR8 and 2–PR45 batteries providing 250 hours of service.
  Model 257, a five valve MF band receiver with tuning, volume and battery switch controls. Batteries fitted were 1–PR8 and 2–PR45 providing 220 hours of operation.
  All models employed 5 inch loudspeakers and were finished with aeroplane cloth.
- Calstan model B54P, a five valve MF band receiver with tuning, tone and volume controls plus power switch. Battery types were 1–PR8 and 2–PR45 providing 200 hours of service. Loudspeaker was a 6.5 inch model.
  Model D54P, a five valve dual wave receiver with tuning, tone, wave change and volume/switch controls. Battery types were 1–PR8 and 2–PR45 providing 200 hours of reception.
  Both B54P and D54P were available in red, green, blue, brown or grey colour finishes.
  Model B44P, a four valve receiver covering the MF band with tuning, and volume/switch controls. Batteries were 1–PR8 and 2–PR45 providing 250 hours of reception. Cabinets were finished in aeroplane cloth fabric.
- Fisk Radiola model 62, a five valve MF band receiver with tone, volume, tuning and battery switch controls. Battery types were 1–PR8 and 2–PR45 providing about 170 hours of operation. A 5 inch loudspeaker was fitted.
  Model 65, a four valve MF band receiver with tone, tuning, volume, battery/power switch controls. Battery types were

1–PR8 and 2–PR45 providing 250 hours of service for A battery and 200 hours for B battery. The receiver was provided with half door cabinet and was available in fawn, green or cream colour finishes. A power unit was available for AC operation.

- Genalex, model 780, a four valve dual wave receiver with tuning, wave change, tone and volume/switch controls. Battery types were 1–PR8 and 2–PR45 providing 250 hours of reception.
  Model 777, a five valve MF band receiver with tuning, volume, tone and power switch controls. Battery types 1–PR8 and 2–PR45 provided 200 hours of operation.
  Both types had cabinets finished in dark brown figured fabric.
- Healing model 500B, a five valve MF band receiver with tuning and volume/battery switch controls. Batteries employed were one 1.5 volt and two P45 units providing 250 hours of operation. A 5 inch Rola loudspeaker was fitted. Cabinet colours were black, grey or brown.
- HMV model 601, with four valves including 1D8GT giving equivalent of five stages. Controls were tuning, volume and tone/battery switch. Batteries were 1–PR8 and 2–PR45 providing 270 hours operation from A battery and 230 hours from B battery. Power units were available for AC or vibrator operation. The cabinet was fitted with turntable for ease of rotation for best use of the loop aerial. Cabinet was available in colours of black with midnight blue mould trim or blue with cream trim.
- Hotpoint Bandmaster model B74MB, a four valve MF band receiver with tuning, volume, battery and power selector switch controls. Batteries were 1–PR8 and 2–PR45 providing 250 hours from A battery and 200 hours from B battery. An AC powered version was also available.
- Kriesler model 4K88, a five valve dual wave receiver designed for dual wave reception and provided with tuning, volume, wave change and on/off switch controls. Batteries comprised 1–PR8 and 2–PR45 providing 200 hours of reception. A set of heavy duty batteries was available as an alternative, to provide 800 hours of operation.
- Monarch model 'Musibox', a five valve MF band receiver provided with combined A and B battery pack providing 225 hours of operation. An AC power pack was also available.
- Paramount model 54, a five valve MF band receiver with tuning, volume and battery switch controls. Batteries were 1–PR8 and 2–PR45 providing 170 hours of operation from A battery and 200 hours from B battery. A power unit for AC operation was also available. Cabinet was available in aeroplane cloth or in maroon or green crocodile leatherette finish.
  Model 71 was designed to same specifications as model 54 but provided dual wave coverage and had two IF stages instead of an RF stage and single IF amplifier.
  Model 82, a six valve dual wave receiver similar to model 71 but with RF amplifier.
  Model 505, a five valve MF band receiver with 6 inch loudspeaker and fitted with 1–PR8 and 2–PR45 batteries. It had a two door cabinet with automatic filament switch operated by front door. Cabinet was available in green or brown grained leatherette.
  Model 656, had same specifications as model 505 but provided dual wave coverage.
- Philips model 3343, a four valve MF band receiver with tuning and volume/battery switch controls. The 1–PR8 and 2–PR45 batteries provided 250 hours of operation. Cabinet was finished in fawn aeroplane cloth.
- Remo model CP950, a five valve receiver with tuning and selector switch controls. Batteries were 1–PR8 and 2–PR45 types providing 225 hours of operation. A power unit was available for AC operation.
- STC model 511P, a five valve MF band receiver with tuning, and combined volume/battery switch controls. The 1–PR8 and 2–PR45 batteries provided 170 hours of operation. Cabinet was finished in buff 'hogskin'.
- Stromberg-Carlson model PD51, a five valve dual wave receiver with tuning, volume, wave change and battery on/off switch controls. The 1–PR8 and 2–PR45 batteries provided 250 hours of operation. An 8 inch loudspeaker was provided.
- Tasma model 777, a five valve MF band receiver with tuning, volume and combined tone/on-off switch controls. The 1–PR8 and 2–PR45 batteries provided 200 hours of operation. Cabinet was finished in brown leather cloth material.
  Model 780P, a four valve, including 1D8GT type receiver provided dual wave reception. Controls comprised tuning, wave change, tone and volume/switch controls. The 1–PR8 and 2–PR45 batteries provided 250 hours of operation. A 5 inch loudspeaker was fitted in the unit. Cabinet was finished in brown leather cloth material.
- Velco model '2 in 1' portable, a five valve MF band receiver with three controls. Batteries comprised 1.5 volt heavy duty and 2–PR45m providing 250 hours of operation. Power pack was available for AC operation. Cabinet was finished in aeroplane fabric.
- Weldon model B423P, a four valve MF band receiver with tuning and volume/switch controls. Batteries were 1–PR8 and 2–PR45 providing 240 hours of operation. Cabinet finish colours were grey, fawn and brown.
  Model B523P, a five valve MF band receiver with two controls. Battery types were 1–PR8 and 2–PR45 providing 230 hours of service.
- Westinghouse model 630, a four valve MF band receiver with four controls. Battery types were 1–PR8 and 2–PR45 providing 220 hours of operation. An AC power pack was also available. The unit was fitted with a 5 inch loudspeaker.

The 1960s saw a dramatic change in the design of portable receivers. The valve was being replaced by the transistor and the loop aerial was being replaced by the ferrite rod aerial. Many enthusiasts imported transistor kit sets to take advantage of the new technology. Vintage radio collections show a number of kit sets were imported as early as 1954 by Australians wishing to be involved in transistor technology.

Typical of the many Australian manufactured portables was the Transistor 7 Portable Type 78T 11 made in 1958 by Stromberg-Carlson A/Asia Pty Ltd. Transistors comprised OC44 oscillator-mixer, OC45 first IF amplifier, OC45 second IF amplifier, OC71 first audio amplifier, OC71 second audio amplifier and a pair of OC72s in the output stage. The pair of OC72s acted as a Class AB output stage with grounded emitters. The diode detector was a OA79.

Today, solid state devices have completely replaced the valve in portable broadcast receivers. Receivers are now relatively cheap, they operate for a long time with a few small dry cells, and have high quality performance. They are also produced in small sizes so that they can be worn on the wrist like a watch, or carried in the pocket so that those who want it, can have music and entertainment on the move.

Modern miniature equipment which provides personal music on the run has had a major influence on the increasing popularity of portable radios and radio/cassette combinations. The Sony Walkman has been a leader in the field since 1979. In 1997, the company released its Sony Model WM-FX465 which features AM/FM digital tuner with 20 station presets, auto-reverse, Dolby B noise reduction, Groove mode and MegaBass, built-in clock, anti-rolling mechanism, automatic volume limiting system and Fontopia headphones. A new Stamina Super Long Life Battery provides around 20 hours of operation.

CAR RADIO RECEIVERS

With the advent of broadcasting in the early 1920s, many enthusiasts adapted a home receiver for use in the car. However, for a permanent installation a great deal more work was required in fitting the equipment to the car compared with setting up a receiver in the home. It was not a simple job of drilling a few holes and connecting the set to the car battery. For example, the receiver had to be mounted in a position which was almost always very cramped and difficult to carry out work, such as drilling etc. The installation of the aerial and earth were particular problems, and even after completion of the physical installation, which in many cases involved renewing and putting back portions of the upholstery, serious problems had to be overcome for good program reception.

Interference from the car ignition system, generator and other units required attention. This required the fitting of suppressor resistances in the ignition leads, by-pass capacitors and chokes in various places of the battery charging equipment and in some cases, the replacement of parts of the car electrical wiring with shielded wiring. Also, some metal parts of the vehicle such as brake rods and other control rods had to be bonded to the main chassis. The installation of the receiver controls and loudspeaker also had their own special problems.

The first Australian-designed car fitted with a radio receiver was The Summit made by Kelly's Motors, Sydney. The car was assembled in 1924 using imported American components. The radio was powered by the car battery and the aerial attached to the waterproof hood. Passengers used headphones to listen to the programs.

In 1931, a new member of the Wooloowin Radio Club, Brisbane purchased an Auto Pilot Kit Set from J C Price, a leading Radio Manufacturer's Representative in Perry House, Brisbane. The Kit Set, number K140, was designed and manufactured by Pilot Radio and Tube Corporation, USA as an automobile receiver and comprised circuit, all receiver components, a steel case, a control cable, panel and 8 inch (200 mm) loudspeaker. Three 45 volt batteries were located in a box and located away from the receiver unit which was mounted on the running board of the car.

The receiver comprised three stages of radio frequency amplification, using screen grid valves, a screen grid detector, one resistance-capacitance coupled audio stage and one transformer coupled output stage. AC type valves were used with filaments wired in series-parallel to work off the car six volt storage battery. Four P224, one P227 and one P245 type valves were employed. Total filament drain was four amperes and anode current about 20 milliamperes.

The receiver unit in a black japanned steel case fixed to the running board was controlled inside the car by wires and a chain terminating on a control box on which was mounted tuning dial, filament switch and pilot light. The cable form housed five flexible wires containing leads for the filament switch, volume control and pilot light and also a pair of flexible tubes which carried a flexible brass chain attached to the shaft of the variable tuning capacitor and the dial via gear wheels.

The aerial was strung from insulators beneath the front and rear axles under the car.

The member was assisted with the installation by Bill Rohde a long-time member who worked at broadcasting station 4QG.

Included in the Kit Set was a printed notice which read:

'IMPORTANT NOTICE

For your own safety and the safety of other drivers, we strongly recommend that you use your automobile radio receiver only when the car is stationary. With road conditions as they usually are, you should concentrate on driving, and you should not have your attention distracted by musical programs or talks while the care is in motion. For this reason, no provisions have been made in the Pilot Auto Radio for the suppression of interference from the ignition system. To prevent a wave of accidents, it is likely State legislatures will make radioing-while-you-drive illegal.'

Radio Servicemen had a major public relations exercise on their hands when the demand for car radios began to increase. Car owners were loathe to accept the fact, in the majority of cases where their radio reception was noisy, that it was the fault of the car rather than the radio equipment. They did not appreciate that the noise problem depended not only on the make and model of the car, but also on its age and the condition of the car electrical system, particularly the ignition system. Reconditioning and fault finding in the car electrics was expensive in many instances, in order to ensure interference-free reception.

Manufacturers of car radios saw considerable potential in the automobile market, and put a great deal of development effort into producing receivers which would overcome some of the inherent problems in the car electrics. High grade receivers were double-shielded to prevent direct pick-up by the internal wiring of the receiver and they were fitted with networks of chokes and bypass capacitors to filter out noise currents from the battery and control wiring.

Power for the filaments was usually provided directly from the car accumulator but anode and screen voltages were provided by dry cell batteries, a generator or a vibrator system. Dry cells were widely used in many early installations but were bulky and expensive. The generator system consisted of an electric motor powered by the car accumulator and driving a permanent magnet generator. It was usually mounted under the bonnet, under the seat or some other suitable location. Since there was some ripple on the generator output, a choke/filter network was provided to ensure a steady DC voltage. One receiver built for generator operation was the Eclipse Series 512. It was a five valve superheterodyne model designed in December 1933.

The vibrator and full wave rectifier was employed right up to the time when transistors replaced valves in car receivers. Instead of a rectifier, some designs employed a synchronous vibrator. The rectifying action of the unit was mechanical instead of electrical. With the subsequent availability of low potential valves some designs enabled the set to operate without the need for vibrator or genemotor HT supplies.

The most distinguishing feature about most car radios, was the tuning control and mounting arrangement rather than any novel circuitry. Nearly all employed the superheterodyne circuit after about 1932. In the earliest receivers and still popular until about 1940, the on-off switch, dial tuning and volume control were housed in a control-head unit which was mounted in a position convenient to the driver. The controls were connected to the receiver proper by flexible drive shafts between the receiver and the control head. The flexible shafts ran in metallic casings similar to the speedometer cable housing. The two most convenient locations for the control head was on the steering wheel column or built in to the centre of the dashboard or instrument panel of the car. Special tuning control escutcheon plates were available to match the finish and colour of most cars.

Regardless of the type of aerial used, one important factor was height. In general, all other things being equal, the higher the aerial, the stronger the signal and this led to many weird and unsafe installations with high aerials. Some had two or four uprights mounted on front and rear bumpers and wires strung between them. Others had the aerial mounted under the running board or under the chassis, while cars with fabric covered roof tops, had the aerial frequently made of chicken wire, installed in or on the roof top. Running board or chassis aerials were subjected to much damage caused by the car being driven over corner kerbstones, concrete islands at petrol stations or over rough unmade roads. Water and wet mud caused considerable signal loss across insulators. From about the 1950s the telescopic type aerial became the standard type of aerial.

Just as with a home receiver, an earthing system was part of a radio installation in the early days of broadcasting — for the car this posed a real problem. Some installations employed a steel strip type spring with one end secured to the chassis and the other pressed to the ground under the car. Other installations dragged a chicken wire net behind the car, no doubt raising a lot of dust and being a nuisance when reversing the car.

Up to the mid 1930s, most car radios were imported.

In 1934, AWA produced one of the first Australian-built models with the Radiola 74.This was quickly followed by receivers built by other firms bearing the names of Astor, Eclipse, Tasma, Croyden, Ferris, HMW, Endeavour, Emmco, Pyrox, Air Chief, Philco and others. Some models were made as combined car/portable radios so that they could be easily unplugged from the dashboard and taken away from the cark to work as a portable with the aid of internally installed dry cell batteries.

By 1938, Australian-made Astor car radios were available in a wide range with special fittings and mountings available for most popular cars of the period including Chrysler, Chrysler-Plymouth, Dodge, Ford, Reo, Nash, La Fayette, Hudson, Terraplane, Studebaker, Hupmobile, Humber, Morris, Standard and others.

The receivers were available as two units and single unit models both employing superheterodyne circuits.

The two unit model was designed for ear level reception by using a header bar speaker and was available as 'Model 6–8 volt' for American cars, 'Model 12–16 volt' for English cars, 'Model F' a special model for Ford cars and 'De Luxe Model' with dual loudspeakers.

The single unit 'Model 6–8 volt' was designed for American cars only. It was very compact, cheaper than the two unit model and could usually be fitted out of sight behind the glove box to minimise interference with the passenger leg room.

In 1939, Astor produced a push-button unit which simplified station selection while driving.

Although universal models were available, car manufacturers soon began to install tailor-made equipment for their cars. These were in-dash types and took up less space than under-dash types.

With the introduction of the transistor, designers anxious to reduce battery drain soon took advantage of the low drain transistor. The first units produced in the 1950s were hybrid types with transistor output, but valves still being used in other stages. Fully transistorised receivers soon followed, and the vibrator disappeared from the scene.

Typical modern sets usually include facilities such as AM/FM stereo radio, cassette replay, multiplay CD, music search, tape switching, Dolby noise reduction and 3-way loudspeakers for front and rear. Electronic preset tuning systems are the norm.

These feathertouch preset tuning buttons allow the operator to preset and tune-in at the touch of a button, typically 10 FM stations and a further five AM stations, for a total of 15 stations. They incorporate automatic reception control circuitry which maintains optimum reception according to the strength of the signals. Built-in noise suppressor circuits keep out ignition noise that may filter through and ensures clear reception of broadcast signals. Telescopic aerials are motor controlled allowing them to be withdrawn out of sight when not in use, a far cry from the old chicken wire aerial system.

Designers have put a lot of research into the design of car aerial systems in view of the fact that listeners are becoming more discerning about their listening. They are demanding higher quality from car radio systems.

Some of the luxury cars are fitted with two radio aerials — one in the roof and another in the windscreen. Research has shown that in some situations, a windscreen aerial gives better results compared with a standard telescopic type, so both are fitted. Outputs from both aerials are sampled and the best signal fed to the receiver input circuit ensuring the best possible reception in difficult areas.

Authorities responsible for safety on roads are becoming concerned about some of the present-day designs of car radio equipment. They feel that car radios are becoming so complicated to use that they are a potential safety hazard.

Although the area occupied on the dash for the radio system has not changed significantly over the past 50 years, the number of features in the equipment has increased greatly. A system which included AM/FM stereo radio, cassette player and a remote CD player can have up to 25 different knobs and buttons with some models. For most installations, this requires the driver taking the eyes off the road for at least a few seconds to operate controls and to make adjustments. With a car travelling at 100 km/hr the car could travel typically 100 metres without the driver looking through the windscreen.

Operation by the driver is made difficult by virtue of bad placement of the unit and poor designations making it hard to access and/or see the controls and to read the designations. The size and legibility of engraving of some dials, knobs and buttons and also the lighting, particularly during night-time leaves much to be desired with some units. Rocking buttons, popular with some designs for volume control, can require that the driver have one hand off the steering wheel for up to seven seconds while carrying out adjustment. The same task with a simple rotary knob takes only a few seconds.

Designers are currently looking at going back to the old ways where controls for operating the radio were mounted on the steering column just under the steering wheel but this time they are developing a system which will allow incorporation of the controls in the car's steering wheel horn pad or other area if air bag is installed.

During 1997, Robert Bosch (Australia) released the Thummer, a remote control unit developed by Blaupunkt which is part of the German Bosch group. The unit which is mounted directly on the steering wheel provided facilities for the remote control of in-dash mounted radio and audio equipment.

One person who had a long association with the car radio industry was Vic Humphrey, a graduate of the Broadcast Operator's Course at the Marconi School of Wireless, and former Final Tester with Breville Radio Pty Ltd, 1943–45.

In 1945, Vic began work as a Technician with A W Barrs' Car Radio, founded by Wally Barrs, former Thom and Smith employee engaged on the manufacture and servicing of Tasma car radios. He moved to Brisbane in 1952 to establish a Branch office of Barrs there, but left the company the following year to take up a position of Field Engineer with EMI. In 1957, he became National Sales Manager of the Car Division, a position he occupied until 1970 when he left EMI to join Electronic Industries Ltd as Assistant Manager of the Car Radio Division.

After periods with AWA as Car Radio Sales Manager for Victoria, and Assistant Commonwealth Manager, Car Radio, with Chrysler, he rejoined Barrs Car Radio in 1975.

Barrs Car Radio subsequently became part of the Philips Car Radio organisation, with Vic being Victorian Manager.

In 1980, he established Humphrey's Auto Sound Accessories Pty Ltd at Gladesville, specialising in radio installation kits to major companies, marketing car radios, and companies assembling or manufacturing cars. For some years after retirement, Vic acted in an advisory capacity to the car radio industry.

Ferris Bros, Sydney was a prominent Australian manufacturer of car radio receivers for many years. The company was founded in 1932 at Mosman as a small radio manufacturing, distributing and servicing business by William (Chum) Ferris and brother, George Ferris.

In 1936, the business became a registered company with George Ferris, Managing Director; Chum Ferris, Technical Executive and Mr E S Wyatt as non-executive Director. At that stage the company began the manufacture of car radios to meet a high demand. However, it took much longer than planned to gear up to full production. In 1938 the company set up Car Radio Australasia in William Street, Sydney but closed the Depot two years later when the country was diverting resources to the War effort.

After the War, in 1947, a portable receiver employing six valves with 6.3 volt filaments was produced. Designated Model 74 it was an improvement on Model 73 produced the previous year. The Model 74 was fitted with a vibrator unit and was a large portable type in metal case designed for use as a car receiver powered from the car accumulator, as a portable powered from an alternative battery source or as a house table set powered from the AC mains.

In 1949, three models available included Model 83, Model 84, a 6 V/230 V AC powered set and Model M84, a 12 V/230 V AC powered set.

In 1952–53 included in the range of Ferris receivers was Model 94, a 6 V or 240 V AC portable/car radio.

With the availability of transistors and printed circuit boards in the early 1960s, new versatile models were produced. Model 104 released in 1962 was one of the top selling models. In subsequent years receivers designed for fixed installations in autos were produced with a range of facilities including push-button tuning and configured to suit a range of vehicles. One of the best-known car radios was the Ferris Volumatic II Series produced during the late 1960s.

However about this time, the company became associated with Channel Master products and radio receiver production was scaled down.

The company was subsequently taken over by Hawker Siddley Electronics Ltd about 1969 and manufacture of car radios ceased.

'Chum' Ferris, the company Technical Executive and Director had obtained some limited experience in radio shortly after leaving school when he worked for Philips and AWA. He was only 18 years old when he established the company business with his brother. In 1957, he became an Associate of The Institution of Radio Engineers (Australia) and in 1961 he became a Member of The Institution.

Modern technology has resulted in the recent introduction in Europe of a system designated Radio Data System (RDS) aimed at the car radio market. Additional information is broadcast on a sideband of the main channel of the transmitting station. The information provides assistance to the motorist and included traffic matters such as sites of new road works, sites where roads are under repair, location of major accidents, congested traffic areas and general travel information. The process of reception is automatic and requires no resetting or retuning of the channel by the motorist. When a nearby RDB station activates its transmitter to broadcast a message, the car RDS receiver will automatically switch off the radio program, CD or cassette being played and receiver the RDS program at a preset volume level. On completion of the RDS announcement, the car radio will return to its former program, CD or cassette source.

Other features of the RDS are that it transmits accurate time information ensuring the radio clock always displays the correct time and it automatically retunes should a received signal fade when the car is being driven through an area of low signal level.

The retuning process involves searching for a new frequency on which the same program is being broadcast.

As at mid 1998, no announcement had been made by the Australian authorities concerning the likely introduction of the system here.

TRAIN RADIO RECEIVERS

The use of receivers in trains for reception of broadcast programs goes back to the early days of experimental broadcasting. Radio Clubs in some States organised regular train trips which were extremely popular. In Adelaide for example, one outing on 16 October 1924 required nine carriages to accommodate the party on a night trip to Hallett Cove. It was the first large scale public demonstration in the State of broadcast reception on a moving train.

The receivers belonged to Club members or visitors, and ranged in size from three valve to seven valve. Some operators employed loop aerials while others used wires suspended from lamp shades or other attachments. In one carriage, an observer noted that fifteen sets were in operation at full volume, and not all were tuned to the same station.

Special programs were broadcast by 5DN and several experimental stations for the occasion. Well-known experimenters and Radio Engineers who operated receivers included Clem Ames, Roy Buckerfield, Harry Kauper, Fred Williamson, Hal Austin and John Hale. John Hale was Manager of the Radio Department of Newton, McLaren Ltd. He had worked with the company since 1917 and established the Radio Department in 1922. The company produced the first radio receivers for commercial sale as early as 1921, well before the establishment of the A and B Class stations in Adelaide.

One of the earliest official installations was fitted to an inspection train which operated for six weeks in mid 1925 on the Port Augusta-Alice Springs line. The receiver was a two valve battery set connected to a multi-wire aerial supported by poles projecting a couple of metres above the carriage roof. Good reception was reported from 5CL Adelaide, 2BL Sydney and 3LO Melbourne with signal strength being sufficient to drive a horn loudspeaker. The system was installed by H H Armstrong.

Although isolated fixed installations were made in State and Commonwealth VIP railway carriages in the 1930s, it was not until 1952 that a co-ordinated program of tests was carried out to assess the reliability of reception on long distance journeys.

Staff of the Commonwealth Railways under Jack Strachan, fitted out a carriage using a wartime National HRO receiver and an aerial suspended just above the carriage roof. Tests on a regular passenger train between Port Augusta in South Australia and Kalgoorlie in Western Australia were very encouraging and the Railways authorities asked staff of the South Australian Post Office Radio Section to undertake extensive tests and to provide recommendations on suitable reception facilities.

Tests using RCA AR88D and Hammarlund Super PRO receivers by Ted McGrath and Arthur Capel over several return journeys found that reception from 5CK Crystal Brook was reasonably reliable between Port Pirie and Kingoonya and from 6GF Kalgoorlie between Rawlinna and Kalgoorlie. The intermediate section was well-served by short wave transmissions from Wanneroo in Western Australia and Lyndhurst and Shepparton in Victoria.

Two German built lounge cars of the Commonwealth Railways were fitted out for public entertainment as a trial.

The receiver comprised a seven valve triple ganged type powered by a DC/AC converter feeding a 5V4G full wave rectifier. The set was tuneable across the medium frequency band and four crystal locked frequencies were provided for short wave reception. The output was fed to 120 watt audio amplifiers which fed a 5 inch (12.5 cm) Rola speaker in each compartment. The receiver was built in the Port Augusta workshops of the Commonwealth Railways to a design by Jack Strachan.

Prior to the installation of radio receivers in the train, news for passengers was supplied in the form of bulletins updated as the train proceeded. A news bulletin was posted just prior to departure from Port Augusta, and before the train reached Tarcoola, another news bulletin would be phoned through to the Station Manager at Tarcoola who would have it typed up ready for posting when the train arrived. The procedure was repeated at Cook and Rawlinna in South Australia, and by the time the train arrived at Kalgoorlie five bulletins would have been posted.

In 1974, similar receivers were in operation on the Marree to Alice Springs route but more modern types had replaced the original sets on other lines.

One of the receivers was donated to the Telecommunications Museum Adelaide collection and was on display for some years.

THE CRYSTAL SET

The crystal receiver or crystal set as it was more commonly known in the golden years of broadcasting, was a complete piece of apparatus adapted for the reception of broadcast programs using a crystal rectifier. It consisted basically of a fixed or variable coil, a fixed or variable capacitor (condenser as it was then known), a crystal detector and a pair of headphones.

There were dozens of circuits successfully employed but some were so complex with various wave traps, noise reducers etc, that there was barely enough audio power to operate the headphones, unless the operator was close to a powerful transmitter.

Hundreds of thousands of crystal sets were in use throughout the world in the 1920s and early 1930s, and with their polished mahogany or teak cases, bright brass terminals and the general aura of being 'hand-made' are today very collectable pieces, and carry high price tags at many sales of antique wireless apparatus. There is also a thriving business in the manufacture of replica models to satisfy the demands of nostalgia buffs who wish to maintain a link with apparatus of the type grandpa used in order to receive wireless programs before transistor radios and television.

At the peak of popularity of the crystal set, nearly all organisations producing valve receivers produced crystal sets. In England alone, records shows that at least 600 companies manufactured crystal sets with more than 400 different brand names being known. One early photograph shows a warehouse with 10000 sets being prepared for shipment overseas.

Although a Licence was required to operate a wireless set including a crystal set, the licence was as expensive as the cost of parts for the crystal set, so many opted to 'take the chance' and operate without a licence. The Radio Inspector in South Australia, Bert Harrington, estimated in 1930 that there were over 7000 crystal sets being operated in the State without a licence.

The crystal set was basically a tuned circuit and crystal detector. The main inductance arrangements included a slide coil circuit, a tapped coil circuit, a loose coupled circuit or variometer circuit.

The slide coil circuit had many variations. Units were available with single, double, or triple slider configurations. However, the triple slider model was extremely difficult to tune for good output signal and was poor in selectivity. For circuit resonance, some models employed a variable capacitor, some a fixed capacitor while others had no capacitor at all. They relied on the distributed capacitance of the coil windings to produce resonance at the station operating wavelength. The set generally comprised a wooden baseboard to which was attached a tube on which insulated wire was wound. The tube was frequently cardboard obtained from the core of a role of linoleum widely used in homes at the time, or a plastic former such as ebonite or bakelite purchased from a local Radio Shop. Mounted on top of two upright end pieces was a square brass bar whereon slid an ebonite knob, the lower part of which had a brass spring plunger attached to it. One end of the plunger pressed against the inside of the brass bar and the other upon an exposed part of the winding. Whilst most designs had the coil mounted in a horizontal plane, others had the coil mounted vertically.

Instead of having a sliding contact move parallel with the coil, a variation known as the Moore system named after its USA inventor Edward Moore in 1923 used a spring loaded radius arm to sweep across one surface of a coil wound on a four sided former. The phosphor bronze spring was about 10 mm wide and had a hole drilled at one end to allow it to be fixed by a terminal post to the receiver base plate. The other end of the spring which contacted the coil, was pointed with a turned-up end. An ebonite knob was fixed to the spring near the pointed end, about two centimetres back from the point. By grasping the knob with the fingers, the spring could be made to slide across the face of the coil in a radial motion to effect tuning-in of the station. It was used in a crystal set known as the Metro Junior and sold by Radio Shops in Australia. One distributor was Wireless Supplies Ltd, Brisbane in 1926 who donated a set to the YMCA Radio Club.

Another slider which used a four sided coil was invented by Charles Marti of Martian Electric Laboratories USA in 1922. The sliding contact was a brass ball about one centimetre in diameter. It was moved over one face of the square coil by turning the handle of a small winder. A grooved shaft moved the brass ball as the handle of the winder was turned. One of these imported sets was exhibited at the Brisbane Radio and Electrical Exhibition in 1926 on the display stand of Home Radio Service Ltd.

Bill Rohde of the Wooloowin Radio Club constructed a set similar to the Marti design but he employed two brass balls, one on adjacent faces of the coil. One ball was connected to the aerial while the other was connected to the crystal so that the inductor acted like an auto transformer. He displayed it at a Club meeting and designated it as 'The Heath Robinson Ultimate'.

The tapped inductance circuit was popular but required some skill in assembly owing to the need to make many soldered connections to the coil and to studs over which a contact arm moved. Sometimes, two sets of radial studs were employed. Operation of this set required more patience than for a single slider set but the circuit was more efficient and produced a louder signal.

The loose coupled circuit was another means of signal reception. It consisted of a fixed untuned coil (the primary) with one end connected to the aerial and the other end to the earth. It was loose coupled to a tuned coil/capacitor combination in the crystal circuit. The coils were mounted in a dual coil holder with the aerial coil being fixed and the other moveable. The procedure for tuning-in a station was to vary the distance between the two coils and then to adjust a variable capacitor. With this and most other circuits, a fixed capacitor about 0.002 microfarads was bridged across the headphone terminals. Other loose coupler arrangements were also used. One popular type used an aerial or primary coil of the slider type with the secondary or tuned circuit inductance being tapped for coarse adjustment. These types were very selective and more efficient than single circuit designs.

One of the most popular and smallest crystal sets produced commercially was the variometer type. Many home-made models were produced, but in the majority of cases, they lacked the efficiency of commercially produced models. The variometer consisted essentially of two parts, an outer inductance and an inner one. The general arrangement was for the inner inductance to be capable of rotation inside the large one which was stationary. For this reason, they were called rotor and stator respectively.

The popularity of the crystal set during the 1920s, is evidenced by the number of articles published in radio magazines, in newspaper radio supplements and in Radio Club newsletters. For example, between mid 1925 and mid 1926, 'The South Australian Wireless and Radio Weekly', only one of many magazines in publication throughout Australia at the time, published the following articles relating to crystal sets: The Crystal Set (Joe Reed); A New Crystal Receiver (A F Harper); Crystal Receiver (A E Williams); Crystal Receiver for Everybody (Southern Suburban Radio Club); Combining Crystal and Valve Set ('Amplifier'); Watts' Circuit for Raising Melbourne with Crystal Set; Double Strength Crystal Set Circuit (F G Long); Selective Crystal Set (Clem Ames); Simple Home Built Crystal Set; Conversion to Slider Crystal Set ('Tuned Anode'); tapped Coil Crystal Set (F Gladstone Carlier); Ultra Crystal Toroidal; Two Circuit Crystal Set (Clem Ames).

Magazines, newspaper articles and Radio Club minutes carried many reports of exceptional performance by crystal sets. The following report prepared in 1924 by Bill Smith who operated a Radio and Electrical business in Wallaroo in South Australia, and later worked at the Adelaide ABC studios is typical:

> 'I have observed with much interest recent reports concerning crystal set reception. I think the results I am getting with a crystal receiver may be of some interest. My set is a home-made single slide crystal set using an iron pyrites crystal and one stage of audio amplification. My air line distance to Sydney is 900 miles (1440 km), and to Adelaide 100 miles (160 km). With the crystal set alone, I have heard all the Australian Commercial stations and by adding one stage of AF amplification I was able to pick up 2FC clearly, and also VLA in New Zealand. Station A5HR which is about 6 miles from my station, comes in very loud. VIA Adelaide is readable at night about 25 ft (7.6 m) from the phones. My aerial is an inverted L type consisting of three wires 85 ft (26 m) long and 50 ft (15.2 m) high. My counterpoise earth is about 50 ft (15 m) long.'

Another comment on long distance reception from a listener at Wondai, west of Maryborough in Queensland, to 'The Queensland Radio News' in 1930 is of interest:

> 'We are using a Selectimax crystal set as described in a previous issue of "The Radio News" and have picked up with surprising volume, 4QG Brisbane, 3LO Melbourne, 3AR Melbourne, 2FC Sydney and 2BL Sydney. The crystal set is not used with an amplifier. The aerial is about 200 ft (60 m) long including lead-in and earth wire and is 30 ft (9 m) high. This result rather

shakes the idea that a crystal set is only useful when operated near a broadcasting station.'

One overseas report of reception of an Australian broadcasting station on a crystal set appeared in the 1 September 1926 issue of 'The Queensland Radio News':

'The SS Tapti reports 4QG picked up 3250 miles (on Panama to Sydney track), clearly audible on Telefunken type E5 crystal, with one LF amplifier. Heard every day from that distance at greater strength than any other Australian or American station. The SS Niagara reports 4QG superior to any station heard on the Sydney to Vancouver run. The Niagara also reports that many Honolulu residents regularly sit up to hear 4QG in preference to the USA Pacific Coast stations.'

Although valve receivers were available from Radio Shops and some Department stores as fully assembled units, they faced stiff competition from the crystal set, notwithstanding the shortcomings of the humble crystal receiver.

During the Christmas period of 1924, the price of a Fortevox crystal set complete with Hertzite crystal and Pico headphones cost £2 ($4) at Adelaide's largest Departmental store James Marshall and Co., Ltd, whereas an imported English made four valve Polar Radiophone receiver complete with valves, batteries and loudspeaker cost £62 10 0 ($125), a considerable sum of money in those days when a Salesman in a Radio Shop was paid £6 ($12) a week.

In a 12 months trading period July 1924 to June 1925 during which time 5DN was operational, followed in late 1924 by 5CL in Adelaide, crystal sets outsold valve receivers by a ratio of 4:1 at James Marshall. The Manager of Harringtons Ltd, W S Corfield reported a similar sales pattern.

The reason for the popularity of the crystal set was that it had a number of advantages over a valve receiver. It did not require high tension battery and accumulator and had no valves which had a relatively short life. Also, the operation of a crystal set was relatively simple. Some of the multivalve receivers employed sophisticated circuitry and were supplied with a booklet of several pages of complex instructions on tuning and maintenance procedures. This did much to discourage many people from investing in high performance receivers.

The initial low cost for parts, ease of construction and zero operating cost made the crystal set especially popular with schoolboys and in some cases, schoolgirls. Many of these young people acquired a lifelong interest in radio as a result of encouragement, particularly by Radio Club members, practical experience and later advancement to battery-operated valve receivers. For many, it provided a path to a lifelong career in Radio Technology.

At most Radio and Electrical Exhibitions where there was an Amateur Section 'novel' crystal sets were often included in the displays. At the 1928 Brisbane Radio and Electrical Exhibition first prize for a Novel Crystal Set went to Wally Scott with a 'birds nest' design. The receiver inductance was wound in the shape and appearance of a bird's nest. It used the basket-weave format employing cotton covered wire. It was mounted on a square wooden base with a replica bird in the nest. The judge gave it high points for performance when tuned to 4QG. Second prize was a smoker's outfit with the coil being wound under the ash tray. Third prize was a crystal set contained inside a Bulimba Beer bottle. Aerial, earth and headphone terminals were mounted externally by drilling holes in the glass. Thirteen items were entered in the competition.

Thirty years later, some enthusiasts kept alive the heritage of the crystal set but had at their disposal more modern materials. In 1960, one popular set in operation comprised a circuit using a parallel tuned circuit of 50 turns of 38 SWG double silk wire wound on gumstrip wrapped around a Ferroxcube B2 aerial rod tuned by a 500 PFD mica compression or air spaced capacitor. The detector was a GEC GEX 34 germanium crystal diode. A BTH CG 10E type was also suitable. Other components included a 220 PFD fixed capacitor in series with the aerial and a 0.001 MFD fixed capacitor shunted across a pair of high resistance headphones.

Kit Sets

The origin of the kit set can be traced back to the earliest days of wireless telegraphy, many years before broadcasting began, but it was broadcasting which made the popularity rise to great heights.

When entrepreneurs imported components from USA and England, radio experimenters usually purchased either single components or a range of components necessary to assemble a complete receiver or transmitter. To assist the novice, many Radio Shops assembled a complete set of components from stock together with a diagram showing the method of construction. These became known as kit sets. Whenever a new circuit appeared in one of the many radio magazines, Radio Shops put together a kit set for the circuit described, and this did a lot to increase sales.

It is not known who produced the first kit sets in Australia but kit sets were imported from overseas before the First World War. Ern Stanton of Enfield, Adelaide imported a receiver kit set from J J Duck and Co., Toledo USA in 1912. The kit comprised a Ferron detector with silicon crystal, a loose coupler of the US Navy type, variable capacitor, fixed capacitor and headphones. The kit was supplied complete with wire, terminals, knobs, drilled baseboard and a construction circuit. The loose coupler and headphones were still in service during the 1930s by Roy Cook who as a boy, had been taught the fundamentals of wireless telegraphy by Ern. Following application to the PMG's Department, Ern was granted a licence to operate spark station XVN from 10 February 1913.

When broadcasting commenced in Australia in 1923, there were many shops already selling radio components, fully assembled receivers and kit sets. The Universal Electric Co., Pitt Street, Sydney was one of many stores with kit sets before broadcasting began. Their Armstrong Super-Regenerative Kit displayed at the 1923 Royal Easter Show created a lot of interest.

Some of the earliest locally assembled kit sets were crystal sets and valve reflex kits. Multivalve TRF kits soon became available followed by neutrodyne and later, superheterodyne kits. The basic essentials of the neutrodyne kit were matched neutroformers (coils) and neutrodons (neutralising capacitors).

In the late 1920s, kits were being produced in large numbers, particularly as coil kits. Typical was the Rodine Coil Kits distributed by Robottoms Radio Store, Melbourne. They were well-made and supplied with detailed construction diagrams. Others included Senior Browning-Drake kit, Junior Browning-Drake kit, Reinartz kit, Special Reinartz coil, Three Circuit Tuner kit, Senior Neutrodyne kit and Junior Neutrodyne kit.

By the mid 1930s, most receiver manufacturers were producing kit sets of various types and designs and sales of these kits formed a major part of the majority of Radio Shops' business. Mail order shops were kept busy supplying country enthusiasts. Typical was Homecrafts of Melbourne with their range of Ezybilt Kits. They included:

- Economy Reinartz Three, an updated version of the original Reinartz circuit powered by AC.
- Melodious Super 3, a battery-powered three valve Reflex Superheterodyne available in medium wave and dual wave band models.
- The Symphony Vibrator 4, powered by an accumulator including Ezybilt matched coil kit.
- The 1937–38 Vibrator 5 available as medium wave and dual wave band models.
- The Air Cell Battery 4, powered by Eveready Air Cell and B batteries.
- Universal Dual Wave Midget, available for operation with 6 volt or AC or DC power supplies.
- Short Wave Converter kit, a complete kit to convert Melodious Super 3 to short wave operation.
- All Wave Battery TRF kit set.
- Radiotron 5 Valve Universal AC/DC Superhet kit.
- Four Valve Battery Portable Receiver kit.
- Four Valve Battery Dual Wave Reflex Circuit kit.

In addition, Homecrafts supplied the full range of Radiokes kit sets produced at the time.

Levenson's Radio established by Joe Levenson in 1927 at 226 Pitt Street, Sydney was a popular Sydney Radio Shop with a large range of kit sets. In mid 1933 they included:

- Two valve battery set, The Little Duke, provided with chassis and panel already drilled, all parts and circuit diagram.
- The Countryman's Four, a four valve battery-operated receiver with simplified assembly details.
- Macs, a two valve short wave receiver, one of the best sellers in the range.
- The Big Broadcast, an all electric set of three valves plus rectifier.
- The Linguist, a three valve battery receiver designed for medium wave and short wave reception.
- One valve receiver employing crystal detector and valve audio amplifier capable of loudspeaker from local stations.
- R J L, a four valve portable receiver.
- The Australian Listener, a crystal set using a new design of low loss variable capacitor with an orthodox circuit.
- Lakes, a one valve receiver with coils for medium wave and short wave reception.
- The Sky Raider, a four valve battery-operated receiver.

Colville-Moore Wireless Supplies Ltd, 10 Rowe Street, Sydney, next door to the Hotel Australia, had a thriving Mail Order business in kit sets which they manufactured or put together in their factory for country clients. They supplied easy-to-understand construction or assembly details, pretested all parts before despatch, and provided a good follow-up service for their clients. One of the most popular kit sets available in mid 1927, was supplied to 42 country customers in six months. It was a three valve Stag receiver widely used by country people to listen to overseas broadcasts from Europe and USA. On many occasions high level loudspeaker volume was provided by PCJJ in Holland and WGY in USA. Parts in the kit comprised two lengths Dilecto rod cut to appropriate lengths, two bakelite pillars, bakelite sub panel, two Emmco back of panel mounting dials, four lengths Dilecto tubing 2_ inches diameter by 1_ inch length, reel 18 gauge enamel covered wire, reel 30 gauge silk green wire, three lengths Dilecto tubing 2_ inches by 1_ inch, 20 special pins and sockets for mounting coils, three H&H porcelain sockets, Geco 4-1 transformer, Geco 2-1 transformer, panel 22 inch by 8 inch by 3/16 inch Radion or Dilecto, two Bradleystats, Geco 11 plate capacitor with vernier dial, Cutler-Hammer battery switch, BMS single circuit jack, BMS double circuit jack, Electrad capacitor and grid leak, 0.002 MFD Dubilier capacitor, one D4 Philips detector valve and two B406 Philips valves. As an alternative to supplying all basic material for winding of the coils, the company would provide factory assembled seven coil and back mounting dials at component cost plus 10 shillings.

Another very popular kit was the Solodyne. With this kit, the coils were Radiokes manufactured units with split primary screened coils.

The kit set approach to radio, particularly for the keen hobbyist, was not confined to complete receivers and coil kits. In keeping with developments in technology, kit sets were put together to add to, or modify equipment, such as short wave converters, adding an audio stage to a crystal set, change-over from battery operation to AC or DC mains, power supply kits to enable change-over to a new set of valves requiring different voltages from the original design, box shield kits to shield the RF stage from the audio stages, adding record playing facilities and many others.

Even enthusiasts who wished to assemble their own console or mantle cabinet were catered for by the availability of kit sets all cut out and ready for assembly and polishing.

The kit set idea has maintained its popularity even with today's technology, being kept alive by such publications as 'Electronics Australia with ETI'.

Many parts which have existed from the earliest days of radio are still used today in kit sets although in slightly modified forms such as resistors, capacitors, inductors etc. Others have outlived their usefulness and disappeared from the scene being superseded by new technological developments, such as the valve being replaced by solid state devices, hook-up wire and chassis replaced by printed circuit boards etc.

SHORT WAVE CONVERTERS AND ADAPTERS

Before the widespread application of superheterodyne design and coil switching principles to domestic radio receivers in the 1930s, the typical receiver circuits employed for medium wave reception did not readily lend themselves to short wave reception.

As the number of short wave stations on air throughout the world increased in number in the 1920s, enthusiasts modified their equipment to receive these transmissions by constructing various devices, including one which linked into the receiver's audio amplifier and loudspeaker or headphone circuits. One of the earliest devices was a simple regenerative grid leak detector constructed so that it could be plugged into the socket of the detector valve of the receiver. A variable capacitor provided control of regeneration.

When the device was added to the low frequency stage of an existing receiver it was known as a short wave adapter but if the design was such that it was added to the high frequency stage and converted the combination into a heterodyne mode of operation, it was generally referred to as a short wave converter.

The devices were readily available in kit set form or could be assembled from components to circuits regularly described in many popular wireless or radio magazines of the day.

Care had to be taken in incorporating devices which were powered from the receiver AC mains supply unit. Trouble was frequently experienced with hum as a reacting detector was very sensitive to external AC fields. Members of one of the Adelaide Radio Clubs in the early 1930s gave a lot of attention to the problem and they came to the conclusion that the adapter had to be provided with its own filament transformer or be fed from a separate winding of the receiver power transformer and bypass capacitors fitted to each filament lead. If this was not done, it was difficult to eliminate hum and ripple noises.

By 1934, many manufacturers had produced converters. Models made by Airzone, DW, Tasma, Essanay and others were available in Radio Shops.

The Tasma Converter was typical of those available. It was housed in a piano finished Midget wooden cabinet and as the converter was normally mounted on top of a receiver, it was designed so that it did not detract from the appearance of the radio already installed in the listener's home.

Three short wave bands corresponding to designated positions on the wave change switch were engraved on the dial. They were 13–27, 25–50 and 50–100 metres. A fourth position on the switch changed over the aerial from converter input to receiver input. The converter was an AC powered unit provided with an on/off switch.

Some of the early circuit designs to provide for frequency conversion were not very satisfactory, and designers produced a frequency converter which incorporated an oscillator and mixer with a separate oscillator valve and non-regenerative detector which could be tuned independently of the other receiver controls. When commercial receivers were designed and manufactured to provide for both medium and short wave reception, tuning capacitors were ganged and switching provided to change over to the coil system appropriate to the particular band selected. Receivers incorporating these facilities became known as 'dual wave' or 'all wave' band receivers.

Although well-engineered commercially produced short wave kit sets could still be purchased from Radio Shops in the 1950s by 'do-it-yourself' enthusiasts, the kit sets gradually disappeared from the stock lists of the Shops with the introduction of solid state technology in the 1960s.

RADIO FREQUENCY AMPLIFIERS

INTERSTAGE COUPLING

There were a number of advantages in employing a radio frequency amplifier to increase the level of the station signal before applying the signal to the detector. This was particularly relevant with early receivers when the current produced by the detector circuit was proportional to the square of the radio frequency current applied to the detector. Also, amplification of the signal at radio frequency improved sensitivity, selectivity and the signal-to-noise ratio of the receiver.

Radio frequency amplifiers were required to be tuneable over the range of frequencies and because of this, special problems were encountered. For example, even with modern amplifiers there is seldom perfect uniformity of gain and selectivity over the complete broadcast band but with early receivers it was a major problem, and often lead to instability, particularly at the high frequency end of the band. The situation was aggravated because of the high inter-electrode capacitance of valves then in service.

A number of methods had been used over the years for interstage coupling of radio frequency amplifiers but the three most commonly employed arrangements were untuned RF transformer, variometer or tuned anode, and tuned transformer methods.

The untuned transformer system used an air core transformer of primary to secondary ratio usually 1 to 1. To ensure a wide bandwidth, the coupling of the two windings was close and resistance was made high by using very fine wire or in some cases, resistance wire. Distributed capacitance of the windings resulted in amplification at, and on both sides of the resonant frequency, but in order to use this technique to cover the broadcast band in use, designers frequently employed transformers with different resonant frequency characteristics in successive stages.

Radio frequency amplification with anode variometer was used with many two or three valve receivers. It enabled regeneration to be obtained easily although it decreased selectivity. When the variometer was tuned, it was possible to obtain not only a maximum voltage drop to impress in the grid of the valve in the amplifier, but also a regenerative or feedback action due to grid-anode capacitance. A variable grid leak was frequently necessary to give stability. Although some early receiver designs featured several stages of amplification with variometer coupling, they required some skill in adjustment to obtain good signal quality.

The tuned transformer amplifier, or tuned radio frequency (TRF) amplifier as it was commonly known, was the most widely employed circuit for the amplification of radio frequency signals.

By using a well-designed transformer, an overall amplification several times the normal amplification of the valve could be obtained. Designers of high class receivers went to a lot of trouble to produce transformers with very low interwinding capacitance otherwise very little step-up in voltage could be obtained. In a well-designed transformer, there was reasonably good amplification over the band and less auxiliary components, such as variable grid leaks, were required.

A transformer of particular interest is the 'regena-transformer' used in the Browning-Drake circuit. The circuit developed in 1924 by Glenn Browning and Fred Drake of Harvard University was basically a four valve tuned and neutralised radio frequency stage with regenerative detector and a specially designed RF transformer. The secondary consisted of 77 turns of No. 20DSC wire wound on a 75 mm cylinder while the primary consisted of 24 turns of 30DCC wire wound in a slot under the secondary at its low voltage end. A rotating tickler coil was mounted at the other end of the coil. Because regeneration was in the radio frequency transformer, and not in the aerial circuit, no interfering oscillatory signals reached the aerial. The transformer resulted in low capacitance coupling between primary and secondary and produced a receiver with good sensitivity and selectiveness. The tickler coil controlled regeneration in the normal way.

The National Company Inc., produced a kit in the USA known as the National Regenaformer Kit. It sold in large numbers with some being imported by Radio Shop proprietors in Australia. Doug Whitburn of Adelaide purchased a kit from Andrews Radio Store in Bowman Arcade, King William Street in 1926. The kit comprised aerial coil mounted on a 0.0005 MFD variable capacitor with 4 inch vernier dial; National Regenaformer mounted on a 0.00035 MFD variable capacitor with 4 inch vernier dial; set of hardware for mounting the items and a blueprint wiring diagram. Later, the Browning-Drake Corporation was formed and manufactured complete receivers as well as kit sets.

IRON CORES

The use of iron core transformers for amplification of radio frequencies had been suggested as early as 1916 by a French engineer Marius Latour, but performance did not usually match theoretical advantages, particularly with cheap units.

In order to reduce hysteresis loss, the core was built up of very thin sheets or layers of silicon iron or of iron annealed in a vacuum. Some manufacturers employed a bundle of very fine wires in place of the iron strips.

It was claimed that the iron core transformer had a broader bandwidth than the air core type and therefore had greater signal transfer efficiency.

Although used with some degree of success in intermediate frequency transformers with early superheterodyne receivers, none of the major manufacturers produced receivers which used iron core transformers in the radio frequency stages that could be considered to be a success. Designers had to wait on the development of iron dust cores before returning to the use of iron in radio frequency transformers.

In the early 1930s, a number of manufacturers in the USA experimented with iron cores in RF transformers using materials known locally as 'Ferrocart' and 'Poly-iron'. Richard Kennell, Chief Engineer of New System Telephones Pty Ltd, Sydney during a visit to the USA in 1934 was able to observe the state-of-the-art at the time. He noted that while the Q of an ordinary air wound duo-lateral coil using plain copper wire was about 100, the Q increased to 160 for a coil using Ferrocart or Poly-iron. However, an air core coil wound with Litzendraht wire resulted in an increase of Q to 130–140.

The most widely-used material by Australian receiver manufact-urers in the mid 1930s, was Sirufer, a high grade, high permeability material. The coils were wound with Litzendraht wire and gave good results. As the diameter of the wire was critical, it had to be carefully checked before setting up the winding machine.

Ferrocart was introduced to Australia by Ferrocart (A/Asia) Pty Ltd, Melbourne who also made vibrator units for eliminating B batteries in receiver power supplies. Receiver manufacturers produced iron dust cores and sold them under various labels. Thom and Smith marketed Ferro Coil while Breville marketed Ferrodyne.

In 1946, Philips announced the development of a non-metallic ferromagnetic material named Ferroxcube. The material had a high specific resistance and high permeability and some grades were suitable for use with short wave coils. The properties of Ferroxcube allowed considerable reduction to be made in transformer sizes and was ideal for permeability tuning circuits.

TUNING

Early technique with transformer circuits was to tune the transformer with a variable capacitor across the secondary or the grid winding. This enabled resonance to be obtained for each setting of the tuning capacitor, so resulting in high amplification and good selectivity. With transformers wound with few primary turns, tendency of the valve to oscillate was reduced.

Some enterprising designers produced circuits with a fixed low loss capacitor and variable inductor to achieve resonance but with varying degrees of success.

Mr C A Maddern who owned Bullock Cycle and Radio Stores, Adelaide in the 1920s manufactured Reactodyne brand receivers and developed a number of tuning capacitors and inductors which he employed in tuned RF circuit stages. Some of the successful designs can be seen in vintage radio collections today.

One capacitor design employed twin rotors driven by a common control shaft and gear wheel acting on two larger gear wheels coupled to the two rotors. The capacitor provided straight line wavelength characteristic, eliminated backlash problems, provided 360 degree tuning, was compact in form, and provided a high minimum to maximum capacitance ratio. The brass plate surfaces were embossed and pressed to ensure a high order of flatness with the 0.015 inch thick material. The dial was fitted with 'micro tuning', a worm drive system providing a 200:1 ratio for accurate fine tuning purposes. The stator was insulated from the earthed frame by small porcelain discs made by a pottery in Norwood.

He found that the most efficient coil for RF transformer stages was a torroid or doughnut-shaped design which he made on the premises and marketed as 'Doughnut Coil'. It had a lower external magnetic field than most other designs and minimised coupling problems. The coil was made on a special machine designed by the workshop staff using 12 turns of No. 24 SCC primary and 225 turns of No. 22 SCC secondary. Inside diameter was 25 mm and outside diameter 87 mm.

UNWANTED REGENERATION

The amplification of radio frequencies had its price. With high amplification, regeneration occurred resulting in instability. In addition to regeneration by means of the valve grid-anode capacitance, it could occur because of interaction among various parts of the circuit such as regeneration from resistance coupling and from magnetic coupling. It was essential for the designer to control these factors to ensure oscillation did not take place as it would seriously increase distortion and reduce signal amplification. Among the various methods adopted included a capacitor placed across the B battery where a common battery was used for all valves to minimise regeneration due to resistance coupling. Magnetic coupling between stages was prevented by using either separate metal compartments or metal partitions with small holes for passage of interconnecting wires. Other methods used included tilting coils, or mounting them at right angles to reduce induction. A further precaution was taken by using shielded wiring, either with an integrated braid or in flexible tubing.

The most troublesome factor in unwanted regeneration was caused by the interelectrode capacitance of three element valves and many devices and circuits were developed to overcome or minimise the problem. These included:

* **LOSSER OR POTENTIOMETER**

  Some Engineers referred to this method as 'brake action' as it reduced regeneration by limiting amplification. Many novel arrangements were in service such as the use of grid potentiometer, shunt resistance on transformer, high resistance transformer windings and even iron core transformers. However, the most widely employed method was control by a grid potentiometer. A common stabiliser for all radio frequency stages was usually sufficient. There were several ways of connecting the potentiometer, but the most popular was to insert the device between the grid tuned circuit and the filament negative battery connection.

  An alternative to the potentiometer, was the use of a series resistance connected directly to the grid circuit. This arrangement was made popular because of its use in Atwater Kent receivers. The resistance tended to damp out the amplitude of the signal oscillations and accordingly the variations of anode current were never sufficient to produce feedback that could result in self oscillation.

  A major weakness with the technique was the lack of sensitivity of the receiver, but its popularity arose from the fact that it was easily applied.

* **TICKLER OR FEEDBACK COIL**

  This method became popular when it was used with the Superdyne receiver. This used a tickler or feedback coil which was reversed in action so as to decrease regeneration. By good design and adjustment, the amount of regeneration produced by the tickler coil was equal to that due to the valve grid-anode capacitance.

  A disadvantage of this method was that the setting of the reversed tickler was not permanent as it had to be changed each time a new station was tuned in. For a two stage radio frequency amplifier this involved two adjustments.

* **REVERSED CAPACITANCE**

  The reversed capacitance back coupling method was used in the neutrodyne circuit receiver. The circuit was developed in the USA by Professor Hazeltine in 1918 and incorporated in a broadcast receiver he designed in 1922 for broadcast station reception. The receiver was called the 'Neutrodyne' and Hazeltine found that inductive coupling between the radio frequency coils was minimised when the coils were mounted at an angle of 54.7 degrees with respect to the line of centres.

* **OTHER METHODS**

  Many other methods had also been used to minimise or eliminate regeneration with radio frequency amplifiers. These included a Rice circuit, a balanced circuit and a system widely used in France in which the anode of one of the RF amplifier valves was coupled by means of a small variable capacitor to the grid of the two previous valves.

  In the Radiola 20, a TRF receiver with two RF stages and regenerative detector manufactured in USA in 1925 and marketed in Australia as Radio 20, neutralisation was effected by a bridge circuit arranged so that the feedback via the grid-anode capacitance was balanced by an out-of-phase signal fed back to the grid via a small variable capacitor. A circuit similar to this was employed in 1926 by Consulting Engineer Hal Austin, Adelaide with one of his Perflex receiver models.

MILLER EFFECT

The interelectrode capacitance between anode and grid was one of the major problems with which early designers had to cope when designing circuits incorporating RF amplifiers. One of the most widely employed valves in use in the early 1920s was the 201A type and this had a capacitance between 8 and 12 PFD. Improvements in valve manufacturing techniques later reduced it to about 4 PFD for many triodes. However, because of amplification of the signal after it passed from grid to anode the equivalent transferred capacitance could easily be up to 100PFD which was a large percentage of the total capacitance.

The problem was not fully appreciated until John Miller later studied the phenomenon. The influence of amplification on the input capacitance became known as the Miller Effect. In essence, feedback through the grid-anode capacitance of the valve (Miller Effect) could result in transferring across the grid-anode path a negative resistance, a positive resistance, a capacitance or a combination of resistance and capacitance. The anode load, impedance and amplification factor of the valve were the determining factors.

NEUTRODYNE CIRCUIT

The neutrodyne circuit was one of the most popular circuits used with broadcast receivers for many years.

In this circuit the valve interelectrode capacitance was neutralised by means of special neutralising capacitors called neutrodons. In some designs, the capacitors were made up of insulated wire inside a metal tube.

The neutrodons were connected in such a way that current fed back from the anode to the grid through the neutrodon exactly equalled and opposed the current fed back from anode to grid through the valve interelectrode capacitance.

In a typical neutrodyne receiver employing two stages of radio frequency amplification, the coils of the aerial tuning unit (or neutroformer), the first radio frequency unit (or neutroformer) and the second radio frequency unit (or neutroformer) were mounted at an angle to reduce coupling between them to a minimum. They were often separated from the rest of the receiver by a metal shield.

The arrangement developed by Professor Hazeltine and Harold Wheeler was considered by many to be one of the greatest Radio Engineering contributions made to the operation of tuned radio frequency amplifiers.

In the USA, a group of companies was formed in the early 1920s to exploit the Neutrodyne patents owned by the Hazeltine Corporation. The group was known as Independent Radio Manufacturers Inc., and their primary purpose was to assist one another in getting around the patents of the RCA organisation. Companies in the group included F.A.D. Andrea (FADA), Freed-Eisemann, Garod and Gilfillan Bros, and when FADA produced the first commercial Neutrodyne in 1923 it was an immediate success. The name Neutrodyne was a registered trademark and any set and firm carrying the name Neutrodyne was sure of good sales. There were fourteen members in the group manufacturing receivers using neutrodyne circuits and they were hard-pressed to meet the demand. People came to accept the Neutrodyne as the last word in radio.

Most models were imported by various Radio Shops in Australia and by 1926 complete receivers and kit sets were readily available. Harringtons were agents for Gilfillan sets, Andrews Radio Stores stocked FADA models, Adelaide Radio Company sold Freed-Eisemann receivers and United Distributors also stocked Neutrodyne receivers.

The Australian representatives of the Hazeltine Corporation were Neutrodyne Proprietary Ltd, who were granted Australian patents in 1924 and 1925.

It is not known when the first Neutrodyne receiver was commercially manufactured in Australia, but the Transatlantic Wireless Manufacturing Company in Adelaide were manufacturing three models of receivers called Newkrodyne and employing the neutrodyne circuit during 1925. They were exhibited at the Radio and Electrical Exhibition in Adelaide on 12 December 1925. The 5CL Radio and Electrical Company also produced locally made neutrodyne circuit receivers about the same time. They were first sold under the Demon brand but this was later changed to Eagle. They manufactured a table model with a glass front panel and two deluxe cabinet models, all with five valves.

Stores which had imported neutrodyne circuit receivers on show at the same Exhibition, included Andrews Radio Store with a Gilfillan which was awarded the Championship Prize, and Harringtons Ltd, with a Gilfillan receiver and kit sets. At the Exhibition which followed on 22 June 1926, the firms displaying Neutrodynes and new models increased, and included Andrews Radio Store with FACA models 195A Neutro Junior, 192A Neutrolette and a magnificent five valve SF30–70 Queen Anne Desk model which was period designed in the form of a lady's writing desk and when opened the panel of the receiver was revealed with pigeon holes on either side together with writing accessories; Harringtons Ltd, with Gilfillan models GN3 of three valves and GN5 of four valves; Newton, McLaren Ltd, with a five valve Stromberg-Carlson receiver and A W Dobbie and Co. Ltd, with a King Quality Products receiver.

Other noteworthy Australian made receivers employing the neutrodyne circuit were the D J Super Six manufactured in the workshops of David Jones, Sydney and the Stromberg-Carlson No. 501 receiver. Both were advertised as ideal Christmas presents in late 1927. The DJ Super Six employed two stages of radio frequency amplification, a detector and three stages of audio amplification. The front panel was earthed metal construction to minimise hand capacity problems during tuning, and the receiver was enclosed in a handsome polished maple cabinet.

The Stromberg-Carlson receiver comprised two stages of radio frequency amplification, detector and two stages of audio frequency amplification. It was used with the Stromberg-Carlson 5A Cone type loudspeaker. Valve types were first and second RF and first audio, Radiotron UX201A; Detector, Radiotron UX200A, and second audio, Radiotron UX171 or PM256.

The Stromberg-Carlson 501 receiver was of particular interest to Australian Engineers. It was a neutrodyne circuit which employed shielding between the coils. It was one of the earliest American attempts at unicontrol. It had two tuning dials with one controlling the aerial circuit and the other controlling the ganged RF stages. The individually shielded RF coils in closely fitted metal cans was a major departure from practice at the time and created a good deal of discussion amongst Australian Engineers who had followed the earlier neutrodyne practice of mounting open coils at 54.7 degrees with respect to the line of centres.

The popularity of the neutrodyne circuit declined sharply from about 1929 when manufacturers began production of receivers using circuit designs employing the screen grid valve.

The neutrodyne circuit technology brought with it the requirement for a range of special tools for circuit adjustment and testing. They included:

- Bakelite Screw Driver made entirely of bakelite rod with a blade for adjusting neutralising capacitors.
- Pocket Set comprising fountain pen size tools designed to be clipped in the Radio Serviceman's shirt or vest sprocket. It included ¼ inch and 5/16 inch socket wrenches and a miniature insulated screwdriver.
- Neutralising and Aligning Kit, a comprehensive kit including 12 separate parts which telescoped into each other forming four separate tools when assembled. They were contained in an attractive leatherette vest pocket case.

REGENERATIVE OR REACTION CIRCUITS

Regenerative or reaction circuits were in widespread use before they were adapted for reception of broadcast station signals. They were also referred to as retroactive circuits, and were developed over the period 1912–13 independently by a number of experimenters active at the time, including de Forest, Armstrong and Meissner.

Regeneration was basically a means of obtaining amplification, and as a general rule, a single valve circuit employing regenerative technique would provide about the same output as a receiver using a straight two valve circuit.

The essential principle of the system consisted in making the amplified signal in the anode circuit retroact (or act back) on the grid circuit so reinforcing the original voltage on the grid resulting in a building up effect of the signal.

A number of circuits were developed by various people in obtaining this effect. One of the most popular was tickler coil regeneration accomplished by coupling the anode circuit to the grid circuit by either induction or capacity effects.

In this arrangement the anode circuit was coupled by induction to the secondary of the tuning circuit. The so-called tickler coil in the anode circuit was so arranged that it could be brought near the detector tuning circuit. The current flowing in the tickler coil set up a magnetic field and induced a voltage in the nearby coil. The winding direction was such that the induced voltage added to that already on the grid circuit. The amplifying action continued until the valve oscillated.

The regenerative action was controlled by the tickler coil coupling which was made variable. In practice, the tickler coil was the movable coil of a vario coupler or one set of honeycomb or spider web coils. The coupling between the coils was varied by altering the angle between them.

Another form was tuned anode regeneration. A variable inductance was placed in the anode circuit and with this arrangement, feedback took place, not by inductive coupling as with the tickler coil, but by the interelectrode capacity of a triode valve. In some circuits, feedback was assisted by connecting a small variable capacitor between anode and grid. One of the most popular receivers of 1926–28 which used the small capacitor feedback was the two valve Sampson receiver. It comprised a detector and transformer coupled audio frequency amplifier. Valve types UX201A were usually employed but Mullard PM3 detector and PM4 amplifier were also popular. The receiver provided loudspeaker strength for transmitters within about 60–70 km.

A disadvantage of the capacitor technique compared with the tickler coil was that adjustments for regeneration, and for tuning, were not entirely independent of each other.

Technical magazines of the 1920s described many other regenerative type circuits. Those with identifiable names included Franklin, Arco and Meissner, Armstrong, Reinartz, Modified Armstrong, de Forest, Weagant and Modified Weagant. There were also circuits described which employed both audio and radio frequency regeneration attributed to Armstrong.

Although regenerative circuits increased the effective range of the receiver, they did so at the expense of quality. Also, many receivers were constructed with the coil units on the outside of the front panel. This gave an untidy appearance and were frequently damaged during house cleaning operations by an over-enthusiastic lady of the house.

One of the most popular commercially manufactured receivers employing a regenerative detector was the Philips mains powered model 2515 (also referred to as 2516). It was a 1928 design sold in many Australian Radio Shops from early 1930 and being of European design, catered for both MF and LF bands. Its appearance was unusual to say the least. It used a metal case of brown crackle finish and looked very much like a Philips B eliminator unit. Three four volt filament valves were employed. An E415 triode used as a regenerative detector was transformer couplied to an E443H type. A 506 full wave rectifier provided HT and bias voltages. In addition to connection to an outside aerial, provision was made for use of the power mains as an aerial through an isolating capacitor. The set required an external loudspeaker.

One of the many Australian designed and manufactured regenerative receivers was the Healing Model 35B, a tuned RF three valve receiver with reaction. Valve types comprised 32 RF amplifier, 32 reactive detector and 33 power pentode. Power requirements were 120 volt B battery, 2 volt accumulator for filaments and 15 volt C battery for bias.

One of these receivers was owned by Cec Hodge a farmer who lived about 20 km west of Bundaberg in Queensland. When local station 4BU began operation just before Christmas 1935, Cec paid a visit to Brisbane to purchase Christmas presents for the family. One of the items he brought back was the Healing receiver, a present for his son whose birthday was also on Christmas Day. He knew Jim Jordan, the Chief Engineer of 4BU and Jim assisted Cec in erecting an aerial using two 20 m water pipes and getting the set to work. Except for a loose knob on the reactive sensitivity control because of a loose grub screw, the set worked perfectly and delighted the whole family. As well as good reception from 4BU, good output was obtained from 4MB Maryborough and 4QG, 4BC and 4BH in Brisbane. One night, Cec's son logged nine stations between 6.30 pm and 8.30 pm.

Another inexpensive receiver with reaction manufactured about the same time by Healings was the Model 201 designed for homes with AC mains supply. It was what was called a '2 plus R' design featuring UY224 screened grid detector, directly coupled to a UY247 pentode output valve and UX280 rectifier. Reaction was controlled by a variable 10000 ohm resistance bridged across an inductance coupled to the aerial coil. A modified version had the shunt resistance replaced by a variable 15 plate capacitor in series with the inductor.

A major disadvantage of the regenerative circuit was that the receiver could be made to oscillate if the regeneration control was increased beyond a critical point. At the point of oscillation, heterodyne whistles could be produced in other nearby receivers. Also, many circuits were difficult to adjust and it was frequently not possible to locate a station exactly on the same point of the dial after retuning.

Although the regenerative circuit was one of Edwin Armstrong's major contributions to Radio Technology, his super-regenerative circuit was more important. He described the circuit at a meeting of the Institute of Radio Engineers in USA in June 1922.

A receiver employing a super-regenerative circuit compared favourably with designs using RF amplification, and produced equivalent performance with fewer valves. However, adjustment and operation of the receiver was somewhat complicated, even for an expert, and the design was not favoured by many experimenters.

One of the first receivers built in Australia to work successfully, was constructed by Mr Fry, Manager of Universal Electric Co., Sydney in 1923. It was a three valve model employing Cunningham valves including a 5 watt audio output valve. Components included Burndept coils of 1500 and 1250 turns; a moulded vario coupler; Master AF transformer; two 12000 ohm non-inductive resistors; and 100 Henry choke. The resistors and the choke were made in the company workshop.

Operation of the receiver was demonstrated to members of the North Sydney Radio Club by Ray McIntosh. Although tuning required some expertise on the part of the operator, the members soon mastered the technique and several Amateur broadcasters on air at the time were received with good loudspeaker volume. Very little distortion was evident during reception of recorded musical items.

Some experimenters who built receivers employing a super-regenerative circuit experienced difficulty in receiving Interstate broadcasting stations when living in Metropolitan areas where high power stations were in operation. They found the receiver was susceptible to shock excitation caused by the local station blanket signal and the broadness of the tuning made it unreliable as a receiver.

The Autoplex, a species of the super-regenerative circuit appeared to overcome many of the problems. The Autoplex concept eliminated the capacitors included in the original Armstrong super-regenerative circuit. The capacitance between an aerial and earth was substituted for the more tangible type of capacitance.

Norm Robinson of South Grafton in Northern New South Wales constructed a single valve Autoplex circuit receiver in 1925 employing two variometers, a 6 volt C battery, a UV201A valve, a 1500 turn honeycomb coil with the natural aerial to earth capacitance forming the local oscillator to set up the audio frequency vibrations on which the action of the Autoplex depended. Mr Robinson reported that he was able to receive Amateur broadcast transmissions nearby and 2BL in Sydney at loudspeaker strength even though the receiver had only one valve.

It is not known whether any commercially produced receivers employing super-regenerative circuits were ever released in Australia, but the matter was under active consideration by Bill Bland of Bland Radio in Adelaide at one stage when he had two prototype designs under test about 1931.

REFLEX CIRCUITS

The cost and operation of valves were important considerations with early home receivers, and any design which used less valves was welcomed by the enthusiasts.

The reflex circuit developed by Marius Latour, the famous French Engineer and inventor of many devices and systems for telegraphy, telephony and wireless enabled a single valve to function as both radio and audio frequency amplifiers.

Included among the early imported reflex circuit receivers was the Radiophone Type D7A, made in the USA and available in 1924 from Norris and Skelley, Melbourne. The receiver comprised three de Forest DV6A valves and a crystal detector. It was also available as a portable version using four valves and operated with dry cell batteries. Mr Duff, an Orchardist, at Panton Hill owned one of the Type D7A models. Filaments were powered by an accumulator kept charged by a wind-driven generator.

The radio frequency signals to which a reflex receiver was tuned was amplified, rectified by a detector (in many home-made receivers this was a crystal), and then amplified at audio frequencies by the same valve.

In many popular four valve reflex circuits, the second and third valves were used as amplifiers simultaneously for both radio and audio frequency amplification. This meant that the four valves were made to produce the effect of six.

The proponents of the use of reflex circuits in home receivers for combining radio and audio frequencies in this way claimed the following advantages:

- less valves were required for a given output power, so reducing cost of the receiver.
- less power consumption resulting from the use of fewer valves.
- fewer controls.
- easier construction.

Many commercially manufactured receivers employing reflex circuits used high grade iron core radio frequency transformers together with potentiometer control on the valve grids to improve stability. However, whilst the potentiometer prevented oscillation, it was unfavourable to the audio frequency signals as it resulted in increased distortion. For smaller single valve receivers, other means were used to improve stability. These included reversed tickler, fixed grid resistance, or fixed anode resistance.

Many variations of the reflex circuit were employed over the years with varying degrees of success such as Harkness, Erla, Priess, Acme and the Grimes inverse duplex circuits.

The Grimes inverse duplex circuit was an attempt to overcome some of the difficulties with reflex circuits such as loading. For instance, in a normal reflex circuit, valve one carried a relatively weak radio frequency current, valve two a stronger radio frequency current and a weak audio frequency current, valve three carried a still stronger radio frequency and strong audio frequency current and valve four carried only a very strong audio frequency current. As a result, some of the valves were overloaded while others were underloaded. In a three valve inverse duplex circuit, two valves were used for amplification and another as detector, giving two stages of radio frequency amplification and two of audio frequency amplification. The radio frequency current passed through the valves in the conventional way, i.e. through valves one, two and three. From there, the rectified current was then passed through valve two, then through valve one. This arrangement increased stability, overloading of valves was reduced and audio frequency noise level was reduced considerably. The circuit operated in a manner similar to the standard reflex type, since there was one control for tuning, one for the valve filaments and one for stability. Listeners with receivers employing the inverse duplex circuit living close to a transmitting station often experienced distortion and sometimes howling due to overloading of the valves by the high level radio frequency signals. In some cases, a 'C' battery was fitted to maintain a suitable negative grid bias voltage.

Hal Austin, Radio Engineer and Licensed Dealer of The Parade, Norwood, Adelaide constructed several Grimes Inverse Duplex circuit receivers for customers about 1927. Of three receivers constructed about Christmas 1927, one was sold to a grazier in the Flinders Ranges, one to Bill Schilling, an Orchardist at Renmark on the Murray, and one to Harry Watts, a farmer in the Mallee. He also constructed a four valve Acme Reflex circuit receiver for the Station Master at Tailem Bend on the Murray about the same time.

At one stage, reflex circuits formed a substantial percentage of the broadcast receiver market in Australia for three/four valve receivers. There was also many reflex superheterodyne circuits in use employing mainly techniques known as anode reflexing and screen reflexing.

One of the early low cost reflex superheterodyne designs was the four valve Model 35E manufactured by A G Healing Ltd, Melbourne about 1935. Valve types comprised 6A7 pentagrid converter, 6B7 reflex amplifier and demodulator, 42 power pentode and 80 full wave rectifier. Loudspeaker was an electrodynamic type with field coil of 2500 ohms. The receiver did not include AVC so the manual control had to be adjusted with care. Intermediate frequency employed was 465 kHz. Controls included volume control, on/off switch, tone and static control and station selector.

One of these models was purchased from the Adelaide Healing branch when Kevin Wadham was Radio Manager, by a listener who lived at Glenelg, a seaside suburb. Kevin installed the set and it was still in operation in 1940 when the owner sold it prior to joining the RAAF for War service.

Kit sets were very popular even up to the period of the outbreak of the Second World War in 1939. One of the kit sets was the Melodious Super 3, a battery-operated reflex superheterodyne employing three valves and sold by Homecrafts, Melbourne. A dual wave kit was available for country constructors wishing to listen to the NBS short wave transmissions.

SUPERHETERODYNE CIRCUIT

Although the superheterodyne circuit was the basic circuit for almost all domestic receivers produced from about the mid 1930s, it took many years before it was universally accepted. Although available in receivers produced when broadcasting commenced in the early 1920s, it was considered to be more of an academic type of receiver than as a practical means of home reception of broadcast programs. It was very expensive, and with most valves available at the time, required a high capacity battery to power the filaments.

However, by the end of 1931, there were some 50 broadcast transmitters on air and even with three RF stages the selectivity of TRF designs was inadequate for separating the various carriers. This led to the superheterodyne circuit being re-examined as an alternative.

The superheterodyne receiver derives its name from the fact that the desired signal is heterodyned to a lower frequency but which is still above audibility (supersonic) and is subject to amplification at the new frequency. It was originally known as supersonic heterodyne. The origin of the circuit can be traced back to work by Reginald Fessenden in the USA with his invention of the heterodyne receiver in 1901. However, the principle was not developed further until the advent of the triode valve and its ability to produce oscillations and to amplify.

Early workers in the field included Arco and Meissner of the German Telefunken Company and Captain H J Round of the Marconi Co., with his autodyne receiver circuit.

During the First World War, a considerable amount of research was undertaken in Germany, France, England and the United States to produce receivers which would give high signal amplification, and much effort was directed to the use of heterodyne principles.

However, it was a Frenchman, Lucien Levy with his patent of 4 August 1917, who made a major breakthrough in receiver design. Levy was looking for a means of reducing interference caused by atmospherics and transmitting stations on adjacent channels. Using a heterodyne arrangement, Levy's invention was to bring the desired signal to such a frequency that it could be easily separated from the atmospherics and interfering stations before being amplified. This was done by means of a heterodyne, the frequency of which was adjusted to cause ultra-acoustical beats when superimposed on the incoming oscillation.

Levy's invention was important as it represented the first recorded contribution to the superheterodyne art.

However, it is Major E H Armstrong of the American Expeditionary Force who is given the major credit for the modern superheterodyne circuit. In his system, the incoming oscillations were combined with the currents of a local oscillator to produce an ultra-audible beat frequency of such a frequency that it could be amplified using valves then available. The inaudible amplified beats which still contained the modulation forming the signal, were then rectified and the audio signals amplified to the desired level.

Armstrong applied for a patent for the superheterodyne circuit on 30 December 1918 but a German, W Schottky of Siemens Laboratory had applied for a similar patent six months previously on 18 June 1918.

Because of the War situation in Germany, Schottky could not investigate the possibilities of his conception and the matter was left in undeveloped state. Armstrong's theory was put into practice when the American Army Signal Crops constructed an eight valve superheterodyne receiver consisting of first detector, heterodyne, three stages of intermediate frequency amplification, a second detector and two stages of audio amplification.

The arrangement of changing the frequency of the incoming signal so that the frequency was constant for all incoming signal frequencies produced a number of advantages. These included:

- Reasonably constant selectivity and sensitivity over the band.
- Highly efficient fixed tuned circuits could be provided to amplify the new frequency.
- High gain per IF stage was possible.
- Improved selectivity when the IF was lower than the signal frequency.
- The total RF gain was distributed over two frequencies so that feedback problems were not so great.
- As no variable capacitors were used in the intermediate frequency stages, space requirements were small.
- Because of the small size of the intermediate frequency LC components, they could be incorporated in aluminium cans, so simplifying shielding.

The device employed to change a range of incoming high frequency signals to a fixed intermediate frequency was known by various names including converter, mixer, modulator, first detector, translator and others. It took many forms before reaching the present-day form ranging from two valve combinations to a single valve with five or six grids.

With the establishment of broadcasting in the USA, Great Britain and Australia in the early 1920s, there was a golden opportunity for the superheterodyne circuit to establish itself as the premier circuit. However, there was a number of disadvantages, including:

- Cost
  It required more valves and components than a straight receiver.
- Power
  The high filament drain for an eight valve receiver was prohibitive.
- 'Dead' Valve
  The oscillator valve played no useful role in signal amplification and was considered to be an expensive 'passenger' or 'dead' valve.

The development of low consumption or dull emitter valves in 1926 was a boon to designers of receivers using the superheterodyne circuit as it reduced power consumption considerably. They required only a quarter of the filament power of many earlier types.

With broadcasting stations established in Brisbane, Sydney, Melbourne, Hobart, Adelaide, Perth, Toowoomba, Bathurst and Newcastle by the end of 1925, listeners in Australia were not content to listen to local stations, they wanted receivers which would receive stations in other towns and metropolitan cities. The superheterodyne was ideal for long distance reception because of high gain and good selectivity.

Radio dealers realised there was a need for these types and even though more costly than straight ones, a number of models began to be stocked in Radio Shops in 1926. They were frequently called supersonic heterodyne receivers and were imported from England and the USA. Imported models available in Radio Shops included:

* BURNDEPT ETHODYNE
  A seven valve superheterodyne receiver, simple and easy to operate. The tuning capacitors were fitted with super vernier dials giving a 7:1 reduction by means of a friction-disc epicyclic gear. A reaction control, a volume control and two switches were the only other controls. The two main controls were mounted in an oval recess in the panel. The standard model was an open fronted cabinet with mahogany front panel. Valve types were Burndept brand types HL310, H310 (three), HL512 and L525 (two). Harris Scarfe Ltd, Adelaide had several of these receivers in stock.
* RCA FLORENZA
  This was a very expensive receiver imported by Duncan and Fraser, Adelaide. It comprised eight UV199 valves and power for the entire receiver was provided by dry cell batteries.
* IGRANIC
  One of the most popular superheterodyne circuit kits to come to Australia was imported by Noyes Bros It was produced by Igranic Electric Company, England. A number can be seen today among vintage radio collections. It consisted of a frequency changing unit, intermediate frequency transformers, audio frequency transformer, various fixed capacitors, valve sockets, terminals, hook up wire etc. In addition to the kit, it was necessary to purchase material for the control panel which included tuning capacitors, rheostats and resistances.
  The receiver consisted of six valves, the first operating as a combined oscillator and first detector on the tropodyne principle, the second, third and fourth acting as intermediate frequency amplifiers, the first as second detector and the sixth as audio frequency amplifier. Reactance capacity couplings were employed in the intermediate frequency units. They were neatly made with the coils being hidden in a casing of polished brown bakelite. The oscillator took the same form and was specially designed to prevent radiation into the closed loop aerial circuit. Three variable capacitors were used for tuning oscillator, frame aerial and outside aerial respectively.
* RANDOLPH RADIO CORPN
  An eight valve kit set imported from Randolph Radio Corpn in the USA by Wireless Supplies Ltd, Adelaide. The Company specialised in kit sets and in addition to the superheterodyne circuit produced Acme, Neutrodyne, Harkness and Cockaday types.
* SILVER MARSHALL INC
  The Silver Marshall Six was imported by Adelaide Radio Company and the entire shipment of five receivers was sold out within three weeks of arrival. The Company followed up with an order of six kit sets. The high frequency transformers were wound on bakelite formers which plugged into hexagonal sockets. The aerial coupling was adjustable and a high degree of selectivity was easily obtainable. The tuning capacitors were silver plated to reduce losses.
* PINNACLE
  The seven valve Pinnacle receiver was sold by Louis Coen Wireless Ltd, and was normally provided with a loop aerial. The receiver was usually sold in kit form but fully assembled models were available for those who were unable to handle the assembly and adjustment of the superheterodyne circuit.
* VICTOREEN
  The Victoreen superheterodyne kit set made by the Victoreen Manufacturing Co., was sold by Oliver J Nilsen with several of the kits being sold through their Melbourne and Adelaide offices during 1927-28. The eight valve kit comprised a

complete set of components including three air core RF transformers, one input transformer, one oscillator coil, one aerial coupler together with a blueprint drawing and comprehensive construction details. The design catered for the use of a loop aerial or an outside type.

All components except valves for the kit were made by the company.

Another imported kit set sold by the Adelaide Radio Company was an eight valve model employing UV199 valves throughout. It was sold complete with panel, batteries, all components and a comprehensive wiring diagram broken down into various sectional views and supplied with a step-by-step numbered wiring scheme. The Company had a working model in the shop so that a customer could refer to this receiver if he/she had any layout or wiring problems. Altogether, there were 60 parts, all numbered to correspond with the wiring diagram. Major components included two All American audio transformers, three All American type R110 radio frequency transformers, one All American type R130 radio frequency coupler, two vernier dials, eight UV199 valves, one 4 volt storage battery and charger, B batteries totalling 90 volts and one 4½ volt C battery. The intermediate frequency of the set was 30 kHz.

Acceptance of the superheterodyne circuit was slow and most sold by receiver builders were built to order. The majority of prospective purchasers were put off by the multiplicity of whistles and interference not present with other less expensive models. Also, it was not unusual for a local high power station to be received at several positions on the dial owing to the presence of harmonics. However, one of the major operational problems with a non-technical listener was the juggling of two tuning controls — one in the signal frequency circuit and one in the oscillator circuit. The majority of straight receivers by 1928 had only one tuning control.

Designers worked hard to overcome the problems of the superheterodyne, and one of the thrusts was to change the intermediate frequency of 30 to 50 kHz then in use. This frequency was employed because of the limitation of valves available at the time as high frequency amplifiers. As valve technology improved, so did the amplification at higher frequencies.

Some designers led the way and increased the IF to 175 kHz reasoning that this was a compromise between stability and selectivity on one hand, and interference on the other. Changes were also made to the IF coupling stage to vary the selectivity/fidelity characteristics to cater for the differing requirements for nearby and distant stations.

The first Australian commercially produced receivers employing the superheterodyne circuit were produced by AWA in 1925. They employed six UV199 valves and were powered by a 6 volt accumulator for filament energisation. The intermediate frequency was 50 kHz. Superheterodynes were also produced in 1926 and 1927, but due to low sales, no further models using this circuit were manufactured until 1933, this time using an intermediate frequency of 175 kHz. From that period, only superheterodyne circuits were employed with AWA receivers.

An IF of 175 kHz proved to be unsuitable with the widespread introduction of dual wave receivers in the early 1930s. It was difficult to separate short wave station fundamental frequencies from heterodyning images. Designers shifted the IF to a region just below the broadcast band. However, in the absence of a standard, more than a dozen different frequencies were employed throughout the industry.

Another superheterodyne receiver built commercially in Australia at about the same period was the Colmovox Supersonic Eight manufactured by Colville Moore Wireless Supplies Ltd. Imported components were used in the construction, and included Gecophone superhet oscillator, filter and intermediate frequency transformers; audio transformers; Benjamin shock absorber valve sockets; Dubilier and TCC fixed capacitors; Precise variable capacitors with vernier dials and bakelite Dilecto panel and sub-panel. The black panels were engraved in white or mahogany finish but were also available with gold engraving. Osram valves were used throughout, and all were of the low filament consumption type — DE3 and DE3B — except the DE4 in the power amplifier stage.

The decade of the 1930s, was to do more to popularise the superheterodyne circuit than the 1920s. It had been held back somewhat by the Neutrodyne circuit, the development of the screen grid valve and the low cost of three valve receivers comprising radio frequency amplifier, detector and audio amplifier output stage.

In January, at the start of the 1930 decade, there were 19 transmitters in operation but during the year, 14 additional stations commenced transmission. The following year, 1931, 17 more transmitters went to air followed by 9 more in 1932 and 5 more in 1933.

The result of this explosion in transmitting stations was that the straight receivers in use were unable to cope with interference produced by such a large number of transmitters, and there was a rapid increase in demand for a receiver of improved selectivity characteristics such as one employing the superheterodyne circuit.

A major problem with the early superheterodyne receivers was the employment of a valve as an oscillator which added nothing to the detection or amplification of the radio signal.

In 1930, some manufacturers employed a 227 triode valve as the oscillator in conjunction with a 224 screen grid tetrode as mixer, with AC powered receivers. Others employed a 56 triode and 57 pentode valve.

Developments in valve technology enabled the function of the oscillator and mixer valves to be combined in a single envelope. This allowed the introduction of what was known as the autodyne circuit about 1931. It was so named because the received signal was automatically heterodyned in the local oscillator or first detector instead of requiring a third or mixing circuit.

The autodyne circuit was employed by most major manufacturers employing appropriate valves with 2.5 and 6.3 volt filaments. The 57 and 6C6 types were typical of valves used until about 1933.

The autodyne had a number of problems including radiation from the oscillator via the aerial, gain control was confined to the IF stage, and difficulty of employment with short wave circuits.

These problems were overcome with the introduction of the pentagrid converter in April 1933 with the development of the 2A7 valve by RCA in USA. It was a single stream valve with elements located radially around the cathode with the two innermost grids being employed for the oscillator section. A battery-powered equivalent, the 1A6 soon followed.

Together with improvement in circuit designs, these new valves enabled the mass production of four and five valve receivers resulting in a sharp drop in prices. The Audiola Model 492 was one of the early four valve receivers employing the superheterodyne circuit.

In 1933, for the first time in Australian radio trade, every major manufacturer produced at least one model of receiver employing the superheterodyne circuit. During the year, some 150000 home radio receivers were produced with a large percentage being superheterodyne models. The manufacturers were encouraged by the fact that most of the 250000 receivers which had been purchased prior to about 1932 were considered to be obsolete and would require early replacement.

Designers took advantage of the encouraging market by introducing a number of new features such as Automatic Volume Control, Push Button Tuning, Permeability Tuning, Magic Eye Tuners, Dual Dynamic Speakers, All Wave Receivers and the Midget Receiver. In many instances the midget receiver resulted in 'two receiver homes' with the midget model frequently being located in the kitchen. Miniature components produced for the midget receiver also led to an upsurge in car radios. Straight receivers were not very practicable for car receivers.

Designers were far from united in the choice of the intermediate frequency and even within a brand, it was not unusual for different intermediate frequencies to be employed. For example, even as late as 1939, frequencies being used with well-known receivers included the following: Arizone 456 and 175 kHz; Aristocrat 452 and 210 kHz; Astor 456, 455, 173 and 550 kHz; Breville 446 and 252 kHz; Briton 462.5 and 472.5 kHz; Calstan 458 kHz; Fisk Radiola 460 kHz; Genalex 458 kHz; Healing 455 kHz; His Masters Voice 460 kHz; Hotpoint-Bandmaster 460 kHz; Howard 460, 220 and 175 kHz; Kriesler 458 kHz; Lekmek 456 kHz; Monarch 455 and 456 kHz; Mullard 456, 472.5 and 175 kHz; Philco 462.5, 262.5, 175 and 460 kHz; Philips Radioplayer 472.5 kHz; STC 450, 455 and 175 kHz; Stromberg-Carlson 458 kHz; Tasma 458 kHz; Ultimate 460 and 250 kHz; and Weldon 465 kHz.

However, it was not long before 455 kHz became increasingly the accepted frequency for domestic receivers as it gave a good compromise between adjacent channel selectivity and image rejection characteristics. This was the frequency used in the USA as required by the RMA Standards Committee.

The employment of an intermediate frequency of 455 kHz for MF receivers has to be taken into account by planners when allocating transmitter frequencies.

The second and third harmonic frequencies of 455 kHz are 910 and 1365 kHz, both of which fall within the MF transmission band 526.5 to 1606.5 kHz. The designated channels closest to these harmonic frequencies are 909, 1359 and 1368 kHz and if allocated for a service could result in some interference problems under some conditions. As at 1997, no stations had been allocated the 909 kHz frequency but 1359 and 1368 kHz each had one station employing these frequencies. One was 4WK serving Toowoomba with a 250 watt transmitter and the other 2GN serving Goulburn area with a 2 kW transmitter. Both were Commercial stations.

By far the most popular superheterodyne receiver produced was the four valve plus rectifier (4/5) model. It combined cheapness with good performance for listeners in urban areas well-served by transmitting stations. By 1924, it had become the standard all-electric chassis and sales of the smaller two and three valve receivers dropped considerably.

Competition was so keen and demand so great that many of the major manufacturers released two models a year with one being released about Easter and the other just before Christmas.

Designers were able to build in improved performance due to the availability of new valve types and developments in circuit technology which was taking place at the time spearheaded by the AWA Valve Company Pty Ltd.

Because valves available had very little inbuilt shielding, it became standard practice to fit earthed metallic split shields or cans over the frequency changer, IF amplifier and detector valves.

During the early 1930s a typical five valve AC receiver employed valve types of the then new 50 series with 2.5 volt heaters such as 57 for frequency changer and detector/amplifier, 58 for IF amplifier, 59 for output valve and 80 rectifier but by about 1936, types widely employed included 6A7 for frequency changer, 6D6 for IF amplifier, 75 for detector/amplifier, 42 for output valve and 80 rectifier.

In early superheterodyne circuit terminology, the valve in which the signal and oscillator frequency were combined was called the first detector and the valve which separated the AF from the IF signal was referred to as the second detector. In time, these terms became converter or mixer, and detector respectively.

To meet a demand particularly from rural listeners for high performance receivers covering short wave bands as well as the medium wave band, many manufacturers produced designs employing 7 and 8 valve battery-powered receivers and 8 or more valves for AC operation. Several manufacturers produced 11 valve models.

Seven valve battery receivers available in the 1930s included Airzone Model 753, Breville Model 141, Healing Model 73B, His Masters Voice Models 305/310, Philips Radioplayer Model 6713, STC Model 734J, Weldon Model 7/39BD. Eight valve sets included Lekmek Model 80–BC, Philips Model 5813, and Tasma Model 245.

Popular AC powered models included AWA Model AWB95 (9 valve), AWA Model 262 (11 valve), Bandmaster Model 707D (11 valve), Reliance York (10 valve), Kriesler Radiogram (10 valve), Lekmek Model 11E (11 valve), Stromberg-Carlson Model 588 (8 valve), Tasma Model 245 (8 valve), Duffy Comet (8 valve), NST Hollingsworth Model 841 (8 valve), Briton Model 94CH (8 valve) and Emmco Model AWB95 (9 valve).

With TRF receivers it was not unusual for circuits to employ three stages of RF amplification but in the case of the superheterodyne circuit there was little benefit in employing more than one stage of RF amplification for MF band reception, although there was some benefit in the case of short wave band reception. This was because, after one stage of RF amplification, the amplifier random noise was greater than the noise of the mixing valve with the types of valves employed at the time.

One problem with superheterodyne circuit designs was the practical difficulty in ensuring accurate tracking between the signal frequency and oscillator circuits. For some time, three point tracking was employed but the situation was greatly improved when Philips introduced a circuit which provided five point tracking with their receivers.

In addition to a circuit employing components used for three point tracking such as tuning, trimmer and padder capacitors, the circuit was shunted by another circuit comprising series resistor and a parallel LC circuit tuned to the oscillator mid frequency.

Superheterodyne circuits with or without an RF stage using valves, remained basically unchanged from about the early 1930s until the advent of the transistor circuits in the early 1960s.

AUDIO FREQUENCY AMPLIFIERS

A great deal of the total distortion which occurred with early broadcast receivers took place in the audio frequency stages. Factors which contributed to the distortion included poorly designed amplifiers, incorrect anode and grid biasing voltages, overloaded coupling networks, the use of unsuitable valves, and loudspeaker problems.

Amplifiers were classified according to the type of device used in coupling one stage to the next. The three principle types employed were transformer coupling, resistance-capacitance coupling and choke or impedance coupling

TRANSFORMER COUPLING

The transformer method was the most popular arrangement employed, partly because additional amplification could be obtained and the low resistance ensured minimum drop in battery voltage applied to the anode. The popularity of audio transformers can be gauged from the fact that more than 100 different brands were available from Radio Shops.

However, the initial use of transformers with broadcast receivers was not without its problems. Audio frequency transformers had been used for many years before broadcasting in wireless telegraphy and telephone equipment. The early designers simply attempted to adapt the same techniques to broadcast receivers, but it was unsuccessful and much development work became necessary.

The wireless telegraphy transformers had been designed to cover an extremely narrow audio frequency range with a peak of 800 or 1000 Hz. The telephone transformer covered a much wider bandwidth but only sufficient for a normal voice conversation with a pass band around 200 to 3000 Hz. With broadcasting and the reception of music, a much wider bandwidth was required and many early designs covered the band about 150–5000 Hz with some of the more expensive types going to 7500 Hz. Later, bandwidths of 50 to 10000 Hz were common, even though some other components in the broadcasting chain were not capable of matching this bandwidth until many years later.

The usual ratio of the number of turns of secondary to primary was 3 or 4 to 1, but transformers with ratio of 10 to 1 could be obtained. The best ratio value was governed by the circuit design and the type of valve used.

A disadvantage of transformer coupling was that with many of the cheaper transformers, the frequency response over the audio range was far from being flat. It was not unusual to find one and sometimes two resonant frequencies which caused severe distortion. Other factors which were a problem to the designer were that the inductance of the primary winding changed as the anode current changed with the signal level, and also, the changes in the signal frequency had an effect on hysteresis and eddy currents losses in the transformer.

The inherent capacitance between primary and secondary windings was a problem as it effectively acted as a capacitor bridging the windings. The effect was greatest at the higher frequencies because of the lower reactance. Many schemes were tried by transformer manufacturers to reduce this problem. These included identifying the winding connections which had to be connected to the receiver elements, for example, the start of the primary winding was connected to the anode and the end of the secondary winding was connected to the grid. Other arrangements were to sectionalise windings, to make the width of the winding small compared with its depth and separating primary and secondary windings by layers of waxed paper.

In receiver designs where transformers of different ratios were employed and the output valve was a power valve, it was usual practice to insert the higher ratio transformer in the final stage. In a number of designs where two valves of the same type were used, the higher ratio transformer was placed in front of the lower ratio model.

Resistance-Capacitance Coupling

Resistance-capacitance coupling was not popular in the days of battery-operated receivers because of the large voltage drop across the anode resistance. Many designers used transformer coupling in the final power valve stage to partially overcome the power loss problem. Another factor which caused designers not to use the resistance-capacitance arrangement was due to the need to compromise the grid resistance. The DC blocking capacitor had to be of sufficiently high capacitance to pass low audio frequencies. This required that the grid leak resistance had to be low, so resulting in lower amplification. Many circuits compromised with a 0.01 MFD mica capacitor and a 2 megohm grid leak. An alternative design was to use a 0.1 MFD capacitor and 100 Henry choke. A typical anode resistance was 100000 ohms, although 50000 ohms was also popular with some designs.

Because the types of valves available in the early 1920s were not suitable for application with resistance-capacitance coupled circuits, there was a problem with output power and resulting loudspeaker performance. Resistance-capacitance coupling required valves with a high voltage amplification factor for best results. Three stages were needed to produce about the same volume output which could be obtained with two transformer coupled stages. Also, early resistors tended to be unstable, being subject to resistance changes with humidity variations, they were noisy and had poor dissipation qualities when carrying the anode current.

The voltage drop across the anode resistances meant that high voltage batteries were necessary, but this problem was solved with the introduction of the B battery eliminator.

Many early designs resulted in a problem known as 'motor boating' when using B battery eliminators or when the B battery was nearing the end of its useful life. The trouble arose due to coupling between the stages because of the high internal resistance of the eliminator or the failing battery. Coupling between the detector anode circuit and the anode circuits of the audio amplifier valves was the principal cause of the 'motor boating' problem, and one solution was to connect a resistor and capacitor assembly between the B power unit and the receiver.

One of the early receivers which employed resistance-capacitance coupling was a seven valve model designed in England for His Majesty King George V and installed in Buckingham Palace. Details were described in a number of Australian radio magazines during 1924–25.

One set to a modified circuit was constructed by Hal Austin, Consulting Radio Engineer in Adelaide for a client who was a grazier at Penola in the South East of the State in 1926. A problem with the receiver was that it required 200 volts for the anodes of the three AF amplifiers to overcome the voltage losses in the 50000 ohm anode resistances. The two RF stages required 120 volts for the anodes. These HT voltages were supplied by banks of miniature Perfectum B Accumulators made by the Perfectum Battery Laboratory in Glenelg. The company which employed a staff of six, including a chemist, normally made batteries for 30, 60, 80, 90 and 100 volts but made up a special unit for Hal Austin's receiver to provide the 120 and 200 volts required.

Choke Coupling

Although the choke or impedance method of coupling had some of the disadvantages of both the transformer and resistance-capacitance systems, it was employed in many receivers. A typical circuit employed a choke in the anode feed with a blocking capacitor and grid leak resistance to the following stage. Two widely used chokes were the AJS and Lissen types. They were only half the price of a transformer and these two models did not have resonance peaks in the audio frequency range.

The main disadvantage with choke coupling was in obtaining a choke in which the reactance did not fall off at low frequencies. When the reactance fell to a value comparable to the valve resistance, the amplification was reduced. Designers adopted the principle that the reactance of the choke should be at least twice the valve resistance at the lowest frequency the stage was required to amplify.

Choke coupling was popular with many designers of early AF amplifiers used in broadcast studios. Typical was the main amplifier used with the Western Electric 8B program input equipment. It was used at 3AR Melbourne in 1927 with 140A retardation coils as choke units in the last two stages of a three stage amplifier. They were used in association with a 243A tapped input transformer connected to the grid circuit. The input stage of the amplifier employed a 233B input transformer with a 22 step main amplifier potentiometer which was bridged across the secondary with the moving arm contact being connected to the grid of the first valve.

Complete audio frequency amplifiers were available from many Radio Shops in kit form or as fully assembled units made by Australian and overseas manufacturers.

One commercially produced fully assembled choke coupled amplifier was the Gecophone Unit made in England in 1927 and distributed in Australia by the British General Electric Co., Ltd, Sydney. The unit was preceded by a transformer for coupling to the detector valve. It comprised two stages of choke coupled amplifiers using four chokes. The three valve holders were Benjamin anti-microphonic type, fitted with fixed interchangeable filament resistors. Individual grid bias tappings to each valve were provided.

The Philips Resistance Coupling Unit gave uniform amplification over the range 50 to 10000 Hz when used with a Philips A425 type valve. The unit contained a wire wound resistor so designed that when used in conjunction with Philips valves types A425, A225 and A125 it gave good performance. The Philips Resistance Coupling Units were furnished with four terminals, the same as with an AF transformer so it was a simple matter to insert one of the units in place of a transformer.

A three stage RC amplifier gave greater amplification than a two stage transformer coupled unit at lower cost, because of the high cost of good quality AF transformers. The units were available from many Radio Shops in 1927.

The Muter amplifier manufactured by the USA Leslie F Muter Company was a popular resistance-capacitance unit in 1926. It was mounted on a bakelite base on which were mounted nickel-plated valve sockets and resistance mountings. Binding post connections were engraved on the panel. Double spring valve contacts ensured positive connection with a patented method being used to prevent the possibility of short circuits. Wiring connections were permanently made with soft copper lugs fastened with screws and lock nuts. The fixed capacitors were mounted in a similar manner, leaving only a few soldered contacts with a heavy tinned bus bar. Pedestal legs protected connections when the amplifier was mounted on the baseboard. The Muter amplifier was distributed by United Distributors Ltd through its many State branches. The company which manufactured Udisco brand receivers in its own factory employed resistance-capacitance AF stages in its range of 1926 receivers.

Kit sets for resistance-capacitance amplifier stages, with valves, were available from Trackson Bros Pty Ltd and Edgar V Hudson Pty Ltd, both of Brisbane, and Electrical Supplies, Adelaide, while the Adelaide Radio Company, Adelaide sold fully assembled units made by staff in the shop.

An audio frequency amplifier which was a combination of transformer and choke amplifiers was manufactured by the USA, All-American Radio Corporation and distributed by O H O'Brien, Sydney in 1927. The unit known as Rauland-Lyric Trio was popular with many set builders because of its high quality performance, with less distortion than an all transformer system. A Rauland-Lyric transformer was combined with two stages of choke coupling. In both choke stages, the inductance, resistance and capacitance were correctly balanced to ensure the advantages of both transformer and choke stage systems were retained.

ANODE AND GRID BIASING VOLTAGES

In designing the amplifier, the designer had to have complete details of the characteristics of the valves to be employed, particularly graphs showing grid voltage/anode current curves for various anode voltages. The recommended anode voltage and voltage drop across the intercoupling circuit load determined the size of the B battery. The B battery was typically made in modules of 22½ or 45 volts and in the case of a 22½ volt battery, the battery was considered to be exhausted when the voltage fell below about 17 volts, because at that point, the amplifier noise rose sharply, with many valves.

The anode voltage and grid bias voltage for the valve to be used had to be so selected as to give an undistorted amplified output because the valve operated as a Class A amplifier. This usually meant operating the valve at about the centre of the straight portion of the grid voltage/anode current characteristic curve. Many of the popular valves were sold in cartons which contained instructions as to recommended anode and grid voltages. Valve data books were also available containing this data and much other useful information e.g. pin connections.

OVERLOADING THE COUPLING NETWORK

Overloading was not usually a problem with resistance-capacitance networks but was often serious with transformer or choke coupling. Each inductance had a saturation point, i.e. a point where a further increase in current did not increase flux density. This often occurred with cheap units with insufficient core section. If the inductance did not have a uniform change in flux density in line with the changing anode current swing, then distortion would result.

One brand used by many receiver constructors in 1924–26 was an All-American transformer obtainable from Australian Radio Shops which stocked that brand. The company — Rauland Manufacturing Co., of Chicago — produced a range of standard audio frequency transformers with ratios of 3 to 1, 5 to 1 and 10 to 1, but they also produced the Rauland-Lyric model, a laboratory grade transformers designed specifically for handling music type programs. It had an almost flat frequency response 50 to 8000 Hz and produced negligible distortion when used with a UV201A valve operated with 90 volts anode voltage and 1 volt grid bias. The English Ferranti transformer type AF3 of ratio 3½ to 1 had similar frequency response characteristics.

VALVE TYPES

Although most general purpose valves could be used with audio frequency amplifiers, valves designed specifically for the purpose gave superior results.

The number of valves which became available from about 1925 was so great that it was difficult for designers to keep abreast of latest issues. For examples, Philips alone produced no fewer than 30 types by end of 1926. On the Australian scene, AWA has five valves in production in the same period. Typical of imported valves employed about 1926–27 in first audio frequency stages included Philips B406 and A609, Radiotron UX201A, Mullard PM4 and PM6 and Marconi DE4 and DE5. If the final stage employed a power valve, types in use included Radiotron UX120 and UX171, Mullard PM254 and PM255, Philips 403, Marconi DEP215 and others. Where power valves were employed, the type of anode supply had to be specially considered. If current drain was high, then large capacity dry cell batteries, accumulator type HT batteries or even a B eliminator often had to be employed. If a B eliminator was employed, the operator had to ensure that it was located far enough away from the receiver that it did not cause a hum problem in the receiver output.

PUSH-PULL OUTPUT

From about 1926, push-pull output became popular with designers of audio frequency amplifiers. It could be employed with two typical audio frequency amplifying valves or two power valves but required a special transformer with one having a tap at the centre of the secondary winding and the other with a tap at the centre of the primary. Where special transformers were not readily available, it was usual practice to employ two identical ordinary audio transformers. In this situation two primary windings were connected in series and the two secondary windings also connected in series. The centre tap connection was made at the point where the two windings were joined together to provide for tapped secondary and primary conditions. Under ideal conditions any even harmonies introduced by the valves would be cancelled out, but odd harmonies would not be affected.

Push-pull mode of operation required that each valve of the pair be in Class B operation, i.e. that the negative grid bias be sufficient to cut off the anode current when no signal was applied to the grid. Variations included Class AB, Class AB_1 and Class AB_2.

By about 1933, the majority of major manufacturers then producing receivers, were marketing models having Class B ratings. A pair of triodes such as the 30 were often used at first, but when valve manufacturers produced the double triode valve, circuits using Class B operation became popular. Typical early double triodes included 53, 6N7, 6A6, 19 and others. These types saved one valve socket on the chassis and the characteristics of the two halves could be more closely matched than was the case with separate single triode valves.

AUTOMATIC VOLUME CONTROL

Until about 1929, typical techniques for controlling the amount of signal amplification of a receiver included changing the terminal voltage of the filament of one or more valves in the radio frequency amplifying stage using a rheostat, varying the filament voltage of the detector valve or shunting a potentiometer of a few hundred thousand ohms across the secondary of the first AF amplifier transformer. Variation of the filament rheostat changed the operating temperature of the filament and so the degree of electron emission.

In a typical six valve tuned radio frequency circuit of the time, the volume was adjusted by a rheostat in series with the filament lead supplying the three radio frequency valves. A smooth control was obtained by varying the terminal voltage of the three filaments. The rheostat was frequently labelled 'Volume Control' but some other circuits employed two rheostats in series. One was labelled 'Filament Control' and set the correct voltage for the filament terminals when the element of the other rheostat labelled 'Volume Control' was shorted out.

With a number of circuit designs where a rheostat was provided to adjust the filament voltage of the detector valve, it was frequently labelled 'Sensitivity Control' and was not intended to be the main volume control. Operating instructions provided with the receivers usually indicated that the 'Sensitivity Control' should be used as a means of adjusting the detector circuit to maximum sensitiveness for reception of low level signals or to 'improve quality and naturalness of speech'.

Another method employed was to vary the control-grid bias of the first valve and the effective length of the aerial coil at the same time.

With the introduction of the screen grid valve, the volume control was sometimes inserted in series with the high tension supply to the screen grid. A bleeder resistor ensured the screen voltage did not fall to zero when the volume control potentiometer was at the minimum voltage position.

One of the problems experienced with early broadcast receivers was that the output signal level varied in proportion to the level of the signal received at the input to the receiver. This meant that the volume control had to be continuously readjusted as the receiver was tuned to stations over the band, in order to avoid inadequate volume or blasting.

Although an automatic volume control circuit had been invented as early as 1926, it was not until about 1932 when mass production of superheterodyne circuit receivers began in Australia that it became commercially established. Patents had been granted in Australia to a French company in 1926 and to an American company in 1927 for AVC circuits, but it took some years for local manufacturers to incorporate AVC circuits in their receivers. When it was eventually taken up, most receivers used a diode AVC circuit employing a single diode detector to supply both the audio signal and the AVC voltage.

The facility automatically varied the total amplification of the signal in the receiver with changing strength of the received signal carrier wave. The term automatic gain control was used by some designers for some time but it eventually gave way to automatic volume control when it became widely used throughout the industry.

One of the early Australian manufacturers to produce a receiver using AVC was Bland Radio of Adelaide. Bill Bland had read an article in the 'USA Proceedings of the IRE' published in January 1928 describing the technique which had been incorporated in a receiver produced by Philco. He had a receiver working with AVC during September 1928 when members of the local Wireless Institute visited his factory. He later incorporated AVC in his range of Operatic brand receivers.

DETECTORS

The problem of finding a sensitive and efficient detector of electromagnetic waves, occupied an enormous amount of time of the early wireless pioneers. Many novel devices were proposed or developed and by 1910, textbooks included descriptions of metal filing coherer, mercury coherer, contact coherer, magnetic detector, de Forest gas flame detector, Sella-Tieri torsion detector, Fessenden barreter or thermal detector, Tissot balometer bridge, Pupin electrolytic detector, Fleming thermionic valve detector, Fleming hot carbon detector, Armstrong-Orling electrocapillary detector and various types of crystal detectors.

CRYSTAL DETECTORS

The crystal detector is of interest because work in the utilisation of galena as a detector was the subject of an early patent in Australia by Henry Sutton of Melbourne.

A very considerable amount of data on the behaviour of crystal detectors had been published by 1910, particularly by G W Pierce and W H Eccles. It was George Washington Pierce, a prolific inventor who taught Communication Engineering at Harvard University for some forty years, who gave the name Crystal Detector to devices based on a wire contact on a mineral. He is also well-known for the Pierce quartz oscillator circuit used in broadcast transmitters.

Several hundreds of different materials had been examined and tested with the majority of the work being concentrated on carborundum, silicon, molybdenite, galena, zircite and chalcopyrite using steel, aluminium, silver and other contacts, as well as crystal-to-crystal contact. Henry Sutton's work was mainly concerned with a galena/galena contact. He gave his device to the Defence Department for trial and later gave a demonstration to the Chief Engineer of the Postmaster General's Department on 6 October 1908. A Provisional Patent was granted on 19 March 1910.

DETECTOR UNITS

Of the early detectors, only the crystal detector and the thermionic valve detector were in active use when broadcasting began. Both devices detected by rectifying and converting the modulated carrier wave into a direct baseband signal. The crystal detectors, particularly the carborundum type, were more efficient than the valve. A great range of crystals, cat's whiskers and holders were available from Australian, American and English sources. For example, in 1925 popular imported detector units available in Radio Shops included Abbiphone with a metal foil feeler, Compton with a dust-proof glass tube, Mic-Met with a micrometer controlling the cat's whisker, Climax plug-in crystal with automatic micrometer, Efesca cartridge detector, Fortevox with chuck end detector arm, Gecophone with breech-fed crystal cap, HTC fixed detector, Neutron semi-permanent two crystal combination, HAH vernier detector, RI permanent detector, Cymosite auto detector, Sterling semi-automatic with knurled wheel adjustment, Edison-Bell twin crystal detector, Wates K crystal detector with two concentric movements, Golton perikon type, Goldtone mercury type, Utility automatic crystal detector, Ferron silicon crystal mounted in nickel cup and others.

CRYSTALS

Crystals, usually supplied in small tins and packed in cottonwool, went under the brand names Tellite, Harmotone, Uralium, Gecosite, Hertzite, Radiocite, Permanite, Tungstalite, Mighty Atom, Midite, Detex, Neutron, Cymosite, Robbins, Goldtone, Power Plus and others. The crystal materials were mainly Arzenite, Bornite, Carborundum, Chalcopyrite, Copper Pyrites, Galena, Magnetite, Iron Pyrites, Molybdenite, Silicon, Tellurium and Zincite.

Many of the crystals were synthetic or artificial forms of natural crystals. For example, Radiocite was manufactured by fusing the native mineral galena in an electric arc furnace at a temperature in excess of 2000°C, the new crystal being deposited in an atmosphere of galena vapour. Combinations of silver and antimony sulphides with native galena were also used to increase the sensitivity of galena.

Carborundum (silicon carbide) patented in 1906, was the most widely used crystal on ship's wireless installations because the strong steel contact ensured good contact even when the ship was rolling in heavy seas. A permanent bias was necessary with carborundum for optimum performance. The exact voltage varied with each crystal. A potentiometer was used to vary the voltage over the range 0.75 to 3 volts.

The voltage had to be so directed as to make the steel point positive relative to the crystal. Great numbers of carborundum detectors were sold by Australian Radio Shops in the 1920s and many were incorporated in battery receivers because they were superior to early thermionic valve detectors. Even some large superheterodyne circuit receivers employed fixed crystals as detectors.

Another efficient detector was silicon, but at the time was difficult to obtain and was also expensive. One of the best known silicon detectors was the Ferron detector, manufactured in 1919 by J J Duck & Co., of the USA. The base was polished Italian dove marble measuring 140 mm by 75 mm by 25 mm thick. All metal parts were nickel plated brass. Ferron was the trade name for silicon crystal mounted in a nickel plated cup mounted on the base. Even today, these detectors can be seen in vintage radio collections in Australia.

Another widely used silicon crystal detector was developed by Greenleaf Pickard of the USA. A sharp pointed brass rod was pressed down by a spring into contact with a piece of polished silicon embedded in a fusible solder of Wood's metal. The solder in which the silicon was embedded was contained in a metal cup resting on a metal plate. Connection to the brass contact rod was by means of a binding post.

The detector was marketed under various names but one branded Silidet was sold by the Norwood Radio Depot in Adelaide in 1925. It is of interest that during the 1940s, when British scientists were investigating silicon as a detector for magnetron radar equipment, they found that the most important factor which determined the RF performance of the crystal was its purity. Wide variations in impurities resulted in large changes in performance as a detector. Pure silicon was unsuitable due to high resistivity. Much development work went into the study of controlled quantities of impurities such as aluminium, beryllium, boron and others. This research proved to be of great value in later years in the development of the transistor.

The most widely employed crystal detector which did not use a cat's whisker or other metallic contact was the perikon detector patented by Greenleaf Pickard in 1906. Pickard had been working on the use of minerals as detectors of wireless telegraphy signals as early as 1903. The device was a combination of two crystals, zincite and chalcopyrite but occasionally some manufacturers substituted bornite or tellurium for the chalcopyrite. Derivation of the word 'perikon' is not known. A search of Pickard's papers in the Smithsonian Institute in Washington gave no clue.

Early perikon detectors were cumbersome and difficult to adjust.

Chalcopyrite was fixed in a lower cup and zincite in an upper cup. A threaded knob screwing on a flat spring arrangement was used to adjust contact pressure. The device was not popular among crystal set makers but designers and manufacturers worked on the problem and by 1925, simple enclosed type models for vertical or horizontal mounting were available from most Radio Shops. Some models used a vernier screw for adjusting pressure between the crystals while other designs used a spindle and spring arrangement. Once set up, they were not as easily disturbed as a standard detector using a cat's whisker.

A detector of interest is the so-called 'automatic' crystal detector. By slowly turning an ebonite knob or thumb wheel the cat's whisker was advanced and withdrawn in turn and the crystal moved round so that the whole of the workable surface could be explored for a sensitive spot. With some designs the crystal remained fixed with the cat's whisker being moved. The mechanisms were enclosed in a removable dustproof case. Brands which employed this design in the early and mid 1920s included Telefunken, Utility, Cymosite, Sterling, Tungstalite, Everset and others.

The Tungstalite model used a round Tungstalite crystal which was a British made synthetic crystal of high efficiency.

The Telefunken model used a crystal cylinder with a rotating cat's whisker which could move horizontally or vertically enabling an enormous number of spots to be explored.

The Everset was made up in cartridge form and held between two clips. It employed a number of points of contact and assumed that one of the points could be relied upon to provide the necessary rectifying action at maximum sensitiveness.

The Welty Crystector made by the William Welty Company, Chicago, USA, and stocked by the Radio Department T C Beirne, Brisbane in mid 1920s was developed as a replacement for a valve detector. The crystal element on a bakelite base with dome top and pins in the base, resembled a valve. It was simply plugged into a detector valve socket.

The device employed a high grade element claimed by the manufacturer to be 'hot all over' and had an adjustable cat's whisker.

Two of the detectors were purchased by Bill McDonald, a member of the Toombul Radio Club who used one as a replacement for the detector valve in his five valve neutrodyne circuit receiver and the other as a detector for a crystal set with one AF stage. In describing his experience with these detectors at a meeting of Club members, Bill said he found both to be highly reliable and more sensitive than other types he had used to that time. He said that the crystal used in the neutrodyne receiver reduced static by at least half compared with the valve detector without reducing the quality of the signal.

In more recent times, crystal detectors available to the crystal set enthusiast have included GEC GEX 34 and BTH CG 10E germanium crystal diodes.

CAT'S WHISKERS

The cat's whisker was the name given to a fine wire or piece of metal that effects contact between the aerial circuit and the crystal, in a crystal detector system.

Cat's whiskers were usually steel, silver, gold, tungsten, phosphor bronze, brass or copper. The majority were fabricated from fine wire in multi-turn coil form, but others were made with a single turn or as a stiff tapered ribbon. The tapered ribbon was used where high pressure was required.

One patented multi-coil type called The Permanent Point, was sold by Morris and Co., Radio, Melbourne in 1927. Its double tension characteristic was reputed to give 'perfect balance, even pressure and permanent adjustment'.

Another interesting cat's whisker assembly was the G and S Silk Core Crystal Detector which could be purchased from Economic Radio Stores, Melbourne in 1927. The makers claimed that a single wire cat's whisker could not pass the energy from a strong radio signal without destroying the contact point of the crystal face. To overcome the problem, a device was developed using a silk core brush composed of seventy fine strands. The aim was to cause the signal voltage to be distributed over many contact points. The seventy silk cords were minutely wrapped with flat bronze tinsel allowing contact on the full crystal face.

Other multiple contact devices were also in use, with one popular type being made from thin pieces of foil cut into a series of points and then rolled up to make a brush.

Besides claiming to distribute signal energy over a wide surface of the crystal face, the multiple point types were said to give better results by virtue of the fact there were many parallel contact paths established. However, many experienced crystal set operators maintained that there seemed to be only one or two sensitive points on a crystal face capable of giving good results, but the problem was to find those particular points. Also, once found, the cat's whisker had to remain on that point. Some operators placed a fine wire gauze over the crystal cup and poked the crystal through the gauze when probing for the sensitive spot. The gauze prevented the cat's whisker from moving off the selected spot.

The type of material used for the cat's whisker appeared to have some influence on the performance of the crystal. For example, a very fine brass wire filed to a needle point gave good results with a hertzite crystal while gold wire or phosphor bronze gave excellent results with a copper pyrites crystal. Steel or copper were preferred for silicon. The reason for good results with these combinations was not fully understood, but it was suggested that it was probably due to the thermo-electric couple that was formed with passage of the signal voltage picked up by the aerial.

Radar Crystal Valve

The crystal detector or crystal valve as it was known, made an important comeback during the Second World War with the invention of the multi-resonator magnetron in 1940 for radar. There was no thermionic valve at the time suitable for use as an RF amplifier or mixer at the frequencies or the magnetron and the crystal was used as an interim detector. However, nothing could match the sensitivity of the crystal, and much effort was put into further development by Drs B Bleany and C J Milner and others of the Clarendon Laboratory, Oxford.

The combination of tungsten or molybdenum tungsten alloy for the cat's whisker with silicon as the semi-conductor gave the best combination of sensitivity and stability. A capsule was developed to ensure reliable contact between cat's whisker and silicon even under high mechanical shock operation and to ensure that no moisture entered the capsule. The cat's whisker and silicon were carried by brass ends which were firmly anchored to a ceramic tube and the capsule filled with wax.

The Thermionic Valve

The thermionic diode invented by Sir John Ambrose Fleming in 1904 was not as sensitive or as efficient as many of the crystal detectors. Although the Marconi Company employed the Fleming diode in some of its receivers, it did not obtain enthusiastic acceptance by operators for many years. The reason for its insensitivity was not fully understood until 1922, the year that active broadcasting began in England.

Two workers, E B Moullin and L B Turner showed that the rectified signal current was proportional to the square of the applied voltage. Radio signals were as a general rule, of low level and the vacuum valve could not compete with a crystal unless some form of signal amplification was provided. Strange as it may seem, the diode was saved by the triode, which after much development, was able to produce regeneration in a receiver. The positive feedback boosted the signal level before detection, so compensating for the inefficient detection that followed.

With other circuit designs using the triode as an amplifier, strong signals could be provided to the detector stage. By employing a triode in the detector stage, it was possible to secure amplification by feeding the signal voltages to the grid of the detector valve.

Three early methods of detector amplification were the anode-bend method, the grid-leak method and power grid method. The anode-bend method could handle a large signal level without distortion but the grid-leak method was more sensitive for weak signals.

Anode Bend Detection

In the anode bend or biased detector, the valve operated on the bend of the anode current/grid voltage characteristic curve by application of an appropriate negative voltage on the grid using either a fixed source or with the bias voltage derived from a cathode resistor. In essence, the valve was biased to anode current cut off point.

When the RF signal was applied to the grid of the valve, the positive segment of the modulated carrier allowed anode current to flow. For a low level signal, the anode current was low whereas a very high level signal could swing the anode current into saturation mode resulting in high distortion of the demodulated audio signal.

To overcome this shortcoming, it was usual practice to design the circuit so that the gain was adjusted to an optimum level prior to detection.

High impedance valves were preferred as anode bend detectors but as distortion was somewhat high for all operating conditions, the technique was replaced during the 1930s when designers were under pressure to provide receivers of high fidelity characteristics.

Grid-Leak Detection

With the grid-leak arrangement, it could be assumed that the detection process occurred in the grid circuit and the resulting audio signal amplified as with an ordinary amplifier. Because of the amplification, the detector was more sensitive than the anode-bend type. The valve detected on its grid-current curve so that the operating point had to be on the curved part of the grid voltage/grid-current characteristic curve. Because it amplified on the anode current curve, the anode voltage had to be set so that the operating point was on the straight section of the anode current curve.

As there was some grid-current flow with this method, a negative voltage drop was produced across the grid-leak which had a value of 1 to 10 megohms. The value of the grid-leak fixed the point on the grid-current curve at which the input signals operated. The grid capacitor bypassed the high resistance for RF currents and had to be of suitable value to give minimum impedance. However, if the capacity was too high, the audio frequency voltages built up across the grid-leak, would be bypassed.

When Lee de Forest, of triode fame built a receiver for use with a station in the Metropolitan Life Insurance Company Building, New York in 1909, the grid-leak consisted of a graphite pencil mark on a strip of paper laid over a piece of hard rubber between two small brass binding posts.

The device was such a success that his company began selling it to experimenters from a Radio Shop he established in the same building. Managed by Quincy Brackett, a Harvard graduate, the business was claimed to be the first Radio Shop in the world selling radio receivers and a range of components to the public.

In many early circuits designs using high vacuum valves, the grid return was connected to the positive filament terminal, whereas for gas filled or gas type detector valves, the grid return was connected to the negative filament terminal, although many constructors did not follow the rule, and in practice there appeared to be very little difference, if any, in how the connection was made.

Valves with high amplification factors tended to perform better than general purpose types with grid-leak circuits.

Power Grid Detection

Because of distortion and hum with early audio frequency amplifiers, designers looked at means of reducing the number of audio stages without substantially reducing the output power.

During 1929, many receivers designs were produced employing only one stage of audio frequency amplifications. This gave rise to the term power grid detection. This meant that the detector produced sufficient audio frequency voltage to load up the final stage. It also had other merits. The advantages of power detection were:

- ability to do away with one stage of audio frequency amplification and so reducing distortion.
- possibility of linear detection and consequent reduction in distortion.
- shifting amplification from audio to radio frequencies decreased noise from hum and the valve.
- reduced receiver cost due to reduced filtering requirements.

The power detector was simply a detector that did not overload with high RF input voltages and which would turn out sufficient power to drive the final stage. There were two kinds, one using a grid-leak and capacitor and the other a battery biased or 'C' bias type.

With the arrival of the screen grid valve, it was used as a detector by some designers. The first grid acted as space charge and the outer grid and anode acted as a grid-leak detector. Care had to be taken in selecting the valve and determining the values of resistances etc.

With improvements in transmission quality and public demand for high fidelity receivers in the 1930's designers investigated the employment of linear detectors to replace those operating with a square law characteristic. Linear detectors had a number of advantages including low harmonic distortion and direct current output proportional to the carrier and independent of the audio modulation and hence not being affected by the per cent modulation or noise voltage. The advantages led to the adoption of diodes or triodes connected as diodes in the detection circuits to provide the linear detection characteristics.

LAYOUT AND WIRING

Layout concerned the process of planning the positions and arrangement of the various controls and components of the receiver to be constructed.

In early receiver construction, layout of the front panel was usually the first part of the project which needed finalisation before other assembly work could proceed. There were no fixed rules, but the majority of home constructed, and even factory constructed receivers, varied little in appearance. Tuning capacitors with their dials or escutcheon plates were frequently located in the centre of the panel which was usually bakelite sheeting, and other controls and items such as variometers, rheostats, switches, valve windows etc put in positions which, to the constructor, gave an aesthetically pleasing appearance. Terminals for loudspeaker, phones, aerial, earth, batteries etc, were mounted on the edge of the front panel or on the back of the baseboard behind the front panel.

Layout of components on the baseboard or chassis had to ensure that the various components could be located in suitable positions where they were not likely to cause electrical or magnetic interference or be obstructed during operation, such as opening the vanes of a tuning capacitor or moving the coils of duo lateral or basket weave type inductors.

After some preliminary juggling, and providing the baseboard was large enough, it was a relatively simple process to satisfy the designer that the next stages of the work such as drilling, mounting and wiring could proceed.

Up to about the mid 1920s, very little attention was paid to screening of components, or sections of the receiver, and much to the annoyance of the constructor, instability sometimes resulted after switching on the set. The experienced designer would ensure that where two or more LF transformers were employed, that they were separated as far as conveniently practicable and the iron cores were mounted at right angles. The same approach had to be adopted for HF transformers with their axes being at right angles. The location of the tuning capacitor in relation to the HF transformer was also important. With the later introduction of screened coils etc, components could be placed much closer together than previously. Screened wire was helpful in reducing instability of the reaction circuit of a detector when the reaction capacitor or coil was some distance from the detector valve holder terminals.

Constructors soon realised that there was no perfect system of positioning components because every circuit and assembly had its own peculiarities and had to be built around the components being used. Reflex, tuned radio frequency and superheterodyne designs all had their own layout requirements to ensure stable operation.

When broadcasting transmissions commenced in Australia in 1923, the most popular circuits were regenerative and tuned radio frequency designs. The regenerative design retained it popularity until about mid 1925 but by about 1927 was not greatly employed with broadcast receiver circuits. With the introduction of the neutrodyne circuit, the straight TRF lost some following but after about 1926, it came back in favour and maintained its popularity up to about 1929–30 when the superheterodyne returned after an unsuccessful launch about 1925. The reflex circuit was another design which enjoyed considerable acceptance well into the 1920s.

Although the neutrodyne appeared on the scene with great promise, it did not have a great following amongst home constructors although many commercial organisations produced receivers to this design. The great number in service in Australia during the 1920s were imported from USA, although Radio Corporation Pty Ltd, Melbourne had a fair share of the market.

The use of the metal chassis in place of wooden or bakelite baseboard provided many advantages and was soon universally accepted. The screening effect of the metal prevented many unwanted coupling problems and it also ensured short earth connections for components which required an earth connection.

In assembling receivers, bare tinned copper square or busbar wire was widely employed in the early 1920s although some use was made of insulated copper wire about 18 gauge. To make bends with the square wire a small wooden former was used. If only a few bends were required a pair of flat-nose pliers would do the job. The wire was purchased in lengths of 60 to 75 cm length and if kinked, one end would be put in a vice while the other was pulled with flat-nosed pliers.

Many expert home constructors and workshop assembly staff preferred the square wire busbar for interconnecting the components giving a geometric style copied from power switchboard wiring practice in use at the time. Many of those who used the square wire considered the use of ordinary insulated flexible wire to be 'very unworkmanlike'.

The system using the rigid square wire was known as the anti-capacity system. In principle, each wire was so positioned that it did not touch or be too close to another wire or metallic body, all bends were made a right angles and connections were made from point-to-point in straight paths. It was normal practice to provide an air space clearance of ¼ inch (6 mm) between conductors carrying low voltages and ½ inch (12 mm) for conductors carrying high tension voltages. Other practices included keeping conductors carrying RF currents remote from one another, and crossing at right angles where necessary. Where possible, wires carrying RF currents were not run in parallel lines.

Connections to components were made by either soldering to terminals or using nutted connections. In the nutted connection, an eye was turned on the end of the wire using long-nose pliers and slipped over the screwed shank of the terminal or other connecting point, and screwed down tightly with a nut. This method had merit in that the entire set could be wired without the need for a soldering iron. Also, it was easy for the Serviceman to isolate components during fault-finding operations. The workman had to be careful to ensure that nuts were not tightened to tightly. Broken connections to AF transformers and RF coils often occurred when the terminal was rotated so breaking the connecting wire to the inside of the component.

An alternative to the use of square busbar was to employ flat strips of copper or brass about 20 SWG and ¼ inch (6 mm) wide.

This was popular with some European manufacturers during the mid 1920s. The owner of a small Radio Shop in Gawler Place, Adelaide had been trained in the Telefunken factory in Germany and when he migrated to South Australia and set up business there he used tinned copper strips in constructing his battery receivers. Insulated posts were employed where necessary to separate strips. No soldered joints were used in assembling the receiver. Flat type mica capacitors were slipped into two clips with connection being made by two spring clips which went directly under the terminal nut. Resistance such as grid-leak were held in position by vertical phosphor bronze clips and terminal posts mounted on an ebonite base. In the case of transformers, the flat strips were drilled and fixed to the transformer terminal posts.

A receiver wired in this manner was displayed in November 1973 in the Hall of the Adelaide GPO to commemorate the 50th Anniversary of the establishment of radio broadcasting in Australia.

In the late 1920s and early 1930s, with the introduction of mains-powered receivers, and also endeavours to reduce production line costs on long assembly lines, the bare busbar method of wiring disappeared to be replaced by point-to-point wiring using flexible wiring with multicoloured insulation for identification purposes. Although each connection was run and soldered separately, some large factories developed wire forms similar to telephone switchboard practices. Wires were cut to correct sizes and ends presoldered to facilitate soldering in the set. However, the technique was not always successful because of feedback problems resulting from some wires which should not have been included in the form. An examination of some receivers constructed with the form arrangement indicates that Servicemen had to cut open some forms to get to wires which had burnt out due to overheating or which were the source of instability in the receiver. With the introduction of circuit boards using transistors in place of valves, the mass of interconnecting wires in radio receivers disappeared.

One of the most difficult jobs for the home constructor or the small Radio Shop which assembled custom built receivers from time to time was providing engraved designations for the various controls and panel mounted terminals. The work could be carried out by a professional engraver or even the local jeweller but it was difficult to justify the expense in many cases. In any case, the proud home constructor often preferred to do the entire receiver assembly work without outside assistance so that he could boast to friends that the entire work was his own. A good job of engraving enhanced the appearance of the finished product.

A procedure adopted by some constructors and Radio Shops was to draw the required letters, numbers, patterns or symbols on the bakelite panel using a soft lead pencil. The actual engraving was done using a sharp point such as the point of a pair of workshop dividers or a scriber heated to an appropriate temperature. Because heat was applied to the tool it was wrapped with a suitable material so that it could be held in the hand during the engraving operation. A small spirit flame was used to heat the point of the tool but care had to be taken to ensure that it was not too hot as excessive heat could give a problem in controlling the depth and width of the cutting in the panel material. A wise workman would try out the procedure on a scrap left over from the panel before commencing work on the panel itself.

After cutting into the bakelite to form the letters etc, the cuts were filled with a compound made by mixing clear gum and powdered chalk to form a smooth paste. Excess compound was wiped off with a dry soft rag before the compound had dried.

An alternative to directly engraving the panel was to engrave small designation plates of ebonite, copper, brass, celluloid, bone etc, and then to attach these to the panel by adhesive or screws. The plate had to be securely fixed to a baseboard when carrying out the work as considerable pressure was applied to effect the engraving. For engraving metal plates, a tool referred to as a 'graver' or 'burin' was widely used. This was a rectangular tool tapering from the handle to the point, which was curved over at an angle to form a lozenge-shaped head. The single projecting point was used as the cutting edge. The handle was usually in the form of a round knob to fit in the palm of the hand. Cutting was made by pressing forward and with a sliding motion. To cut away the ground of the designation plate, a tool known as a 'scorper' gave good results. It was a U-shaped section tool ground to a cutting edge terminating at the curved portion. It removed the metal and left the surface slightly hollow. For brass or copper plates, the filling compound was black rather than white for bakelite or ebonite panels. Some home constructors who went to the trouble of making their own engraving tool soon became experts in the work and undertook work for others at a fee.

When Roy Buckerfield was in charge of the workshops manufacturing glass-front Newkrodyne receivers for the Transatlantic Wireless Manufacturing Co., in the 1920s in Adelaide, he developed a device for engraving the plates for the receivers by using a dentist's drill attached to a flexible steel cable driven by an old foot-powered sewing machine. It engraved designation plates which were glued to the glass front panel.

Another South Australian who worked in the Radio Department of the Electrical Supplies Depot in Rundle Street, Adelaide in the mid 1920s under ex-RCA Engineer Rupert Barker, had qualifications in chemistry and used acid to engrave the designation plates for receivers assembled in the company workshop. Samples held in the former Telecommunications Museum in Adelaide collection, showed the work to be of a high standard using the acid technique.

TUNING

For the non-technical listener, adjusting the receiver for optimum reception was a daunting task, and in many homes the task was left to a younger member of the family who soon fathomed out 'which knob did what' and became the family wireless expert. Even so, most early TRF receivers had three tuning controls and adjustment of the set required a lot of patience.

Many early receiver designers were also Amateur station operators who relished in equipment loaded with knobs, dials, switches, lights, meters, terminals, jacks etc This thinking transferred to the broadcast receiver with separate rheostats for controlling filament voltages; variable coils; variable capacitors within inbuilt trimmers; peepholes for observing valves; terminals for batteries, loudspeakers, aerial and earth, and jacks for headphones. Connecting up all the external facilities such as loudspeaker; A, B and C batteries; aerial and earth wires was bad enough, but operating the array of knobs and dials was another thing. Many receivers had an operating instruction sheet which in itself was difficult to understand as the non-technical listener could seldom follow the jargon. Such words as tickler coil control, wavelength, oscillation, neutralising, filament, aerial tuner, reaction, rheostat, high tension, low tension, bias etc, were completely foreign, and if the listener was fortunate to obtain a signal, all controls were frequently left as they were, and only the battery on/off switch operated. This did little to advertise the merit of broadcasting as a home entertainment medium.

Typical of the array of designations, knobs, switches and other controls is that which was provided on the six valve, battery-operated Federal receiver sold in many Radio Shops in 1925. The TRF type 61 receiver comprised three high frequency stages, a detector and two audio frequency stages. It was made by the Federal Radio Company, USA who also made wireless equipment for the American battleships and it is evident that the designers gave scant attention to the difference in technical know-how between a Navy Wireless Operator and a housewife. The sole agent for Federal Wireless equipment in South Australia was Mackenzie and Maddern and notwithstanding its high cost and complexity, it was purchased by South Australian country listeners at Renmark, Quorn, Port Augusta, Penola, Wakefield and Murray Bridge.

Designations and controls on the front panel were as follows:

- Primary Inductance 1 — eleven position stud switch.
- Primary Inductance 2 — eleven position stud switch.
- Primary Capacitor — five position stud switch.
- Secondary Wavelength — graduated dial and knob.
- Vernier — graduated dial and knob.
- Selectivity — graduated dial and knob.
- RF Amplification Control — graduated dial and knob.
- Amplification Selector — four position knob/switch.
- First RF Rheo — rheostat control knob for filament.
- Second RF Rheo — rheostat control knob for filament.
- Det. Rheo — rheostat control knob for filament.
- First AF Rheo — rheostat control knob for filament.
- Second AF Rheo — rheostat control knob for filament.
- Loop-Aerial — bar knob switch.
- One Stage RF- Three Stage RF — bar knob switch.
- Phone — jack.
- Loop — terminals for loop aerial.
- Antenna — terminals for aerial.

The receiver was very expensive, selling for £150 in 1925.

In addition to building receivers, the company manufactured a wide range of components such as rheostats, sockets, audio and radio frequency transformers, headphones, capacitors, plugs, jacks and microphones, all of which could be purchased in Australian Radio Shops. The Company also operated WGR, a large broadcasting station erected in 1922 in Buffalo.

The larger manufacturers soon realised that people were not anxious to buy receivers because they were too difficult to operate, and designers were put to work to come up with solutions to simplify the product.

The problem was attacked by combining a number of previously separate functions onto a single knob shaft. Many weird and wonderful devices such as a rack and pinion for rotating four tuning capacitors, a four bar mechanism for linking tuning capacitors, tuning capacitors ganged using steel bands or chains, ganged filament rheostats, ganged variometers and others were incorporated in receivers by manufacturers.

However, some of the mechanical devices gave more trouble than the electronics. The manufacturers were aware that some of the complex tuning mechanisms were likely to give trouble so instructions were provided on how to disengage the mechanism to allow individual operation of the ganged components should the mechanism fail.

A major problem with ganging capacitors was that it was difficult for all stages to track correctly over the full range of tuning. For perfect tracking, all coils had to be of equal inductance and the capacitors had to be matched throughout their full rotation. This was not easy to achieve with mass-produced components and the way items were mounted in the receiver. For example, stray capacitance of the coil winding which added to the capacitance of the variable capacitor upset the system. Designers came up with capacitor vanes shaped to a logarithmic law, so that for any initial setting of the vanes, coil stray capacitance did not matter to any extent.

Ganged tuning had an effect on selectivity. With the popular neutrodyne circuit, tracking was poor with mechanically linked radio frequency stages, unless selectivity was sacrificed. However, the principal feature of the neutrodyne was the ability to stabilise the receiver using neutralising capacitors and this could be used to advantage by providing high gain.

A feature of Atwater Kent TRF receivers was the use of spring steel bands for ganging the tuning capacitors. Any slight electrical misalignment was accommodated by using a stabilising resistance in each RF circuit. The resistance of several hundred ohms connected at the grid was a crude attempt to decrease the tuner's ability to separate a desired signal frequency from other signal frequencies. A number of South Australian designed Reactodyne receivers also used this technique to achieve stability with similar effect on selectivity.

A lot of development work went into improvement of tracking and tuning for TRF circuits and by the early 1930s had reached a high level of efficiency. Unfortunately, the superheterodyne circuit made a comeback and TRF receivers disappeared from the broadcast receiver scene very quickly.

The problem of tracking the tuned circuits with the superheterodyne circuit was a complex one. In order to produce the intermediate frequency, the oscillator circuit had to be kept tuned to a frequency higher than the incoming signal frequency. An ordinary ganged capacitor was not suitable except at one point on the tuning dial. Designers employed a series capacitor in the oscillator tuned circuit. It was known as a padder. At the same time, trimmer capacitors were placed in parallel with the tuning capacitors. The trimmers were adjusted so that the receiver would track over the high frequency end of the band and the padder adjusted so that the circuits tracked over the low frequency end. Although tracking was not perfect, with correct size of oscillator coil, deviation from perfect tracking was of little consequence. In multi-band receivers, appropriate trimmers were switched into circuit by the wave change switch.

Some component manufacturers provided complete factory assembled and aligned tuning units because of tracking difficulties often encountered by home constructors when they bought individual components. A typical tuner produced in 1928, was the Emmco single or double control unit. Each system was assembled as one unit and included an embossed moulded bakelite face plate which contained logging windows and openings through which the drum controls projected. Each drum contained an indicating strip for calibration purposes.

The tuning was friction vernier drive and included a separate capacitor plate for balancing purposes. The capacitor plates of the Stratlyne capacitors were made of brass and specially designed for ganging application. Cone bearings ensured smooth trouble-free movement.

Each capacitor was mounted on a bakelite base and incorporated soldering tags and pigtail connections. The face plate was available in black or mahogany finish.

With the development of 'automatic' tuning of the push-button selector type in the early 1930s, radio parts manufacturers were quick to begin production of suitable units for incorporation in new receivers by manufacturers and also for Radio Servicemen and do-it-yourself hobbyists to convert existing receivers to the new tuning arrangement.

Crown Radio Manufacturing Co., of Sydney was one company which marketed these units. Two basic units were produced. One unit the PB/8ST was primarily designed for use by manufacturers of new sets while the PB/8SP was designed for modification to existing receivers.

Both units were assembled on to a standard Yaxley 8 button switch enabling complete coverage of the broadcast band. One of the assemblies was completely permeability tuned and incorporated 16 coils, while the other carried eight oscillator coils only. Each coil was fitted with Sirufer cylindrical plug of the moulded-in screw type.

With most push-button schemes, a push-button cut-in a fixed amount of capacity for resonance of a particular station frequency and at the same time released any other button which may have been previously depressed.

A problem was that tuning was only approximate and distortion would occur if tuning was too far off the carrier frequency. Also, to cater for tuning intermediate stations, a variable capacitor and dial were still required.

An alternative favoured by some designers, employed an assembly with the appearance of a large telephone dial plate geared to a capacitor gang spindle. Intermediate stations could be easily tuned-in and the system was relatively simple and cheap to produce. A modified version used an electric motor to control the variable capacitor shaft. The motor was controlled by push-buttons.

Variations of these systems were employed but were not entirely satisfactory. Tuning was seldom accurate and frequency drift was common, even though temperature compensated fixed capacitors were employed. Automatic control of the oscillator frequency was attempted but it introduced a number of alignment problems in the production line assembly.

Staff of Bland Radio Co., Adelaide, manufacturers of Operatic brand receivers devoted considerable effort into development of a pre-set system. A separate set of pre-selectors and oscillator tuned circuits were provided for each of the Adelaide broadcasting stations on air just prior to the Second World War and were cut into circuit by the operation of push-button switches. The tuning circuits were pre-set by small semi-variable capacitors similar to those employed for trimmer circuits with a fixed inductance. Problems were experienced with frequency drift due to temperature variations and the project was abandoned.

Breville Radio Engineers developed a novel mechanical system called Zip Automatic Tuner which was fitted to receiver models released in early 1939. The system consisted of a series of heart-shaped cams which were operated by a shaft which was an extension of the shaft of the gang tuning capacitor. A station was selected by depressing a key. The action caused a roller to turn the cam and the ganged capacitor shaft. When the roller fell into the top of the heart, the gang stopped and the nominated station was received. Cams were individually set by a screwdriver during the alignment procedure. Advantages claimed for the system included:

- Entirely mechanical.
- No capacitor trimmers which could result in frequency drift with temperature changes.
- No switch required to change from automatic to manual control.
- New stations could be added without removing the escutcheon or the chassis.

Following development work into the application of ferromagnetic cores with coils during the War period for Services equipment by Kingsley Radio Pty Ltd and others, post War application included the employment of ferromagnetic tuning of broadcast receivers as an alternative to capacitance tuning. In late 1945, Kingsley Radio produced a pre-aligned Ferrotune front end that provided straight line tuning from 540 kHz to 1650 kHz, with each revolution of the tuning knob covering 100 kHz of spectrum.

Just as in the 1920s, when there was a backlash against home radio receiver designs which incorporated multiple rheostats, several controls and switches, and independent tuners, consumers today have demanded more user-friendly equipment with home entertainment equipment.

For some 30 years, home entertainment systems were dominated by Japanese technology with each new development resulting in more and more functions and features being added to each new equipment model.

Researchers about 1990, found that many people were frustrated and baffled trying to come to terms with complicated operating procedures, and in fact, many did not know how to use all the controls on traditional AM/FM tuners let alone programmable CD players, graphic equalisers, spectrum analysers, dual cassette decks, infra-red remote controls, disc carousel changers, and many others. The researchers found, following a visit to some owners who had purchased equipment one year previously, that nearly all controls were still on the same setting as left by the Serviceman following home installation and setting up. The survey found that consumers simply wanted to be able to use their equipment and not spend hours fiddling with controls and reading through manuals. Also, there was a strong preference for slimline equipment which is attractive and unobtrusive in the home. People are no longer prepared to accept cumbersome hi-fi equipment. They want a system that sounds 'great', but does not overpower the living area visually.

To meet theses requirements, Bose produced several systems in their Lifestyle range including a slim line compact disc player no bigger than a box of chocolates; twin speakers the size of milk cartons and a bass module designed to be hidden away, with the system being completely operated by a simple remote control. The equipment is distributed in Australia by Bose Australia. Bob Schenk was Manager of the company in 1998.

MAINS OPERATION

The need for three different types of batteries was one of the greatest drawbacks to selling the idea of a 'broadcast receiver in every home' to the public. The batteries were expensive, had a short life and some types were very heavy and contained hazardous liquid which could quickly burn a hole in an expensive lounge room carpet.

It was therefore logical that designers should look to the use of other means of providing power to the receiver, such as the electricity supply to the house to replace the A, B and C batteries. There was also the running cost factor. At the time, it was estimated that the cost of power from the public mains supply to operate a typical home receiver of five valves was about one-eighth the cost of providing the energy from batteries.

Very few owners had spare batteries on hand, and the A battery could be away at a garage for several days or more for recharging. To overcome this problem, some garages had a loan system whereby they would loan a fully charged battery at one shilling per day while the owner's battery was being recharged. The City Motor Supply Co., in Swanston Street, Melbourne was one garage in 1928 which provided this service. Charging costs varied with the capacity of the battery. For a 6 volt 44 Ahr battery, the cost was two shillings, while a 6 volt 85 Ahr battery cost three shillings.

Before handing over the recharged battery the Serviceman often attached a label to the side of the battery which read, 'In case of acid spill on the carpet, immediately use a liberal application of ammonia or bicarbonate of soda to minimise damage to the carpet'.

Where people had access to mains DC supplies it was possible to design a receiver to operate from the mains rather than use batteries. However, there were some problems and traps for the unwary. Murray Bridge in South Australia was a typical town with DC mains supply before conversion to AC. The town was supplied with a three wire system providing 230 volts positive to ground and 230 volts negative to ground. Distribution was arranged so that every second house was connected up to 230 volts negative to ground. In receiver construction technique, it was usual practice to connect the high tension negative terminal to chassis but if such a receiver was connected to a DC supply with 230 volt negative to ground, the chassis would be at a hazardous potential and some precautions had to be taken. Either the metal chassis had to be isolated from earth and enclosed to prevent accidental contact by the operator or the negative line isolated from the chassis.

Valve heaters were generally operated in a series chain with a suitable dropping device such as lamps or resistor.

In the early 1930s many towns in Australia were provided with DC mains supplies. Supply voltages comprises a range of voltages including 110, 220, 230 and 240 volts DC. There were at least 208 towns throughout the nation comprising 21 in Queensland, 35 in New South Wales, 42 in Victoria, 39 in South Australia, 66 in Western Australia and 1 in the Northern Territory.

Some towns had both AC and DC power systems distributed throughout their electricity service areas and radio installers had to take care to verify the type of system to which the set was to be connected. The problem was aggravated by some buildings having both AC and DC systems installed particularly where lifts were installed. Adelaide was one of the towns with both AC and DC systems distributed throughout the city area.

The owner of a restaurant in Rundle Street approached D Harris and Co., who had a small radio manufacturing and distribution business in Charles Street off Rundle Street for a demonstration in his restaurant of a Gulbransen radiogram which D Harris and Co., had in stock. The radiogram had been manufactured in Sydney and was a very large and heavy unit.

One of the employees and the brother of the Proprietor, manhandled the radiogram down the stairs from the first floor workshop, along Rundle Street, and down stairs to the restaurant located in the building basement. After positioning the unit and making a quick check of the turntable, the employee was instructed to plug in the lead and switch on the power. There was an immediate explosion and black smoke poured out from behind the unit.

The power point had been wired into the building DC distribution system but the radiogram had been designed for operation from an AC source. An examination revealed extensive damage to the equipment and the two men had the difficult task of taking the radiogram back to the workshop for repairs.

A somewhat similar case occurred in Toowoomba in Queensland in 1934. The manager of a high class men's tailoring business in Margaret Street went to Brisbane to purchase some cloth for his business and while there bought a five valve AC powered Radiola Model 47 receiver from J B Chandler and Co., in Adelaide Street, Brisbane. At the time Toowoomba power system was 240 volts DC.

Two days later when back at work, he plugged the receiver into a lamp socket and switched on the power. There was a loud explosion and smoke billowed out from behind the receiver. A customer in the shop rushed next door and asked the attendant to call the Fire Brigade. In the process the cotton covered light cord was smouldering when the Fire Brigade arrived.

The owner was so embarrassed about the episode that he later put the damaged receiver in his store room and it was still there when he died eight years later.

Local commercially made and imported units were available for use where direct current mains were in service. They were known by various brands and names and included Ashdown High Tension Converter, Henderson High Tension Supply Unit, Neutron High Tension Battery Eliminator and Philips Type 3005 High Tension Supply Unit. Typical input voltage ratings were 200 and 220 volts DC giving output voltages of 50, 80, 100 and 120 volts DC.

In the case of alternating current mains supplies, the solution was difficult because valves in the early 1920s were not suitable for operation with AC on the filament due to the production of high level hum. However, B battery eliminators were available by 1926 and this allowed the expensive B battery to be replaced. By early 1927, large stocks of imported and Australian made designs could be purchased from Radio Shops, with Emmco and Rectodyne being among the most popular.

Of the imported units, Philips was very popular. They were reliable and many are still operational today in vintage radio collections. They included the Type 372 using a type 373 half wave rectifier, the Type 3002 with a type 506 full wave rectifier and Types 3003, 3005 and 3009.

C bias battery eliminators were usually incorporated with B battery eliminator units.

A battery eliminators giving AC voltages were not successful with the type of valves then in use, so the usual approach was to use a trickle charger to keep the A battery fully charged, or in the case of 'all electric' models to use copper oxide rectifier units to provide DC for the filament. However, it was not until 1929 that suitable AC filament valves became available in quantities for manufacturers to begin production of receivers capable of full mains operation.

Many of the early all electric sets gave considerable trouble resulting from the large amount of heat generated by the rectifier system and to overcome the problem, several cabinet designs incorporated a hinged lid with instructions printed on the inside of the lid to the effect that the lid should be raised during operation of the equipment. The Imperia made in 1929 by Harringtons was typical. Many owned by collectors are still in operation with the original Pilot power pack.

The introduction of the all electric set was not without its price. It added considerably to the total cost of the receiver, it required a valve that added nothing to performance of the receiver and required a power transformer, choke, electrolytic capacitors and frequently a bleeder resistor. All these operated at high voltage, generated considerable heat and introduced hum if not well-filtered and shielded. Component failure in the power section was much higher than in other sections of the receiver.

The high voltage involved, also meant that the days of the do-it-yourself receiver constructor were over, except for those who had been suitably trained in Radio Servicing principles.

The mains power supply unit was the source of many faults in domestic receivers because of the high voltages employed and the heat generated. An important factor in ensuring high reliability was good design coupled with high quality control measures particularly during manufacture of the power transformer.

Transformers were usually made in two types, an upright (U) type and a level (L) type. Some manufacturers designated the level type a flat (M) type.

In typical transformers available from Radio Shops, primaries were tapped to provide operation with 220/240/260 or 200/230/250 input volts and to produce 385/385 secondary voltages with currents of 60, 80, 100 or 150 Ma. Windings providing voltages for filaments were determined by the types of valves employed in the receiver. As example, the Radiokes U80-6 manufactured in 1938 provided windings to produce 5 volts at 3 amperes, 6.3 volts at 3 amperes centre tapped and 6.3 volts at 1 ampere. Other models of the period provided voltages of 2, 2.5 and 6 at various current levels.

Top quality power transformers were fitted with electrostatic shields, cores lacquered black and covers painted bright silver colour.

Prior to about 1939, there were many brands of power transformers available from Radio Shops with Radiokes, Saxon, Velco, AWA, Capitol, Aegis, Hilco, ABC, Power, RCS and Bland being amongst the best selling lines. During the War years, many companies manufactured power transformers for Service equipment with some continuing in the business into the 1960s when demand ceased due to the introduction of transistor portable receivers which operated from dry cell batteries. During the late 1940s, manufacturers included Cliff and Bunting Pty Ltd (Trimax); Swales and Swann; Ferguson Radio; Hilco Transformers Pty Ltd; Transmission Products Pty Ltd; Display and Radio Pty Ltd; Endurance Electrical Company; Radix Power Supplies; P A Henderson and Co.; A & R Electronic Equipment Co., Pty Ltd; Red Line Equipment Pty Ltd; and Bland Radio Ltd.

For some years, receiver designers worked on the problem of devising a simple circuit which would enable a receiver to operate from an input power source of 240 volts AC or DC. The release of the Radiotron 302 barretter for use with 300 Ma heater valves overcame the problem.

AWA Engineers developed a number of circuits, including one in 1937 which featured series inverse feedback which reduced harmonic distortion to less than 3.5% at full 2.5 watts output for a five valve design.

The 302 Barretter was capable of accommodating all line nominal voltages between 200 and 260 volts so it was not necessary to employ any tappings for different mains voltages within this range.

The 25Z5 rectifier in the AWA five valve circuit had 100 ohm resistors placed in each anode line to limit peak currents charging the first filter capacitor to a value within the capabilities of the valve and also to distribute evenly the current between the two halves of the rectifier. The heaters of the valves were arranged in series with the Barretter at the higher end of the feed line.

Because of the wide variations in voltage and frequency of electric supply systems throughout Australia in the 1930s, designers had to take this into account in producing mains powered receivers. Supply voltages included 110 V, 200 V, 230 V, 240 ,250 V at 50 Hz; 250 V at 40 Hz; 230 V at 60 Hz; and 80 V, 110 V, 200 V, 220 V, 230 V and 240 V DC. In the case of many South Australian towns, including Adelaide where the supply was 200 V 50 Hz, Radio Shops and Servicemen were very busy fitting new power transformers or changing taps when the supply voltage was later changed to 240 V at 50 Hz.

One person engaged in this conversion work was Bill Walker. Bill had his first contact with broadcasting in 1924 while still at school. It was a very important year in the history of broadcasting in the State. B Class station 5DN and A Class station 5CL both commenced operation in Adelaide during the year. Before he left school, Bill had constructed several crystal sets and a multivalve receiver. His first job was with the Adelaide Electric Supply Company in 1928. The company supplied power for the City of Adelaide and some nearby centres. In his spare time, Bill studied the theory of radio and learnt the Morse Code, obtaining his Amateur Operators Certificate of Proficiency in 1934 and being given callsign VK5WW.

In 1934, the power supply company changed the city supply voltage from 210 volts to 240 volts AC and because of his interest in radio, Bill was given the task of modifying consumer's radio receivers and the city broadcast stations equipment to operate on the new voltage.

Many receivers in SA vintage radio collections today show evidence of this change in input voltage.

It was while undertaking this conversion work, that Bill learnt from a local Radio Inspector that the PMG's Department was about to conduct an examination for entry to the Department's Radio Section. He sat for the examination and being successful, was offered an appointment in April 1940.

Bill then began an association with the National Broadcasting Service which lasted until his retirement in 1976. Much of the early period was spent at the ABC Adelaide Hindmarsh Studios where he was engaged in all the technical functions encountered with studio operations, including outside broadcast work. He also worked at NBS transmitting stations including operation and maintenance functions at 5CK, 5CL and 5LN and installation work at 5MV and 5PA.

When the studio technical facilities were taken over by the ABC from the PMG's Department, Bill transferred to the ABC as Shift Supervising Technician, later becoming Supervisor Radio Operations.

Home generating equipment, particularly those employing charge/discharge or floating battery systems, added to the problems of manufacturers who were forced into the situation of having many short runs on the production line, so adding to overhead costs.

In the majority of designs capable of operating on either AC or DC, they were marketed under various categories such as AC/DC, Universal or Transformerless radios. Most did not include a power transformer. Filaments and dial lamps were connected in series through a current regulator, barretter or series resistor to provide the correct voltage drop to suit the particular supply voltage. Many designs employed output valves and rectifiers which required high voltage filament supplies, typically 25 V.

Radio Servicemen had to be careful when working on these receivers, as in some cases, the metal chassis was at full mains voltage above earth. In better designs, the chassis was isolated from the mains by an earth bus connected to the chassis via a high voltage capacitor. Other safety features included insulated shafts for controls which came to the front of the cabinet, and a capacitor in the aerial lead terminal.

The introduction of mains-operated receivers caught the radio industry by surprise insofar as the Law was concerned. In New South Wales in particular, the Electrical Contractors and Electricians Licensing Act 1924-28 which became law on 14 March 1929 had been drawn up without consideration of the possibility of the conversion of radio receivers from battery power to AC mains power operation.

At the time, those responsible for drafting the legislation did not foresee the enormous growth in the number of receivers, and the radio industry, which was to escalate within a year or two of the Act becoming law.

Although some Radio Dealers and Servicemen had run up against the provision of the Act, it was the members of the NSW Division of the Wireless Institute who began to express concern because of the effect of the legislation on the activities of its members. They saw the Act as preventing any experimenter, professionally or in an amateur character, engaging in any experimentation. They saw the legislation as allowing members to operate a transmitter providing it was installed in accordance with the Standards Association of Australia's rules and had been inspected by the Electrical Authorities, but as for carrying out experiments, making any alterations, repairs or modifications, the Act did not permit this to be done.

The Institute approached the Board suggesting a special licence for Radiotrician as the majority of radio experimenters and Radio Servicemen could not meet the conditions of Electrical Trade experience to meet licensing conditions for an Electrician.

The Board was unsympathetic, ruling that it had no power to issue a special licence for radio work. According to the Board, a Radio Serviceman could ascertain the fault in a receiver but if it was anything in the power circuit, the Serviceman would have to cease further work and obtain the services of a licensed Electrician to correct the fault. In the case of a person building a radio receiver, the receiver could not be connected to the mains unless the cord and plug were made and prepared by a Licensed Electrician. The receiver could then be installed by an unlicensed person.

On 23 November 1931, the Institute called a special meeting to discuss the matter in the Conference Hall of the State Theatre Building, Sydney. It was one of the largest gatherings of Radio Technical people, with about 300 being in attendance.

The meeting resolved that a Committee be formed to meet with the Minister responsible for administering the Act. It was the opinion of those at the meeting that if a person had passed the AOCP or received the Radio Trade Certificate he/she should be a qualified person to hold a Limited Electrical Licence.

After the conclusion of official business, those at the meeting decided to form a Radiotrician's Association for the purpose of protecting the rights and livelihood of people engaged in the radio industry as Technicians.

Membership was to be open to all persons engaged on the designing, drafting, testing, installing, erecting, operating, repairing and estimating costs of wireless and associated apparatus, and employees engaged in the teaching of wireless technique, both theoretical and practical.

A Committee was appointed comprising Messrs Homfray and Head (Radio Engineers); Messrs McLeay, Bullimore and Norville (Manufacturers); Messrs McClay, Higgens and Sheedy (Servicemen) and Messrs Bale, Stender and Crook (Radio Retailers). Ossie Mingay was Secretary.

LOUDSPEAKERS

Reception of wireless telegraphy signals was initially in the form of a printed record, but about 1903 the telephone receiver was adapted because of its greater sensitivity. It remained unchallenged until the appearance of broadcasting.

It had a number of deficiencies for broadcasting work. The high resistance types in use depended on their sensitivity for a degree of mechanical and electrical resonance in the neighbourhood of 800 to 1000 Hz. They were obviously unsatisfactory for reception of the wide bandwidth frequencies of speech and music. Also, the concept of broadcasting was totally different from that of point-to-point wireless telegraphy communications. The broadcast program was intended to be listened to by everyone in close proximity to the receiver and not just one person.

One of the earliest loudspeakers was developed from the telephone receiver by placing a small conical horn in front of the diaphragm. It not only acted as a megaphone by concentrating the energy from the diaphragm, but the weight of the air column acted to dampen the sharp resonance peak of the diaphragm. Although simple conical horn loudspeakers could be purchased from Radio Shops, many people built their own, usually from the material of a jam tin. They were popularly known as 'jam tin speakers' and many can be seen today in vintage radio collections.

The next development was an improvement to the horn which gave more uniform frequency response. It was found that the logarithmic type of horn was ideal, provided it was sufficiently long. However, a very long horn of some five metres in length was obviously not practicable for a home receiver so a compromise had to be adopted. Because of the greatly reduced size of the horn, the average loudspeaker had a frequency response which cut off at about 100 Hz at the low frequency end of the spectrum and at 4000 Hz at the high end. Response between these points was variable, usually with a high resonant point around 500 Hz and another of less intensity about 2500 Hz. The horn was apt to be clumsy, and twisting it for compactness introduced other troubles.

The most widely employed drive mechanism was known as 'balanced armature' method.

Notwithstanding the best efforts of designers to improve the reproduction quality of loudspeakers, not a great deal was achieved during the early 1920s. Even loudspeakers manufacturers produced 'add on' components which were reported to improve the loudspeaker performance.

In 1926, William Blogg, the Australian Representative in Sydney of the English company Alfred Graham and Co., manufacturers of the Amplion brand, supplied a device to Australian Radio Shops called The Siftron. It was fitted between the receiver and the loudspeaker unit and a brochure supplied with the unit described it as follows:

'The Siftron acts as the connecting link between the receiver and the loudspeaker. For sifting or filtering the output in such a manner as to modulate the current flowing from the receiving set to the loudspeaker — for cutting down distortional effects and safeguarding the loudspeaker against breakdown — and for "Better Radio Reproduction", this attachment is invaluable.'

At the time, the device cost more than a Amplion Swan Neck Model AR38 loudspeaker unit.

No technical details of the design or guaranteed performance characteristics are available, but Bert Lampe, President of the Blackwood Radio Club in Adelaide in mid 1926, while giving a talk to Club members on loudspeakers, said he had purchased a Siftron from Newton, McLaren Ltd and commented, 'I wasted my hard-earned money'.

The design of the diaphragm received a lot of attention in the early 1920s. Although all designers came to the conclusion that it had to be round, a lot of development work took place with different materials, and the form of the diaphragm. Materials employed included flat iron discs, various non ferrous discs with an iron centre, mica, aluminium and brass. Those comprising non-ferrous materials were driven by a rod or lever attached to the armature of an electromagnet, a technique later employed with cone loudspeakers.

Mathematicians were consulted by designers to produce a shape which would cause the natural resonant frequency of the material to fall outside the voice band to be reproduced. Nearly all designs which employed corrugation techniques can be categorised as follows:

- Small concentric circles evenly spaced.
- Large concentric circles evenly spaced.
- Concentric circles spaced in sections.
- A conical diaphragm with circular corrugations close-spaced near the edge.
- A conical diaphragm with wide-spaced corrugations near the edge.
- Small logarithmic spiral corrugations.
- Large logarithmic spiral corrugations.
- Symmetrical indentations.
- A conical diaphragm with six to eight radial corrugations.

The corrugated diaphragm was not new. It had been used for many years with headphones before designers began to use similar designs with loudspeakers. However, very few were an improvement on performance characteristics of a simple flat iron diaphragm.

One of the few Australian manufactured aluminium corrugated diaphragms was developed by the Transatlantic Wireless Manufacturing Co., in Adelaide. It was designed in 1925 by Roy Buckerfield in charge of production of the firm's Newkradyne receivers. It was included in a range of about ten overseas manufactured loudspeakers from which customers could make a selection.

The diaphragm was a conical type with six radial corrugations. The loudspeaker used a straight copper horn mounted on a universal joint to allow the horn to be raised, lowered or pointed in any desired direction. It is not known how many loudspeakers to this design were manufactured, but about 1931, one of the units was brought to the Radio Workshops of Newton, McLaren Ltd in Adelaide for repair. Subsequent tests by staff showed that it had no unacceptable resonant peaks in the range 400 Hz to 4000 Hz. Above 5000 Hz, response fell off sharply.

Included in the overseas loudspeaker set-up in the Transatlantic Wireless Manufacturing Co., showroom was a set of six horn loudspeakers manufactured by S G Brown, London. They comprised types H1, H2, H3, H4, Q and HQ. All had 2000 ohm drive units.

A wide range of materials was used in the manufacture of horn loudspeakers. Materials included aluminium, copper, brass, steel, ebonite, papier mache, plaster of Paris, diecast alloy and wood in the form of plywood petals. Shapes varied from a horn with a straight axis to various forms of folding and shapes. The symbol of early radio was the graceful swan neck construction. Unusual shapes included shells, Dresden figures, rose bowls, bugles and a crude form of the human ear such as used in Operadio models.

One of the unusual designs which created a lot of interest in South Australia in 1924 was a loudspeaker made from a sea shell by Arthur Cotton, President of the Port Adelaide and Suburban Radio Club. Arthur was one of the early experimenters with experience going back to the spark wireless period before the First World War. The shell which was over 180 mm in diameter at the aperture was of the Turbo Marmoratus family found in the Indian Ocean. The drive unit was the earpiece of a candlestick telephone fixed to the apex of the shell.

At the Radio and Electrical Exhibition organised by the Adelaide Railways Radio Club in December 1925, one of the employees of Duncan and Fraser, manufacturers of Dunfra brand receivers, was a qualified tinsmith and built a loudspeaker from sheet copper in the shape of a trumpet with an earpiece from a Sterling headset being used as the driver unit. The loudspeaker was basically a folded horn but had all the trapping of a trumpet musical instrument including the keys. It was connected to the company six valve De-luxe receiver and produced a very loud sound which could be heard at the other end of the display hall.

On the occasion of the opening of the first Federal House of Parliament in Canberra on 9 May 1927, a large public address system was installed by Standard Telephones and Cables (Australasia) Ltd to enable the huge crowd, estimated at more than 6000 people, to hear details of the proceedings. The loudspeakers employed were about three metres in length. The driver was a Western Electric electromagnetic moving coil type with a small metal cone about 3 cm diameter. Many of these types were used for large public address systems during the period.

A more modest application of this WE loudspeaker took place at a party on the beach at Sandgate near Brisbane on 1 May 1928. Some members of the Brisbane Apollo Club gave a choral performance in the Brisbane School of Arts with the performance being broadcast over 4QG. Members not involved in the performance, their families and friends held a 'Twilight Dinner Party' under a large Moreton Bay fig tree, with the broadcast which commenced at 8 pm being received on a seven valve receiver constructed by one of the members of the Apollo Club. He was also a member of the Auchenflower and District Radio Club. A two valve AF amplifier was placed between the receiver output and the loudspeaker to provide sufficient drive power. The musical items broadcast were appropriate for the occasion and included 'Freely Blow' (T Cooke); 'Eventide' (F Shepherd) and 'Twilight' (D Buck).

One of the most unusual Australian made and manufactured horn loudspeakers was the Expona made in Adelaide and fitted to

Expona receivers produced by the Insulating Tile Company, Bowden.

The company had been involved in the manufacture of gramophones and horn units in 1929, and when it built a two valve battery receiver in a tall Grandfather type cabinet, it used a once folded 2.2 m horn.

The A and B batteries were located in the bottom of the cabinet. The designer claimed that due to the high acoustic efficiency of the horn, the receiver gave adequate output in a normal room with B battery voltage of 45 volts. When the receiver was used at 'woolshed' dances, the HT was increased to 60 volts and produced more than enough signal to overcome the crowd noise. Receivers produced as late as 1930 were still being fitted with this horn loudspeaker.

Many designers abandoned the horn for a large diaphragm type loudspeaker in which sound was communicated to the air by a large diaphragm operated by some form of electrical movement. Although a number of pleated cones were in use, the majority were smooth conical shapes. The driving system consisted typically of electromagnets which attracted iron armatures or reeds or even diaphragms. Response varied with designs, but ranged from about 60 to 7000 Hz with peaks of various levels between about 800 and 2000 Hz.

One of the earliest cone loudspeakers developed in Australia was made by George Ramsay who manufactured Romley brand receivers in his Adelaide factory. The loudspeaker made in 1924, used eight horseshoe type magnets as used in motor cycle ignition systems at the time. The cone, frame and magnet systems were fixed to a cast iron base. The unit was donated to the Adelaide Telecommunications Museum collection by George.

Material used for cone types included cardboard, fabric doped with paint or stiffener, metal foil, corrugated paper or paper reinforced with fine copper wire either as spokes or spiral form as in Celestion units. The Atwater Kent Type E2 made in 1927, had a cone of thin wood veneer.

Although some cone type loudspeakers were freestanding and unprotected, like the Sterling Primax with a gold painted Lumiere paper cone, the Western Electric Kone with gold painted paper cone, the Geocophone BC 1650 with grain embossed paper, Philips four pole balanced armature with red painted long fibre cardboard cone and others, most were mounted in cabinets of various forms and shapes. Elaborate fretwork was a feature of many models.

The Western Electric hornless loudspeaker was a very popular unit in the early days of broadcasting. It was employed not only with domestic radio receivers but also used as monitoring loudspeakers at broadcast transmitting stations. It was granted USA patent 74114 filed on 5 August 1924 on behalf of George Lunn of the Bell Telephone Laboratories. Production began in October 1925 and within a year, 1000 units were being manufactured per day to meet local and overseas demand. It was marketed as the Western Electric Kone loudspeaker and featured a balanced armature double cone on a cast metal base and gold painted paper cone. In the USA, it was known as Model 540AW and in the UK as No 44007. Diameter was approximately 18 inches (450 mm) and overall height 21 inches (525 mm). The coil had a resistance of 750 ohms and average impedance over the range 800 to 1600 Hz of 5000 ohms.

At the Second Radio Trade Exhibition held in Adelaide in April 1927, Unbehaun and Johnston who were the local Western Electric agents and distributors, exhibited one of the WE Kone loudspeakers together with No 44004 two stage amplifier designed by the London WE company for use with the Kone loudspeaker. Input to the amplifier was provided by a locally constructed U and J five valve receiver. A card with the loudspeaker describing the main features included the paragraph:

> 'The double cone loudspeaker provides non directional, stereoscopic effects with sound giving the impression that it emanates from multiple sources.'

Two versions of the hornless Sterling Primax loudspeaker made in the UK in 1924 by Sterling Telephone and Electric Co., Ltd were also featured at the Exhibition on a stand mounted by Newton, McLaren Ltd. The design was licensed by The Gramophone Co., Ltd and featured a magnetic reed moving iron design with gold painted Lumiere thick paper diaphragm which produced sound over a wide angle. One model was mounted on a bronze finished aluminium frame and stand, while the other was a statuette design 42 inches (1050 mm) high with a coil resistance of 2000 ohms.

A major breakthrough came with the development in 1925 of the moving coil loudspeaker by Rice and Kellogg in the USA. It employed a coil in a magnetic field instead of a moving iron mechanism. The relationship between sound output in one direction and input current to the coil could be made to approximate closely to the ideal of equal sound pressure output for equal current input.

Although some early moving coil models produced mechanical resonances at low frequencies and 'breaking-up' of the cone at high frequencies, particularly around 3500 to 4500 Hz, it was very successful when used with or without a baffle in home receivers.

The acceptance of the moving coil design was held back because receivers at the time did not produce sufficient output power to drive the unit for full output. The development of the UX210 valve which gave an output of one watt with an anode voltage exceeding 400 volts went a long way to producing receivers using moving coil loudspeakers but it was not until the mass production of mains powered receivers in the 1930s that the moving coil loudspeaker had widespread acceptance. Not only did the mains powered receivers produce adequate audio output power but the high magnetic field problem was overcome by electromagnetic systems.

Well-known brands of early moving coil loudspeakers manufactured in Australia include Amplion, AWA, Jubilee, Kingsley, Kriesler, Lekmek, Magnavox, Monitor, Precedent, Rola, Saxon, STC, Stromberg-Carlson and others.

Other designs including capacitor and piezo-electric reproducers appeared in the 1930s but the moving coil design held its ground, and today, the loudspeaker has been improved to such a level that loudspeaker performance is no longer viewed with the same suspicion that it was in the 1920s.

A major problem which affected the performance of early loudspeakers was DC current passing through the coil winding. Some designers fitted a 2 or 4 MFD capacitor in series with the speaker unit and passed the anode current through a choke in order to prevent flux saturation of the speaker iron core unit. Passing the DC current through the coil could also lead to demagnetisation of the permanent magnet if passed in the wrong direction. This is the reason why many horn loudspeakers, and even some headphones, had the terminals marked with polarity symbols.

The number of brands of early loudspeakers used in home receivers would be very large, but popular brands, many of which can still be seen today in vintage radio collections include:

> Acme, AJS, All-American, Amplion, Atlas, Atwater Kent, Audiophone, AWA, Bakers, Baldwin, Beco, Blue Spot, Bosch, Brandes, Bremer Tulley, Brown, Brunswick, BSA, BTH, Bullphone, Burndept, CAV, Celestion, Claritone, Crosley, Dulcivox, Eclipse, Edison Bell, Ediswan, Efesca, Emmco, Empire Cone, Ericsson, Ethovox, Farrard, Federal, Fellows, Ferranti, Fuller, Gecophone, Goldtone, Hartley-Turner, Hawley, Helios, Hegra, Hetri Cone, Jensen, Jubilee, Kellogg, Kolster, Lissen, Loewe, Magnavox, Majestic, Manhattan, Marconiphone, Mellovox, Monitor, Mullard, Music Master, Operadio, Oriel, Ormond, Oxford, Pausin, Peerless, Philips, Puravox, Racon, Radioglobe, Radiola, Radiovox, RCA, Reflectone, Reichmann, Role, Scientific, Sears, Sferovox, Siemens, Sparta, Spitfore, Sterling, Stewart-Warner, Stromberg-Carlson, Symphony, Tangent, Telefunken, Teletone, Thompson, Thorolla, TMC, Ultra, Utah, Western Electric, Wright de Coster, Zampa and others.

The HRSA Loudspeaker Notebook 3rd Edition 1993, compiled by Ray Kelly for the Historical Radio Society of Australia contains many other brands as well as technical details of loudspeakers.

The demand for loudspeakers was enormous and manufacturers throughout the world were hard-pressed to satisfy the demand. Alfred Graham and Co., of London who manufactured Amplion brand loudspeakers expanded its factory in 1924 to produce 10000 Amplions per week.

Even though there were many factories in the USA producing loudspeakers, Alfred Graham received an order from a distributor in the USA in 1923 for 12000 Amplions. In the same year 5000 were sent to a distributor in Canada. It is not known what quantities of Amplion units came to Australia in the early days of broadcasting here, but in 1926, AWA who were the Australian distributors had a stock of UK made Amplions which exceeded 300 units and included Concert Dragon Model AR 23, Dragonfly Baby Amplion AR 102, Portable Loudspeaker in box with tripod and cord, Standard Dragon Model AR 19, Swan Neck Table Model AR 88, New Junior AR 111, New Junior De Luxe Model AR 114, AR 58, AR 38, Radiolux Models in Oak and Mahogany, as well as Gramophone Adaptors for the Standard and Concert Models.

Alfred Graham and Co., undertook an extensive program of development and new models became available every year. In early 1928, the most popular Amplion cone loudspeakers being sold in Australian Radio Shops included No AC1, Junior Open Type; No AC2, Junior Hanging Type; No AC3, Open Type Senior Model; No AC4, Junior Cabinet, Oak; No AC5, Dark Oak, Senior Model; No AC7, Jacobean Oak, Senior Model and No AC9, Chippendale Mahogany, Senior Model. The cones of these units were made of strong seamless fabric material treated to be unaffected by changes in atmospheric humidity.

In Australia, AWA later undertook the local manufacture of Amplion designed loudspeakers and when the company set up its Manufacturers' Special Products (MSP) group, the units were marketed under the MSP label.

Magnavox (Australia) Ltd was typical of manufacturers in Australia who had direct access to overseas developments in loudspeaker technology. The company was established about 1922 for the distribution of Magnavox loudspeakers manufactured by the Magnavox Company in USA.

Mr W M B Veitch was the Australian representative and Technical Expert when the company began operation at 220 Pitt Street, Sydney. He joined the New Zealand Post Office in 1910 and spent four years in the Wireless Service before being promoted to the Professional Division of the Engineering Branch and becoming Radio Inspector responsible for examining candidates for the Commercial Wireless Certificate. He joined the Magnavox Company about 1922 and came to Sydney as their Technical Expert.

The Australian company later became involved in the local manufacture of loudspeaker units about 1930 at Camperdown, Sydney. John Westerlund an Engineer with the Californian branch of the Magnavox USA company came to Australia to superintend the setting up of the manufacturing facilities.

The USA Magnavox Company was formed in 1917. The founders, Edwin Pridham and Peter Jensen had in1915 modified a phonograph loudspeaker to amplify the voice of a baseball official and named it Magna Vox (Latin for great voice). However, it was not until 1920 that production began on a model designed for radio receivers.

Demand for the loudspeaker exceeded expectations, and the company decided to expand into the manufacture of receivers and valves. However, this part of the business was not a success so they abandoned the venture to concentrate on the manufacture and development of loudspeakers.

Pridham and Jensen made considerable contributions to the development of the dynamic (moving coil in a magnetic field) loudspeaker and filed a patent on 28 April 1920 on their work but it was two other Radio Engineers, Chester Rice and Edward Kellogg of the General Electric Company who produced the first practical system which was marketed by RCA in 1925.

Some of the earliest English made Magnavox loudspeakers displayed in Australia were seen at the 1925 Sydney Easter Shown when Lawrence and Hanson incorporated 14 inch and 18 inch horn loudspeakers as part of their radio equipment display. The Magnavox loudspeakers had been made by the Sterling Radio Company in England under licence from the USA Magnavox Company. In 1927, Pat Manley, a former AWA employee established Amplion (A/Asia) Ltd occupying the positions of General Manager and Director.

In 1930, he formed Speakers (A/Asia) Ltd to manufacture Amplion loudspeakers in Australia. On 19 September of the same year he registered Amplion (Aust.) Ltd.

From 1934, Amplion (Aust.) Ltd became the controlling body with Pat Manley as Managing Director.

Pat Manley began his career in telecommunications with the Telephone and Telegraph Divisions of the Victorian Railways. He served in the Army Signal Engineers as an Officer for two years before the First World War at the time when the Army had a number of Marconi pack-saddle type wireless telegraph systems using rotary spark transmitters and carborundum detectors in the receivers. At the outbreak of the War, he joined the AIF Signals and served until 1919 when following discharge, took up a position as a Ship's Wireless Operator. In 1923, he joined the AWA Sales Department marketing a range of AWA receivers to meet the demand with the establishment of broadcasting in Australia. In 1927, he left AWA to form Amplion (A/Asia) Ltd.

One of the popular Australian made Amplion loudspeakers was the Model M known as the 'Minnie' loudspeaker. It was a dynamic type introduced in 1933 and had an overall diameter of 5 inches (125 mm). Special care was taken during manufacture to ensure the absence of rattle, a problem experienced with many imported loudspeakers at the time. The cone was treated so that it was unaffected by changes in temperature and humidity. It was available in 3 and 5 watt models.

Amplion loudspeakers fitted to receivers during 1934 included Q, P, M, L, O1 and O3 types.

In 1928, the Radio Department of The Myer Emporium Ltd, Melbourne were wholesale distributors of Magnavox in Melbourne, and supplied many of the local Radio Shops and receiver manufacturers. Included in the store stock at the time were Unit No 700, a 200 volt AC unit combining a rectifier, loudspeaker and a power amplifier; Unit No 80, a 230 volt AC unit with metal rectifier; Unit No 6, a six volt DC unit and Unit No 7, a 200 volt DC unit. All loudspeakers were dynamic types.

Because early magnets were not capable of providing the necessary flux levels for loudspeaker operation, designers put a lot of effort into the development of electromagnet systems energised by the receiver power supply unit or a separate copper oxide rectifier unit. A bonus from this work was that the field winding had sufficient inductance to enable it to form part of the power supply filter so doing away with a separate inductor. In order to overcome a hum problem reproduced by the loudspeaker from the DC ripple component, a number of methods were examined with a hum bucking coil arrangement proving the most successful.

This arrangement of energising the loudspeaker field winding was unacceptable for battery-operated sets, particularly portables, but fortunately about 1932 improved magnets became available employing a chromium alloy. These units became known as Permag (PM) loudspeakers.

Many different materials were used for cones over the years and included paper, varnished cloth, shim metal, spun aluminium and wood veneer. One wood veneer loudspeaker made by Atwater Kent in 1927 was made operational in a demonstration at the Adelaide Telecommunications Museum during a visit by a group of 'audio buffs' in 1980.

The range of loudspeakers produced by Philips in their factory at Eindhoven in Holland during the late 1920s and early 1930s including the PCJJ, PCJJ Junior, Baby Grand, Concert Grand and Sevenette models, were manufactured using a plastic known as Philite the brand name of a type of bakelite invented by the Belgian Chemist, Baekeland at the beginning of the century. Philite raw materials were phenol and cresol, both derivatives of coal. The

Manager of the Philips factory at the time, was a Chemist, and equipment was developed and installed to produce material not only for loudspeakers but for components and as sheet for receiver panels. It was easily machined and gears were made for tuning mechanisms and other parts requiring machined insulation. It had good insulating properties and was also used in high voltage X-Ray equipment manufactured by the company.

The raw materials were put into a mould in powder form or sometimes pre-pressed into pastilles. A corresponding counter-mould was pressed against the mould the material melted by heat while under pressure. The material was then baked in order to harden it. When made into sheet form or in moulded form where the material was on display, interesting and colourful patterns were produced.

The company also produced Arbolite, a Philips trade name for a thin plastic laminated board employed as a cabinet material with some of their receivers, such as the All-Electric Type 2511 produced in 1929 and others. The Arbolite panels were fitted into a steel frame. It came in a variety of coloured patterned finishes from flecked oxblood to different wood grain imitations.

In a leaflet issued by Magnavox (Australia) Ltd in the early 1930s when it outlined specifications of its Symphonic Tone Series of Direct Current Magnavox Dynamic Speakers, it claimed that the new Models, 142 and 144 represented the culmination of 20 years in building loudspeakers. They also stated that they were proud of the fact that as pioneers of radio loudspeaker manufacture in Australia they were the first in the field with a dynamic loudspeaker designed for operation with the new pentode valves.

It is of interest that Magnavox loudspeakers sold at the time, carried a tag advising the purchaser that 'by installing a Magnavox Dynamic Speaker in your apparatus, your radio is insured against Fire and Burglary with Lloyds, London without cost to the owner subject to conditions on the certificate attached to each genuine Magnavox Speaker'.

In addition to Models 142 and 144, other early Australian Magnavox loudspeakers included L, M and D series; and models 404, 512, 33, 66, A130, A132, 152, 154, A165, A166, 180, 182 and others.

Besides Magnavox, another company of American origin which was a major loudspeaker manufacturer in Australia was the Rola Co., (Aust.) Pty Ltd of Melbourne. It set up business in the early 1930s. For many years it was probably the largest manufacturer of loudspeaker units in Australia, carrying out design and development work producing units for radio sets, public address systems, theatre installations, car radios, studio monitoring equipment and recording studios. It also had a large range of radio cabinets of various designs which it employed in its developmental project works.

In 1938, the company built what was considered at the time to be the most modern and efficient loudspeaker factory in the Southern Hemisphere. It was located at The Boulevard, Richmond, Melbourne. New equipment incorporating the latest in technology enabled complex design work to be undertaken.

Features of Rola loudspeakers during the period included:

- Newly developed diaphragms moulded by a special process and moisture proofed, making for high sensitivity coupled with improved frequency and transient response characteristics.
- Rola Isocore transformers were hermetically sealed in a drawn sheet steel case obviating the danger of breakdown due to electrolysis.
- Patented dustproofing system to exclude dust from the moving coil and the gap.
- With the introduction of 1.4 volt valves for portable receivers, Rola produced a range of loudspeakers suitable for receivers employing these new valves. The new models became known as 8/42, 10/42 and 12/42, having overall dimensions of eight inch, ten inch and twelve inch respectively. They embodied the latest in permanent magnet material and included 42 ounce alnico magnets providing a very high flux density in the air gap which housed the voice coil. It was claimed that the new 42 ounce magnets gave a flux density of an equivalent of nearly 30 watts excitation in an electrodynamic field. High magnetic damping counteracted 'peaky' reproduction.

The company had a major branch office in Sydney with Mr G R S Allen being Service Engineer just prior to the Second World War.

George Brown and Co., Pty Ltd, Electrical and Industrial Engineers, 267 Clarence Street, Sydney were New South Wales Agents and Factory Service Representatives for Rola. The company had a well-equipped Service Depot with supervision being provided by Rola Engineers.

By 1939, the Rola range included many electromagnet and permanent magnet types. The electromagnet types included DP5B, F4, F10, K8, K10, K12 and G12 with output capabilities ranging from 5 watts to 15 watts while the permanent magnet types included 5-6 PM, 6-6 PM, 8-8 PM, 8-20 PM, 8-21 PM and 10-21 PM with outputs ranging from 4 watts to 7 watts.

The DP5B was a 6¼ inch unit incorporating a newly patented dustproof and acoustic filter assembly. It was widely used in mantle sets and car radios. The F4 was the smallest in the range at the time and was designed for midget receivers. It was also available with permanent magnet with the model 5-6 PM. The G12 was a 12 inch high fidelity model capable of handling high power over the range 50–7500 Hz. The permanent magnet types employed ALNI steel and all types were fitted with sealed Isocore transformers.

By the mid 1950s when there was a high demand for high fidelity loudspeakers, the Hi-Fi Rola 12-Ux was one of the popular units produced by Rola. Main features included:

- Frequency response 40–14000 Hz ± 6 dB, with useable responses to 30 Hz in a Rola recommended vented enclosure.
- Power handling capacity, 20 watts.
- Voice coil impedance, 15 ohms at 400 Hz.
- Intermodulation distortion, less than 2% at 20 watts output (F1/F2; 45/7000 Hz; Ratio 1:1).
- A 50 mm voice coil driving a 300 mm diameter cone and supplementary 115 mm diameter cone.

Most electrodynamic loudspeakers required a transformer for matching of receiver output circuit to the loudspeaker unit. The transformer was often referred to as an 'output' transformer when referring to the receiver, and as an 'input' transformer when referred to the loudspeaker unit. The transformer was designed to match the anode impedance of the power valve to the lower impedance of the moving coil. When push-pull output stage was employed, the output anode impedance was equal to twice that of one of the matching pair of valves.

Typical circuit designs of push-pull circuits over a number of years show popular triode and pentode valves in use to include types 1F4, 1J6, 2A3, 6F6, 6L6, 6V6, 45, AL3, CL4, EL3, KL4 and others. Operating conditions included valves configured as AB1, Class B triode, Class A1 self bias, Class AB1 self bias, Class AB1 fixed bias, Class A1 pentode self bias, Class AB pentode fixed bias, Class A1 pentode fixed bias, Class AB1 pentode, Class A pentode, Class B pentode and others.

Popular single ended designs included valve types 1A5, 1C5, 1D4, 1D8, 1L5, 1Q5, 1S4, 2A3, 2A5, 3S4, 6F6, 6L6, 6V6, 42, 47, AL3, CL4, EL2, EL3 and others.

The Rola company manufactured a range of transformers designed to match the different models of loudspeakers to various types of valves operated under a specified set of conditions.

Post War loudspeaker transformers included:

- Type B, designed to operate with the 12R loudspeaker with a voice coil impedance of 8.4 ohms. It was an unsealed unit and previously designated Type G12.
- Type C, designed to operate with loudspeakers with a voice coil impedance of 2 ohms. The core and windings were sealed in a metal can. It featured an Isocore transformer design which minimised faults due to electrolysis, a major problem with early transformer designs.
- Type D, based on the Type C design but smaller in size and normally employed with 6H and 8H loudspeakers.

- Type E, previously designated K5 and designed for use with Model 5C loudspeaker with AC operated receivers. The unit was unsealed.
- Type F, a smaller version of the Type E transformer designed to match loudspeakers with voice coil impedance of 3.7 ohms and recommended for use with Model 3C loudspeakers.
- Type G, a small Isocore type designed to match loudspeakers with voice coil impedance of 3.7 ohms.

During the War years, the Rola company produced a large number of loudspeakers, dynamic microphones and receiver inserts for the Services. The development of the dynamic microphone required much original research work new to Australia, particularly in the development of magnetic materials. Magnet winding wire was another major contribution. Up to the outbreak of the War, this material had been imported from overseas sources.

By the mid 1960s, the company had become part of the Plessey Group and was trading as Rola Special Products Pty Ltd. Popular loudspeakers manufactured at the time included the Rola C9–6L, C7–5L and Stereo C8MX.

The C9–6L and C7–5L were the latest version of the most widely used Rola range of loudspeakers for car radio purposes. They incorporated newly developed Ferrite magnets which besides greatly increasing the acoustic efficiency of the loudspeaker also allowed savings in space required for their fitting, an important feature in car radio installation.

The Rola designed 'Slimline' enclosure was developed specially for use with the C8MX and for application in the home where living space was usually at a premium. The dimensions were 26 inch (650 mm) high, 18 inch (450 mm) wide and 6⅜ inch (160 mm) deep.

The C8MX was designed specifically for stereo. Its frequency response was 40–12000 Hz ±6 dB, with peak power handling capacity of 16 watts.

The company ceased the manufacture of Rola loudspeakers during the 1970s.

By the 1950s, other loudspeaker manufacturers were in the business mainly to manufacture units for their receivers. They included EMI (Aust.) Ltd and Kingsley Radio Pty Ltd. AWA was also manufacturing units designated MSP, but had been in the business of manufacturing loudspeakers from the early 1930s.

With the introduction of Hi-Fi home entertainment equipment, some Australian businesses set up facilities for the design and manufacture of high quality units to meet the demand, and many were still active in the late 1990s notwithstanding the competition from imported units. One of these manufacturers was Lorpen Audio, Adelaide with the Lorpen Audio HP4 loudspeaker system designed by Garth Pennington. Each HP4 enclosure weighed about 54 kg and had dimensions 1130 mm high, 430 mm wide and 520 mm deep.

Another well-known Australian designed range was Hayes loudspeakers. The range included the Hayes Pascuan f80 designed to provide omnidirectional frequency response. The model featured a frequency response of 70 Hz to 20 kHz and hemispherical directional response from 70 Hz to above 10 kHz.

Hayes loudspeakers employed what is called Fractal Spatial System technology. It is a passive system designed to provide true spatial imaging without electronic circuitry. This is accomplished by employment of a geometric reflector positioned near the tweeter unit. The effect is the radiation of sound waves which appear to the listener as an omnidirectional sound source.

Other Australian systems available in recent times include, Aaron, Accusound, Ambience, Audiosound, Axis, De Magis, Duntech, Krix, Lenard, Orpheus, Ramp, Richter, Sonique, Subsonic, VAF and others.

Some of these brands are available in a large range of models. For example, in 1997, VAF Research Pty Ltd, a South Australian based business headed by Philip Vafiadis, Managing Director and Chief Engineer had 13 models in production. Included were four Signature Series models incorporating state-of-the-art in moving coil technology with Model 1–93 being top of the range. It featured:

- A heavily braced 40 mm by 25 mm MDF cabinet with extra front baffle trim to reduce diffraction effects.
- Two by 215 mm hard paper cone woofer with solid copper phase plug and edge wound high temperature voice coil.
- Two magnesium cone midranges with solid copper phase plugs and edge wound high temperature voice coils.
- Time aligned 25 mm all Sonotex double chamber tweeter with pure silver voice coil wire.
- Frequency range 17 Hz to 21 kHz with response level ±1.2 dB in the range 21 Hz to 19 kHz.
- Sensitivity 89 dB/W/M.
- Nominal impedance 3 ohms.
- Designed for employment with amplifiers 10 W to 500 W.
- Size 1515 mm high, 270 mm wide and 491 mm deep.
- Finishes available as piano gloss Santos Palisander, piano gloss European Beech and satin European Beech.

Philip Vafiadis registered the company when he was only 17 years of age and released his first panel loudspeaker in 1986. Keith Arnold who assisted with the design and development was in charge of company Research and Development in 1998.

Broadcast studios and recording studios invariably employ loudspeakers designed and manufactured specifically for control room conditions. They are critically manufactured and tested systems. In the mid 1980s, a large range was available with systems being designed and manufactured in USA, England, Japan and Australia. Brands included AGK, ATC, Audiocon, Auratone, Audiosound, B & W, Celestion, Court Acoustics, Electrovoice, Fostex, IMF, JBL, JPW, Klein and Hummel, Koss, Martin, Meyer, Proac, Quad, Quasar, Revox, Rogers, Sierra Audio, Solton, Sontron, Tannoy, Teac/Tascam, WHD, Yamaha and others.

The Australian system, Sontron, was custom built to suit the specific control room acoustic characteristics and was provided complete with power amplifiers and crossover networks using wooden dispersion horn, dual or single 30 cm bass driver, and time compensated crossover network.

A considerable amount of development work has been undertaken in recent years in producing miniature high fidelity loudspeaker systems for radio receivers.

In 1995, Bose Australia released The Wave Radio, a compact AM/FM stereo clock radio incorporating an acoustic waveguide system developed by Dr Amar Bose who had been working on the technology since the 1960s. Improved sound quality is generated by a 68 cm twisting tube or waveguide which is folded inside the enclosure of the system. The device was subsequently patented.

The wave Radio, first released in USA in 1993, is built around two five centimetre diameter loudspeakers. The left-hand loudspeaker feeds the waveguide which enables the system to generate bass frequencies down to 70 Hz and frequencies above 200 Hz which cannot be heard on any other system of this size.

Dimensions of The Wave Radio are 11 cm high, 35 cm wide and 16 cm deep and weighs about three kilograms. It is housed in a low profile plastic cabinet and is supplied with a miniature remote control facility.

Another system released by Bose in 1995 was the Lifestyle 20 Music System. It features:

- Two very small Direct/Reflecting Jewel Cube loudspeakers made with neodymium iron boron magnets. The loudspeakers are 4.5 inch by 2.25 inch by 3.25 inch (112 mm by 56 mm by 81 mm) in size.
- CD changer with six CD magazines with skip, seek and random play.
- Stereo AM/FM radio with 30 presets, skip and seek.
- Remote control facility.
- 200 watt total power from three built-in amplifiers providing 50 watts per cube loudspeaker and 100 watts for bass module.
- Driver complement: two magnetically shielded proprietary 2 inch (50 mm) Bose wide range drivers in each cube loudspeaker array, two 5¼ inch (131 mm) woofers in bass module.

- Each loudspeaker array consists of two attached Jewel Cube loudspeakers which can be rotated as much as 180 degrees to achieve the desired balance of reflected and direct sound.

In 1996, the company released the 301 Series IV and 201 Series IV loudspeaker systems. The 301 was first launched in 1975 and the 'bookshelf' loudspeaker is now in its fourth generation employing advanced technologies and with a sleek new design. The smaller 201 model was launched in 1982 employing the Bose Direct/Reflecting technology. Direct/Reflecting loudspeaker units recreate the natural balance of reflected and direct sound heard during a live performance producing a sense of realism not available with conventional designs.

The 201 is intended for use with amplifiers producing 10 to 120 watts per channel and the 301 for amplifiers with 10 to 150 watts per channel making both systems compatible with most home stereo systems. The units are available in black or rosewood finish.

Manufacturers of loudspeakers designed specifically to meet the demanding requirements of today's car radio/music system buffs have introduced many new words to describe the products. They include: 'Big Bass Subwoofer'; 'Bass Kicker Boombox'; 'Tube Subwoofer'; 'Power Pumper'; 'Power Subwoofer' and many others. One advertiser described a product imported from USA as 'A 12 inch 250 watt subwoofer cone for pumping out unbelievable bass sound'. Another described a product as 'A 10 inch speaker pumping 200 watts at full volume is built so tough that it will churn out bass that will really make you move'.

The history of the love affair with the loudspeaker has been like fashion. It came, it went, and it came back.

To start with, the loudspeaker was a separate unit from the receiver or record player and designers struggled to improve the aesthetic appearance to overcome the problem of 'that hideous open-mouthed monster sitting on top of the cabinet'.

By the early 1930s, loudspeakers were hidden out of sight by being built inside the cabinet. This was achievable even with the smallest table model.

However, modern technology with its FM Stereo hi-fi systems has caused the loudspeaker system to take a backward somersault. It is back to its original place as a separate unit from the receiver or CD player — and not just one speaker unit, but two or more units and multispeakers at that.

Now the loudspeakers stand in boxes in the corners of the room, often left completely naked with all the innards of the tweeters and woofers exposed for all the world to see, although in more recent times, miniaturised versions have been developed.

Radio Parts and Accessories

In order to supply the great demand for components and even fully assembled receivers, especially immediately after the first broadcast stations began transmission during 1923–25 in capital cities, large numbers of Radio Shops were established throughout Australia. In South Australia alone, there were some 180 in operation in 1926 with the majority being in the central business district of Adelaide.

Some Shops traded exclusively in components and receivers while others set up radio sections only as a sideline to normal business. Typical were, chemist shops, garages, electricians, hardware shops, department stores, hobby shops and a few isolated cases of butcher, grocer, hotel, tinsmith, carpenter and in at least one instance, a doctor. One well-known Chemist/Licensed Radio Dealer was John Lunn, Sandgate near Brisbane.

Typical of large Radio Shop was Louis Coen Wireless Pty Ltd with headquarters in Melbourne. Company policy was 'Everything in Wireless'. The business incorporated a Radio Ade Department under the supervision of Radio Technical experts to provide a free service on any Radio Engineering technical matter, advice on component selection and application, and advice on the construction of special apparatus for new and advanced circuits.

The company had one of the largest range of parts and accessories in Melbourne. The following is representative of popular components and items held in stock in mid 1927:

* Aerial and Earth Equipment
  Stranded enamel aerial wire 7/20 and 3/20 gauge; Igranic lead-in tube and arrester; Pinnacle folding loop aerial; Bodline loop aerial; Pure Tone Talking Tape indoor aerial; Electron aerial wire; earth clips; Ducon Dubilier electric light adaptors; egg type porcelain aerial insulators; lead-in insulators 6 to 18 inches; spike insulators; Parkson lightning arresters; Advance arrester and switch; Eagle ground clamps; Mohawk lightning arrester; Emmco bakelite lightning arrester; pulleys, shackles and others.
* Accumulators – A Batteries
  Clyde 2, 4 and 6 volt, capacitors 25 to 105 Ahr; CAV 2 and 6 volt, 25 to 85 Ahr; Exide 2 volt, 20 to 60 Ahr; LBC ebonite case, 2 volt, 20 to 60 Ahr; Willard 6 volt, 75 to 100 Ahr; Oldham OVD (DTG) types; LBC celluloid, Pyrex glass and Dagenite cases, 2 and 6 volt, 20 to 85 Ahr; Amplion Carboncels type 229, 1.5 volt and type 222, 1.5 volt and others.
* Accumulators – B Batteries
  Buckingham 20, 60 and 100 volt units with tappings on 60 and 100 volt models; Exide, 20, 60 and 100 volt units; Philco glass cells 48 and 80 volt units; LBC 30 volt unit.
* Dry Cell — B Batteries
  Armax, 22.5, 45 and 60 volt; Ever-Ready, 45 and 60 volts; Columbia, 22.5, 45 and 60 volts; Burgess, 22.5 and 45 volts; Hercules, 60 volts; Hellensen, 60 volts.
* C Batteries
  Armax and Ever-Ready tapped to 9 volts.
* Battery Chargers and Eliminators
  GR Wavemeter and Charger; Balkite trickle charger; Emmco B battery eliminator; Balkite A battery charger; Tungar 2 and 5 ampere A and B battery chargers; Valley charger tapped for various voltages; Philips rectifier unit; Philips B battery eliminator; Apco Rectodyne B battery eliminator; CAV 2.5 and 6 volt charger; Clyde chemical rectifier for charging B batteries; Emmco B battery eliminator; Dongan B battery power unit; Clock eliminator; Clock Raytheon A battery charger.
* Advance Radio Products
  Lightning arrester; arrester and switch combined; straight line frequency tuning capacitors, 0.00025, 0.00035 and 0.005 MFD; Centralygn tuning capacitors; straight line frequency dual tuning capacitor 0.00035 MFD; straight line frequency triple gang capacitor 0.00035 MFD; midget capacitors; neutralising capacitors; vernier dials; shielded rheostats 6, 10, 20 and 30 ohms; shielded potentiometer 200 and 400 ohms; porcelain UX valve sockets; Junior and Senior neutrodyne kits; Junior and Senior Browning-Drake kits; Equamatic kits; Masterdyne kits; two and three coil mountings; plugs for coil mountings; Supreme AF transformers; valve peep screens.
* Capacitors — Variable
  Advance dual, triple and single SLF; Centralygn; General Radio; Amsco STL; Amsco triple SLF; Emmco Stratelyne; Ajax straight line separation; Igranic; USL SLF; Ormond SLF friction control, vernier; Igranic Pacent SLF; Advance neutralising and midgets; Harmo neutralising; Colvern neutralising and vernier; Astor neutralising; GR micro balancing; Renrade neutraliser; Igranic balancing and micro; Grodan neutralising capacitors.
* Capacitors — Fixed
  Therla; TCC; Dubilier; Electrad; Igranic Freshman; Sangamo; W and M; Tintobe; Tobe Deutschmann capacitor blocks.
* Crystals
  Super Neutron; Harmotone; zincite; bornite; molybdenite; galena; Hertzite; QSA; Mighty Atom; Uralium; Powerplus; Carborundum.
* Crystal Detectors
  Micrometer; Powerplus; HGB; Perikon; Grodan perikon; Harmo; Celerundum Detex-it.

* CAT'S WHISKERS
  Silver; gold; steel; copper; brass and double spring types.
* DIALS
  Premier; English; American; Bakelite; Kurz Hasch vernier; Igranic indigraph vernier; General Radio; Igranic Pacent micro vernier; Emmco De Luxe; Emmco De Luxe with illuminated dial and switch; Pilot vernier.
* PANELS
  Celeron (Bakelite) in a wide range of precut sizes and full sheets in black or mahogany veneer pattern.
* FORMERS
  Cardboard, ebonite and bakelite in diameters 2, 2½, 2¾, 2⅞, 3, 3½ and 4 inch, and lengths cut to requirements; Grodan spider web formers; Grodan anti loss formers.
* CELLULOID
  Lightweight white and black; tortoiseshell; Mother-of-pearl; transparent; pink and No 12 heavy white.
* GRID-LEAKS
  W & M; Therla; Dubilier; Igranic; Igranic variable; Watmel variable; Lissen; Lissen variable; Bradleyleak; Eagle; Tridot; Daven; Emmco; Amsco; Amsco Metaloid; Freshman combined with variable resistor and fixed capacitor.
* HEADPHONE EQUIPMENT
  Emmco; Brandes; Brown F type; Brown adjustable A2 type; Ediswan; Sterling; Kellogg; Scientific; Western Electric; Para; Baldwin; Front headphones.
  Cumfit earpads; earcaps; diaphragms; cords.
  Hale single circuit open 2 point; Hale single circuit 3 point; Hale double circuit closed 4 point; Hale double circuit filament control; Ashley non solder radio jacks DC; Emmco SCFC; Emmco DCFC; Emmco DC; Emmco SC jacks.
* KITS
  Pinnacle 7 valve superhet amplifying unit and coupler; Astor superheterodyne; Advance Junior neutrodyne; Advance Junior Browning-Drake; Advance Senior neutrodyne; Advance Senior Browning-Drake; Advance Equimatic; Advance Masterdyne; Amsco resistor coupler; Emmco superhet; GR superhet; All American Toroidal; Daven 3 stage amplifier; Grodan Binocular; Koh-i-nor Reinartz kits.
* LOUDSPEAKERS
  Amplion Radiolux RS1, RS2, RS3, RS4, RS5, RS6 in oak, mahogany, Queensland maple, rosewood, Tasmanian blackwood and metal case; Amplion cone cabinet; Amplion AR65 Dragon mottled horn, AR65 wooden horn, Dragonfly, AR19 large Dragonfly, AR88 swan neck metal horn, AR38 New Junior, AR114 Junior Deluxe oak, AR111 Junior, AR58 metal horn, AR35 gramophone adaptor, AU4 units; Brown cabinet HQ, H, H2, H3, H4, oxidised silver disc, black and gold disc models; Crystavox; Bullphone; Nightingale; Burns black celluloid, tortoiseshell; Ediswan Dulcivox; Ediswan black and gold Dulcivox; Kellogg large; Majestic GGH; Sterling Dinkie, Baby, Mellovox floral cone; Tower Meistersinger; Scientific; Brandes Table Talker; Sferox; Baldwin loudspeakers.
* METERS
  Sterling voltmeter 0–75; Sterling voltammeter; Wallsall panel voltmeter 0–150; Wallsall double reading voltmeters 0–8, 0–80 and 0–7, 0–140; Wallsall panel voltmeter 0–60; Wallsall milliammeter 0–50 panel or pocket type; AJS voltmeter 0–100; Weston double reading voltmeters 0–7 and 0–140; Weston milliammeter 0–25.
* POTENTIOMETERS
  Ajax 200 and 400 ohms; Advance 200 and 400 ohms; Bradleyometer; Igranic high resistance 30000 ohms; Igranic Pacent 400 ohms; Carborundum stabilising units.
* PLUGS
  Ajax double; Ajax automatic; Igranic Pacent headphone plug; Tapa plug and socket; Wander plug for B batteries.
* RESISTANCES — FIXED AND VARIABLE
  GR coupler; Watmel variable anode; Lissen variable anode; Dubilier 50k, 80k and 100k ohm anode; Amsco Metaloid fixed grid-leak, resistor coupler kits, fixed resistors of various values; Amperite wide range fixed types; Electrad Royalty variable types A, B, C, D, and E; Daven fixed of various values; Emmcostad variable 2500 to 500000 ohms.
* RHEOSTAT
  Ajax 6 and 30 ohm bakelite; Advance 6, 10, 20 and 30 ohm shielded; Ajax 6 and 30 ohm with raised arrow knob; Premier Clarostat; Lissenstat Minor carbon type; Bradleystat; Pinnacle 6, 20 and 30 ohms; Igranic 4, 6, 10 and 30 ohms; Amsco Tom Thumb 10, 20 and 30 ohms; Daven filament ballast, automatic filament resistance; Faven filament ballast.
* SWITCHES
  Switch arms; SPDT on porcelain base; DPDT on porcelain base; SPST on porcelain base; DPST on porcelain base; series/parallel units; Cutler Hammer filament; Cutler Hammer Radioloc; Ashley non solder push-pull; Brachstats; Emmco rheostat switches.
* SETS — RADIO RECEIVERS
  Astor 5 valve Jacobean console; Astor 5 valve Jacobean table model; Astor console Custombuilt 8 valve superheterodyne; Astor table model Custombuilt 8 valve superheterodyne; Astor console batteryless model; Porta portable model; various two valve battery models; range of crystal sets.
* TRANSFORMERS — AF AND RF
  All American toroidal kit; AWA Super RF 200 to 1500 metres; Igranic FR nos 1, 2, 2a, 3 and 4; Peerless; Ferranti AF3 and AF4; Emmco AF2, 3½, 5 and 7½ to 1; Emmco push-pull; Emmco midget 2, 3½, and 50 to 1; Brunet 3 and 5 to 1; Thordason; GR 2 and 6 to 1; Kellogg 3 and 4½ to 1; AWA 3, 3½ and 5 to 1; All American push-pull; All American Rauland Lyric; Igranic AF 3 and 5 to 1; Advance shielded transformers.
  Emmco, Thordason chokes; Emmco tone purifier.
* TUNERS
  Grodan shielded choke coils; Hercules Reinartz choke coils; Igranic variometer; Tridot variocoupler; Airzone three coil tuner; Grodan three coil tuner, single rotor; Grodan three coil tuner, double rotor; Airways variocoupler; Aladdin three coil tuner.
* TERMINALS
  No 2 large clamp; No 8 small clamp; No 3 large phone; No 4 large phone; No 5 small phone; English valve legs with sockets and nuts; Klutch brass; ebonite engraved sets of 8; Belling-Lee Bakelite lettered as C+, C–, B+, A+, A–, Aerial, Earth etc; double brass phone terminals; Panel transfers; insulated eyelets.
* VALVE SOCKETS
  English standard; Amsco UX floating shock absorber type; Amsco UX bakelite; Parker Aeolus bakelite UX; Premier UX; English standard anti capacitor type; Composite UX; Cutler Hammer UX; MAC UX bakelite; Pinnacle table top; Weco; Igranic anti microphonic; Benjamin UX shock absorber; Advance porcelain UX; Emmco non microphonic UX; Emmco sub panel sockets.
* VALVES
  Large range of Raytheon; Radiotron; Philips; AWA; Radiotechnique; Ediswan; Weco; de Forest; Mullard and Superton valves.
* WIRE
  Wide range for set wiring, coil winding, transformer and choke winding, loudspeaker extension, electrical, aerial and guy wires including enamel, silk and cotton covered wire in 4 ounce reels. Gauges included 16 to 30 for DCC enamel and 20 to 36 for double silk covered wire.
  Covered busbars, round and square in 2 ft lengths; loop wire, cotton or silk; phosphor bronze; double flex; bell flex; lead-in wire.

Coloured sleeving; resin cored solder; Grodan wire connector clips; soldering set on cards.

In 1925, the Wireless Supply Depot, Gawler Place, Adelaide with Bill Bland as Manager, came up with what was publicised as the 'Instalment Method' of assembling a complete receiver using units which could be purchased separately.

The company had its Workshop's staff assemble a range of units designated WSD Crystal Set, RF Stage, Detector Stage and AF Stage.

These units would be purchased by enthusiasts as funds became available and strapped together with rolled brass straps to form a complete receiver. Later, additional RF and AF stages could be added to improve the performance of the set.

The WSD Crystal Set comprised a crystal detector with cat's whisker, variable capacitor in series with the aerial circuit inductance, headphones, binding posts and straps. The set could be used as a standard crystal receiver but when employed with a Detector Unit, the bridging straps automatically eliminated the crystal detector from the circuit.

The Detector Unit comprised rheostat, valve, valve socket, grid capacitor and leak, binding posts, brass straps, and battery leads and clips. Battery requirements comprised 6 volt A battery and 22½ volt B Battery.

The RF stage comprised a tuned RF stage covering the bands occupied by all Australian broadcasting stations at the time, valve, valve socket, binding posts, brass straps, battery leads, A and B batteries.

The AF stage comprised rheostat, valve, valve socket, input and output transformers, binding posts, brass straps, battery leads and A and B batteries.

Unit were built into matching polished mahogany cabinets all of the same height and width but the length being determined by the equipment mounted therein.

Bill Pitchford, a member of the West Suburban Radio Club, Adelaide, had an installation which completely covered a table with interconnected units. It comprised a wave trap, an aerial loose coupler unit, three RF stages in cascade, a detector stage, two single valve AF stages followed by an AF stage with two valves in parallel. A switch pox enabled the AF output to be fed to a selection of loudspeakers including Atlas, Sterling Magnavox or an AR15 Amplion Music Master.

Bill Bland had plans to include modules for assembly of a superheterodyne receiver as there was a lot of interest with the superheterodyne circuit at the time by members of Radio Clubs. Papers found amongst records in later years showed drawings for units comprising RF Stage; Oscillator Stage; 1st Detector Stage; 1st IF Stage; 2nd IF Stage; 3rd IF Stage; 2nd Detector; 1st AF Stage; 2nd AF Stage and one designated 'Anti Oscillation Stage'. The purpose of this latter stage is not clear. He imported several brands of IF transformers for assessment purposes including one of unusual appearance from USA. It was made by St James Laboratories Chicago and looked like an ordinary glass envelope valve with standard base and plug-in socket with screw terminals. The air core windings inside the glass envelope were in a vacuum claimed to be 0.001 mm. All internal connections were silver soldered and each transformer was subjected to extensive testing before leaving the laboratory and was provided with its own characteristic curve.

RADIO SERVICE WORKSHOP

The majority of Radio Servicemen operating a small business, sometimes with one or two assistants had a well-kept workshop equipped with a collection of tools and test equipment appropriate for the work.

A typical workshop of the mid 1930s had a floor space of at least 12 square metres where the owner operated the business alone. If there were employees, about 7 square meters would have been provided for each employee. This space would be additional to areas required for office and receiver display room.

Workshop furniture usually comprised workbench for radio repair and test functions, a solid workbench for mechanical work activities, a table for unpacking and packing receivers etc, doubling as a repolishing or varnishing area, cupboard for holding spare parts and materials, filing cabinet for service manuals and other associated technical literature, a small cupboard for storage of test instruments not usually housed on the repair bench and shelving for holding receivers waiting repair, and repaired units.

The worktable where repair and test work was carried out was an important part of the workshop. The design varied to suit the particular needs of the Serviceman but it was usually fitted with a raised shelf at the back for mounting test instruments at eye level. A number of drawers were provided under the bench and to one side.

One Serviceman at Clayfield, a Brisbane suburb had the following items in a table provided with two drawers:

- Top drawer. A selection of the most frequently used small tools such as side cutters, combination pliers, wire stripper, set of watchmaker screwdrivers, three screwdrivers, a set of BA spanners and several small boxes containing a selection of resistors, tubular paper capacitors, electrolytic capacitors, and a selection of BA nuts and bolts.
- Bottom drawer. About 20 tested valve types commonly employed with receivers of the period mounted on a pineboard base suitably drilled for the valve pins to allow the valves to be mounted vertically. The valves were marked with a coloured label to ensure they were not accidentally left in the receiver under test, following a substitution test.

The front panel of the raised instrument shelf accommodated a loudspeaker wired to cater for several input impedance values; terminals for connection to an outside aerial; an earth terminal; several outlets for local mains power on the front; several outlets for mains power at the rear for test instruments; switches to energise test instruments; a neon lamp to indicate 'power on'; an overload switch, and a separating transformer with a range of output voltages brought to outlets on the panel for testing and repairing AC/DC receivers.

The right-hand side of the table was reserved for the soldering iron, wire brush and solder.

The solidly constructed workbench usually contained a drawer and bottom shelf. Heavy tools fixed in position on the top comprised a bench drill, an electrically powered grinding wheel, and a vice provided with copper faces to minimise damage to material surfaces by the vice jaws. Typical items found in the drawer included a BA plate; set of drills; BA taps and dies; pin and centre punches; hacksaw blades; key files; letter and figure punches; cold chisels; scriber and steel ruler. The bottom shelf frequently housed a small vacuum cleaner.

A tool shadow board was a vital part of a well-organised workshop to accommodate such items as files, file brush, hammers, hand and small electric drill, wood chisels, bolt cutter, vernier callipers, set squares, dividers, pliers, box spanners, screwdrivers, adjustable open end wrench, set of open-ended spanners, offset screwdriver and test leads.

In some workshops, there was a shelf provided for a small oil can and several bottles of cleaning fluid.

Many Servicemen had a cupboard for the purpose of containing a selection of small tins of paint, varnishes and french polish for touch up purposes as required during repair operations where some small damage or marking may have occurred.

A cupboard housing spare parts and materials was fitted with a number of solid shelves and about 18 drawers of at least three different sizes and fitted with partitions. The cupboard contained in a well-organised shop, items including a wide range of valves employed in receivers at the time; a range of mains power transformers; paper capacitors; resistors; loudspeaker transformers; potentiometers and rheostats; valve shields; a selection of moulded knobs; fuses; yaxley switches; electrolytic capacitors; valve sockets; variable capacitors including trimmers and padders; IF, RF and Oscillator coils; RF chokes; power cord; hook up wire; shielded wire; a wide selection of nuts, bolts and washers particularly BA series; wood and metal screws; soldering tags; a selection of mechanical items for repair of radiogram record player units; several loudspeakers and a range of A, B and C batteries and vibrator units for battery-powered receivers.

To cater for handling heavy console models, the workshop would be provided with a base board with roller wheels to facilitate movement of these receivers.

Test instruments were expensive at the time and many Servicemen operated with only a few units. One well-known Radio Repair Shop in Brisbane, The Valley Radio Shop had the following items in its well-equipped workshop, Calstan All Wave Oscillator, Calstan Set Analyser No 385, Palec Valve Tester, Palec Multimeter, Palec Model DR Oscillator, Palec Model MI Oscillograph, Weston Model 772 Analyser and locally made Vacuum Tube Voltmeter, Loudspeaker Test Unit, LCR Bridge and Electrolytic Capacitor Tester.

Another well-established Brisbane radio service business which in 1950 had a franchise for Philips receivers and components had a workshop fitted out mainly with Philips test instruments. Items included Philips Multimeter Type TA175, Philips Measuring Bridge Type GM4144, Philips Insulation Tester Type TA200B, Philips Vacuum Tube Voltmeter Type GM6004, Philips Cathode Ray Oscilloscope Type GM5655, Signal Tracer Type GM4575, Philips Beat Frequency Oscillator Type GM2307, Philips Modulated HF Oscillator Type GM2883, and Philips Valve Measuring Apparatus 'Cartomatic' Type GM7633. The facilities included a number of other items which the owner manufactured in the shop to assist in the servicing and testing operations. One of the locally assembled items was a mobile cart on which was mounted a number of test instruments for use by the Serviceman when attending to repair work in the home.

The development of the printed circuit, solid state devices, the digital voltmeter and the frequency counter in the early 1950s have had an enormous impact on the development of radio receiver test equipment in recent years.

Although analogue multimeters are still available, there is a greater range of models available as digital readout units. Many are small hand-held models, with some small enough to be carried in a pocket. While some are designed for specific or restricted measurements, others have capability for measuring such parameters as inductance, capacitance, resistance, and frequency and also logic circuit test, transistor and diode test and continuity, with a single instrument. Bench type instruments such as RF Signal Generator, AF Signal Generator, AC Millivoltmeter and others are also available.

The modern day Serviceman has available a range of probes, testers and other devices which can facilitate fault location and adjustment operations. They include voltage tester with screwdriver for checking batteries, switches, lamps and LED's; AC voltage finder which can sense AC voltages above about 100 volts in a cable form; logic probe to check logic states; logic pulser for injection of signal into a logic circuit; resistance substitution wheels and many others.

Test instruments and probes available today are very reliable and accurate and do not cause the same problems as some of the multimeters in use in the early 1930s. Many of those multimeters did not provide a true indication of the state of the operating circuit. When some were employed to measure say, the valve anode voltage, the instrument placed a resistive load in parallel with the anode resistance often about the same value or even less, and so effectively reducing the resistance between battery and anode to about half of its normal working value. The meter, therefore, did not indicate the real working voltage at the point of measurement. The Serviceman had to be alert to this and other problems in interpreting the meter reading. Measurement of high value of resistance was also a problem with some early instruments due to cramping of the scale at the top end.

In 1932, when there were about 60 broadcasting stations serving some 470000 licensed receivers throughout Australia, Radio Servicemen had a range of charges to cover various types of work. Typical charges levied by one Adelaide suburban Radio Serviceman at the time were:

- Maintenance call to check receiver performance including testing of valves and batteries — 4/6 (45 cents).
- Repair work undertaken on all models of battery-powered receivers delivered to the Shop — 7/6 (75 cents) plus cost of parts.
- Repair work undertaken on all types of AC powered receivers delivered to the Shop — 10/6 ($1.05) plus cost of parts.
- Installation and setting to work of receivers including material and erection of two pole inverted L or T type aerial, lightning arrester and earth stake — 25/- ($2.50) excluding any mains wiring associated with AC powered models.

In 1998, a typical charge by a Radio Serviceman would be of the order of $50 per hour plus a service call charge plus cost of parts.

During the Second World War, Radio Servicemen, particularly those in country areas found it extremely difficult to obtain test equipment, spare parts and to retain experienced staff, in order to satisfy the needs of repairing local receivers.

Denham's Radio Service, Maryborough in Queensland was able to maintain an active business and in fact supplied difficult-to-obtain test instruments and spare parts through an extensive Mail Order Department. John Bristoe, the Radio Manager of the business was an expert in test equipment design and construction and in 1942 built several Signal Tracers which were described in detail in an issue of 'Australasian Radio World'. In the mid 1940s, they had a large range of new and used test equipment in stock including oscilloscopes, oscillators, multimeters, vacuum tube voltmeters, valve testers, and meter movements.

FEATURES OF MODERN RECEIVERS

Great advances have been made over the past 75 years in the technology incorporated in modern radio broadcast receivers. Compared with models manufactured in the early days of broadcasting, today's receivers are noted for their high efficiency, high quality performance, lightweight characteristics, relatively low cost and incorporation of advanced technology, much of which would have been only a dream for the broadcast pioneers.

There is an enormous range of models and designs available from the major retailers of electrical appliances with nationwide branches, such as Chandlers Australia, Harvey Norman, Retravision and others. Although some receivers are sourced from European manufacturers, the majority are from countries in East and South East Asia. In broad terms, receivers may be categorised as Multi-Band Receivers, Multi-Purpose Models, and Home Entertainment Mini and Midi Systems.

* MULTI-BAND RECEIVERS

Many brands are available from Radio Shops and Electrical Retailers with models from USA, Germany, and Japan being popular with listeners. Two of the late 1997 models include:

- Sangean Model ATS-606, a compact receiver covering the frequency ranges FM, 87.50 to 108 Mhz; LW, 153 to 513 kHz; MW, 522 to 1710 kHz and SW, 1.715 to 29.995 Mhz. It provides direct keyboard frequency entry and 45 memories for accurate short wave tuning, plus an auto tuning system which will locate the nine strongest AM and FM stations and memorise them for future access; LCD screen; scan tuning; dual alarm clocks; lock switch; stereo earphones for FM stereo; aerial and soft carry case. It is powered by three AA batteries.
- Sangean Model ATD 909, providing full AM/FM/LW for broadcast reception. Short wave reception modes include 1 kHz and 5 kHz tuning steps. A total of 307 memories are provided for storing desired frequencies with 261 for SW, 18 each for MW/FM and 9 for LW with battery free EEPROM memory backup. Other features include, keypad frequency entry; auto

tuning system for strongest signal location; narrow/wide IF filters for SW reception; FM stereo earphones; battery and signal strength meter; worldwide clock; ANT–60 wind-up aerial, carry case and AC adaptor. Four AA batteries are required for portable use.

Other models in the company range include 10 band portable; 9 band receiver with world clock; micro-compact 9 band receiver; 45 memory short wave receiver and all-band world receiver with cassette.

There are also receivers made by a number of well-known manufacturers referred to a 'Communications Receivers'. They cover not only the broadcast bands but many others as well. They are popular with keen DX fans but are much more expensive than receivers designed for reception of broadcast bands only.

* MULTI-PURPOSE MODELS

These models are usually either straight receivers or receivers plus accessories such as clocks, cassettes and CD player units. Brands and models available from the major retailers during late 1997 include:

Philips FM/AM clock radio with power backup for clock, wake to radio or buzzer, repeat alarm and LED display; Panasonic FM/AM clock radio with 'Sure Time' battery backup system, LED digital display, doze and sleep function; Akai stereo FM/AM clock radio with dual alarm function, auto dimmer function, snooze function and battery backup; Sanyo FM/AM cube clock radio with LED display, humane alarm system and auto dimmer; Sanyo Sportster FM/AM radio cassette player with auto stop mechanism, Bass-expander, three button control and earphones; Panasonic FM/AM personal stereo with extra bass system, tape selector and auto stop; Panasonic FM/AM pocket radio with LED tuning indicator, slide rule tuning dial, earphone and hand strap; Panasonic FM/AM stereo clock radio with cassette player, two 8 cm dynamic loudspeakers, built-in condenser microphone, one touch and follow-up recording; Sony FM/AM Walkman with megabass, 16 hour long battery life, anti-rolling mechanism and Fontopia earphones; Sony FM/AM digital tuner Walkman with 20 station preset, 22 hour long battery life, auto volume limiting system and Fontopia earphones; Panasonic FM/AM portable radio with 8 cm dynamic loudspeaker, earphone jack and AC/DC operation capability; GE portable Super Radio III high performance radio with FM/AM, two way loudspeaker and AC/DC operation capability; Philips FM/AM mono radio cassette recorder and one touch recording, auto stop and headphone socket; Sanyo FM/AM stereo radio cassette player with 10 W PMPO, single cassette, one touch recording, twin full range loudspeakers and headphone jack; AWA clock radio with AM/FM tuner, dual alarm, snooze, red LED and battery backup; Philips CD radio cassette recorder with 60 W PMPO, dynamic boost, 20 track programmable CD, single cassette deck with CD synchrostart recording, microphone and headphone socket; Sony CD radio cassette with 60 W PMPO, single cassette, AM/FM analogue tuner, BRB design for bass power, synchronised CD dubbing, 1 bit D/A converter and tone control; Panasonic CD radio cassette with acoustic separate cabinet with bass reflex ports for high quality sound, extra bass system, LCD indicator, CD synchro-start editing, ful;l auto stop, cue and review controls, soft eject; Panasonic personal stereo with digital synthesiser tuner with dual mode preset memory, shell lock system, auto reverse playback, extra bass system, detachable belt clip; Panasonic CD radio cassette with 240 W PMPO output for high power sound, digital synthesiser tuner with 29 station memory, dual cassette deck, four preset graphic equaliser, multi information LCD display, sleep function and remote control; Sharp portable CD stereo system with twin CD player, double cassette, three band graphic equaliser, AM/FM tuner, variable X-Bass, detachable two-way four loudspeaker system and remote control; Sanyo FM/AM radio cassette player with top load CD, repeat CD function, 10 cm full range loudspeakers with 50 W PMPO output, full auto stop mechanism cassette deck; Panasonic stereo CD radio cassette recorder with bass reflex ports, CD synchro start editing, MASH 1 bit D/A conversion system and 30 W PMPO; Sony compact FM/AM radio cassette player with top load CD player, 60 W PMPO, 1 bit D/A converter, synchronised CD dubbing, single cassette and tone control; Philips FM/AM radio single cassette player with top load programmable CD player, 30 W PMPO, dynamic bass boost; Sharp stereo radio cassette recorder with twin drawer CD changer, full auto stop, variable X-Bass and one touch recording; Philips FM/AM clock radio with CD player, quartz clock, dual alarm wake by buzzer/radio; and many others.

* HOME ENTERTAINMENT MINI AND MIDI SYSTEMS

A large range of models are available as standard units sold as Mini and Midi Systems plus Pro Logic Home Theatre Entertainment Sound Systems with the radio receiver being one of a number of units comprising a system.

The Mini models include an Akai Model with remote 3 disc CD changer, 2000 W PMPO, FL display with Spectrum EQ, dynamic super bass 30 programmable CD tracks, dual logic cassette with auto reverse, Dolby NR–B system, PLL synthesised tuner, headphone and microphone, and 3 way loudspeaker system.

In the Midi model range a Philips unit is one of the few available with integrated turntable. It also features 500 W PMPO, dynamic bass boost, digital sound control, 20 preset station digital tuner, dual stereo cassette decks and 3 way loudspeaker system.

The Home Theatre Entertainment Sound Systems are promoted for the listener who wishes to enjoy the experience of being in a cinema but in the listener's own home with surround sound from Dolby Pro Logic home theatre systems. They are the home cinema variant of the Dolby Stereo Theatre System which introduced four audio tracks into the space normally occupied by two stereo tracks.

A Dolby Pro Logic decoder extracts the sound tracks and sends the sound signal via four channels; front right, front left, centre and rear loudspeakers. The front right and front left sounds are the normal stereo right and left channels, the centre loudspeaker handles dialogue and effects related to on-screen action, and the rear loudspeakers create audio ambience.

A typical system is Technics Remote Dolby Surround Pro Logic Mini Component System with 5 disc CD players, 100 W by 2 RMS, 3 Dolby surround control 15 band spectrum analyser, double auto reverse deck, full Karaoke function, digital output terminal, stereo synthesiser tuner, video in/out terminals, 3 way loudspeaker system with 14 cm woofer and 3D space surround tweeter.

Midi systems are also available from some manufacturers.

Instead of investing in a complete expensive system, upgrade packs are available to make use of existing home entertainment systems. The Philips AV 900 Dolby Pro Logic system is typical. It consists of a set of loudspeakers with a built-in Dolby Pro Logic processor and a stereo VCR Model VR656. It adds three loudspeakers to the two normally available with a stereo audio system.

Broadcast receiver technology is about to enter a new era with the planned introduction of Digital Radio Broadcasting (DRB). The Minister responsible, has already announced the in-principle support for a system known as the Eureka 147 system and trials have already taken place in Sydney, Canberra and Melbourne.

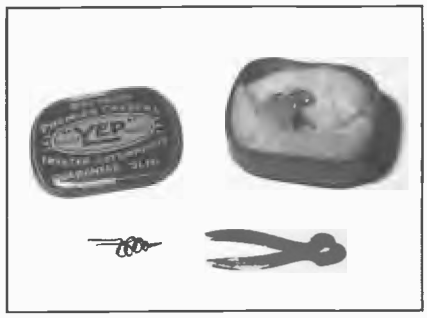
The Eureka 147 system is already operational in Germany, France, Norway and Sweden, and many other countries are planning the introduction of digital broadcasting employing various systems.

In Great Britain, transmitters were being installed in 1998 in advance of the availability of receivers and the BBC has estimated that within 10 years, about 40% of householders would possess receivers capable of receiving the new technology.

The radio digital service to be provided in Australia will not only make more efficient use of the radio spectrum but will provide a greatly improved service to listeners. It will not affect stations already operational in the FM band. The new service will operate on the 1.5 GHz band and one channel will have capability for provision of five CD quality programs or 12 AM services or 30 voice channels or combinations of these services.

Until such time as digital radio can be delivered via satellite, it is likely that the present AM service will continue for some time. Some trials were conducted in Australia using the Optus B3 satellite during 1995 but dedicated digital radio satellites such as Afristar, Asiastar and Ameristar are planned for service within about 18 months and the use of digital broadcasting by satellite in Australia is a possibility in the near future.

Typical metal containers for crystals which were usually packed in 'cotton wool'. Most large Radio Shops stocked an extensive range of brands and materials. In 1926, Harringtons Ltd with outlets in all States had 16 different brands of crystals in stock including 5 of Australian origin.

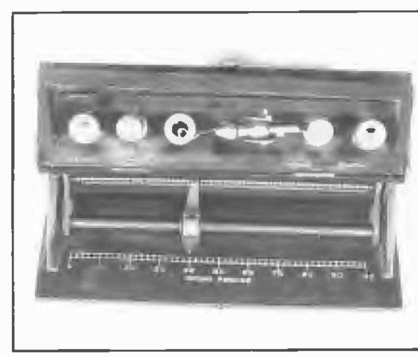


Most commercially produced crystal containers also included a cat's whisker and a small pair of tweezers. Crystals were either natural mineral such as galena or synthetic, manufactured using a special process.

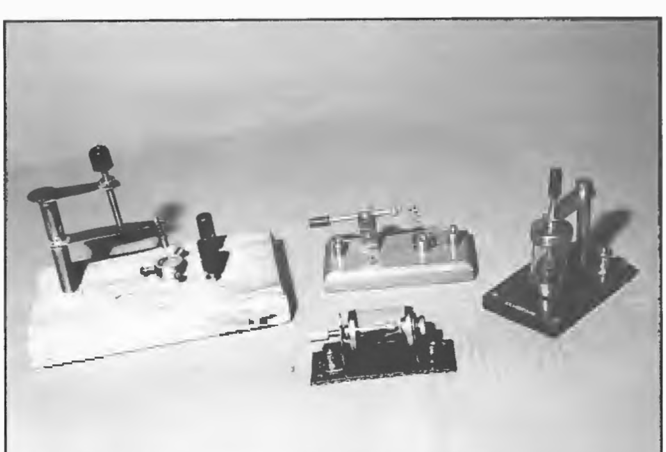
Homemade receiver using open crystal detector and single valve audio amplifier. Tuning by capacitor, and rheostat provided for valve filament voltage adjustment. Constructed 1926 by member of Glenelg Radio Club, Adelaide.

Crystal set using a tapered coil and single slider available in 1925. Distributed capacitance of the winding provided resonance conditions. The tapered coil enabled a more even spread of station positions along the slider. The crystal was gripped by a screw mechanism with a moveable serrated jaw. Radio Shops which sold this model included John Lunn, a Chemist and Licensed Radio Dealer of Sandgate near Brisbane, and Varcoe and Co., Adelaide.

Crystal sets employing basket weave coils had a strong following in the 1920s. Although more difficult to wind than a standard cylindrical type, they could be easily made up as a fixed/variable combination. The method of winding was to turn the wire in and out between spokes on a special former, or slots in a cardboard former. A kit set for the crystal set shown was available from Bullocks Cycle and Radio Stores, Adelaide in 1927.

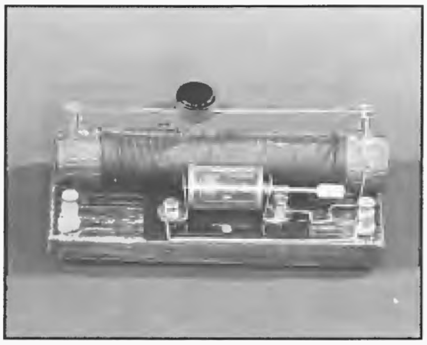


The Listener E R Fone crystal set made by Kenmac Radio Ltd, London, 1925. The edge of the book opened to expose slide coil tuner, crystal and cat's whisker and terminals. A selection of case covering materials was available including tortoise shell. Harris Scarfe Radio Department, Adelaide stocked this model.

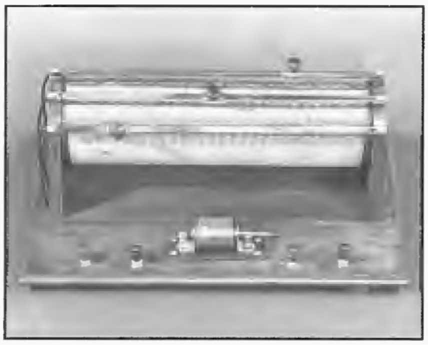


Typical detectors of the 1920s employing crystals and cat's whiskers. Models include homemade unit with micrometer adjustment, standard open ball-and-socket type, enclosed horizontal type with universal ball joint and single post vertical type with universal joint.

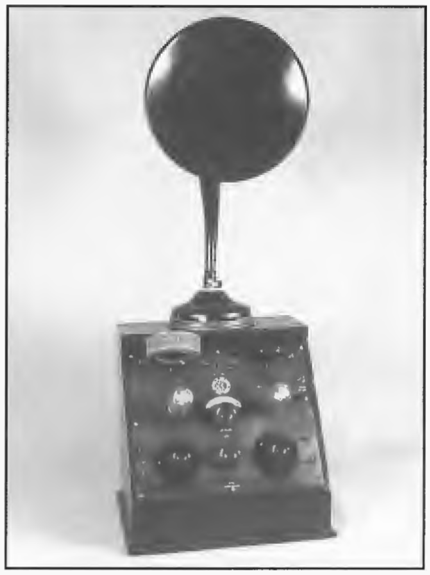
The Super crystal set manufactured by Oliver J Nilsen and Co., Melbourne, 1926. It employed an enclosed crystal and cat's whisker and plug-in coil. The model was popular even in the early 1930s.



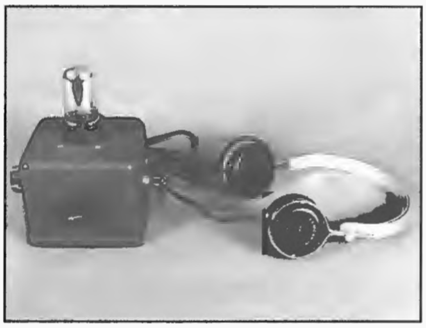
Simple crystal set comprising horizontal coil with single slider, enclosed horizontal detector and parallel mica capacitor mounted under the baseboard. The unit was homemade in 1927 with the coil being wound on a solid wooden core. Constructed by an Adelaide listener.



A 1926 crystal set employing three sliders. No 1 slider connected to aerial, No 2 connected to crystal detector and No 3 connected to tuning capacitor. One end of the coil was connected to earth and the other left floating. The set was difficult to tune as adjusting any of the three taps necessitated readjustment of the tuning capacitor and often readjustment of the other taps to obtain optimum result. The tuning capacitor located in a separate box not shown in the photograph.



Fellophone Super Two, a two valve receiver manufactured by Fellows Magneto Co., Ltd, England, 1923 and purchased by a listener at Murray Bridge in mid 1925 from Varcoe and Co., 57 Gawler Place, Adelaide. The receiver had a sloping fronted cabinet with an ebonite panel on which was mounted controls, valves and plug-in coil. One high frequency valve and one detector were used with reaction. Selectivity was obtained by coupling the tuned anode coil.



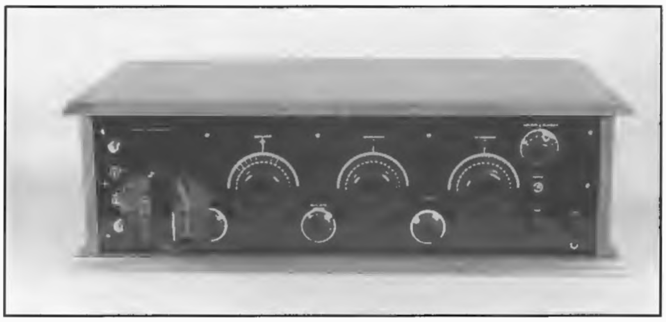
Left: Crosley Pup Model 50 receiver manufactured by Crosley Radio USA in 1925. The receiver was a one valve regenerative circuit type designed to fit in a 4 inch square metal box with a WD 12 valve mounted on top. It used a 'book' capacitor with control knob mounted on a threaded shaft to actuate the moving plate. Many Australian Radio Shops stocked this popular cheap receiver.

Two approaches to battery receiver cabinet designs of the early 1920s. In one model, the A and B batteries were housed in wing compartments while in the other they were mounted in a cabinet below the receiver. The Browning-Drake receiver (right) used a circuit developed by Glenn Browning and Fred Drake in USA. The key to the receiver's high performance was a new type of RF transformer known as the National Regenaformer.

Far Left: Five valve battery-operated Mulgaphone receiver manufactured by the Broadcasting Department of Westralian Farmers Ltd, Perth, in mid 1920s. Westralian Farmers Ltd were the operators of A Class station 6WF which began transmission on 4 June 1924 on a wavelength of 1250 metres. The receiver was on display in the Wireless Hill Museum near Perth.

Left: The Trav-ler portable receiver was manufactured by Trav-ler Manufacturing Co., in USA, one of the largest manufacturers of portable receivers in the 1920s. It was marketed as 'The Original "one man" portable radio'. The first model was produced in 1925, and updated versions appeared at yearly intervals until 1930. Until 1929, they were five valve designs employing two RF, one detector and two AF stages using triodes, but in 1930, the RF stage used screen grid valves. The receiver was self-contained with loop aerial and batteries. Owner purchased this receiver from Warburton Franki (Melb.) Ltd, Bourke Street, a few days before Christmas Day, December 1927.

(A)



(B)

Six valve Igranic superheterodyne assembled kit set manufactured by Igranic Electric Co., England, 1925. Australian distributors were Noyes Bros, Pty Ltd. The receiver comprised six valves, the first operating as a combined oscillator and first detector on the tropodyne principle, the second, third and fourth acting as IF amplifiers, the fifth as second detector and the sixth as AF amplifier. The three tuning capacitors operated independently.

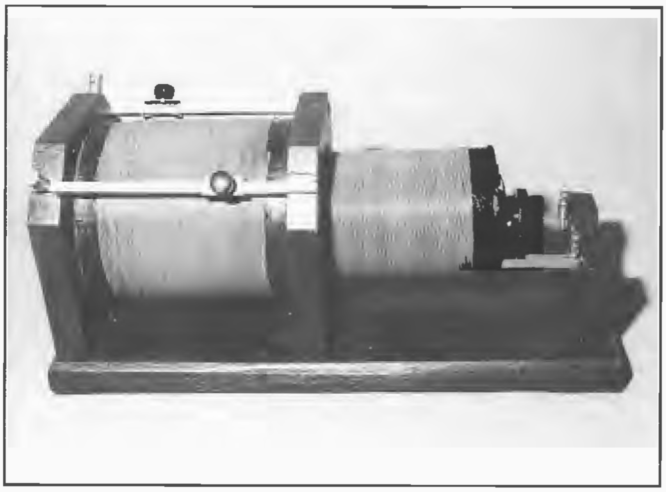
(A) shows inside view of the receiver. (B) is a front view. This receiver was purchased as a kit set from Noyes Bros, Adelaide, in 1927 as a birthday present for a 15-year-old boy who was a member of the West Suburban Radio Club.

Glass fronted Eagle De Luxe five valve Neutrodyne receiver with three tuners manufactured by the 5CL Radio and Electrical Co., Adelaide, in 1926. The company also manufactured receivers under the Demon brand name. There is no evidence that the company had any association with the local A Class station 5CL.

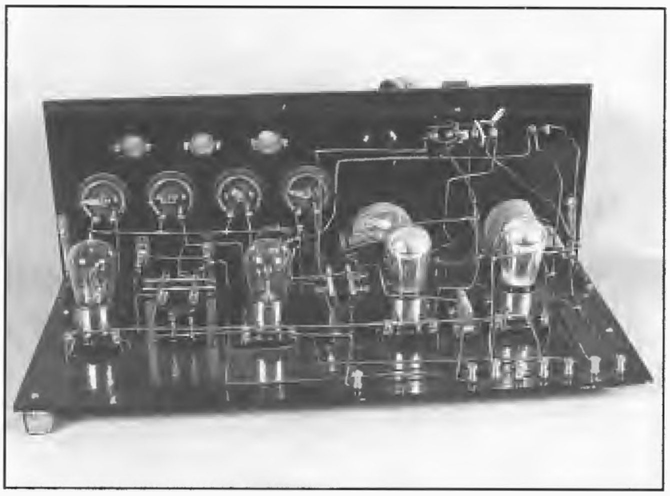
King Neutrodyne three dial receiver manufactured by King Manufacturing Co., USA, 1926, employed two stages of RF, a detector and two stages of AF, built-in loudspeaker and space for batteries. The Brown Q external loudspeaker was not part of the original receiver. The receiver was owned by Alick Clark, Manager of Harris Scarfe Ltd Radio Department. The company were distributors of King radio equipment and components in South Australia.

The Radiola 20 was manufactured by General Electric and released by Radio Corporation of America in USA in 1925. It employed a TRF circuit with ganged tuning with two RF stages and regenerative detector. The cabinet had a 45 degree sloping front panel, lift up lid and routed decoration on the front and sides. Two thumbwheel controls were surrounded by ornate brass escutcheons. The controls were labelled 'station selector' and 'amplification'. Receivers sold in USA were branded Radiola 20 but those marketed in Australia had the letters 'la' ground off the embossed brass badge and blacked out on the circuit diagram under the lid. This was done to avoid conflict with the right of AWA to the name 'Radiola'. Receiver purchased from Australian General Electric, Clarence Street, Sydney, in October 1927. It was originally supplied with a 1925 Radiola Model 100 cone loudspeaker. The 1927 Model 103 shown, was purchased in 1929.

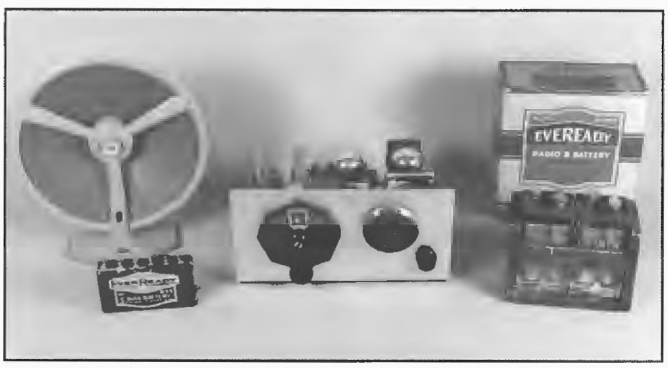
Commercially produced Eddyola Five receiver manufactured in Adelaide by Eddys in 1926. It featured a five valve Aperiodyne circuit with three tuning controls. The circuit was basically the standard Neutrodyne circuit minus the capacitors which were replaced by potentiometer control on the first and second valves. Wings on the cabinet housed the batteries. The company was one of the first in South Australia to manufacture a combined radio/phonograph unit. It was displayed at the Radio and Electrical Exhibition, Adelaide, December 1926.



Loose coupler purchased from Newton, McLaren Ltd, Adelaide, together with a crystal set by a listener in the Adelaide Hills in June 1926. At the time, stations 5CL, 5DN and 5KA were on air and some crystal set owners experienced difficulty in isolating the stations. The loose coupler consisted of two tuneable inductors so arranged that the magnetic induction could be varied by alteration of the position of each coil. It was used mainly as a means of aerial tuning. It provided greater selectivity of signals and consequently reduced interference by stations on nearby frequencies.



Four valve assembled kit set comprising RF stage, grid-leak detector and two transformer coupled AF stages purchased from D Green and Sons, Licensed Radio Dealer, Adelaide, 1926. Note the use of square section wire for interconnecting components and valve windows in the front panel. The company also sold four and five value Neutrodyne kit sets at the same period.

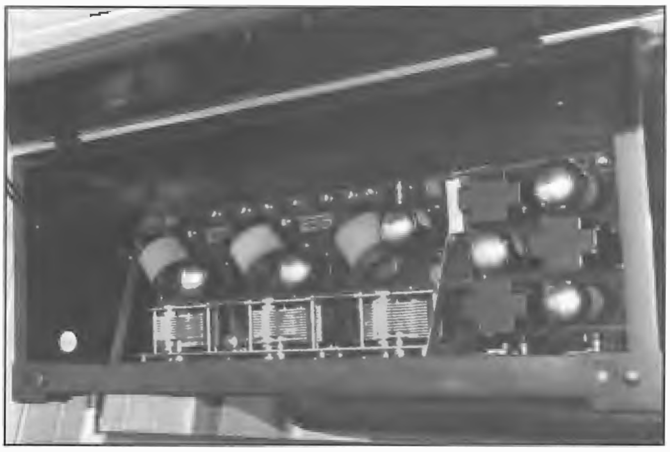


Right: A two valve receiver together with A, B and C batteries and Hegra loudspeaker. Built in 1929 by Al Smythe who built a machine for winding low-loss air-wound coils used with the receiver.

Two valve battery receiver made in 1927. It employed a regenerative circuit with reaction being achieved by variable capacitance feedback. Dials controlled tuning and the reaction capacitor. The third control was a rheostat for filament voltage control. The owner, a Mechanic in the Post Office built the set while living in Perth but brought it to Adelaide in 1929 when transferred to that city.

Kolster Model 20 manufactured for Kolster Radio Corporation, USA, in 1928. This receiver was purchased from Homecrafts, Melbourne, about 1930. The receiver cabinet and a matching loudspeaker were patterned using wood under high pressure in a steel mould. The patent for the process was held by Brandes Laboratories. The set was AC powered and employed 7 valves including rectifier, three RF, one detector and two AF stages.

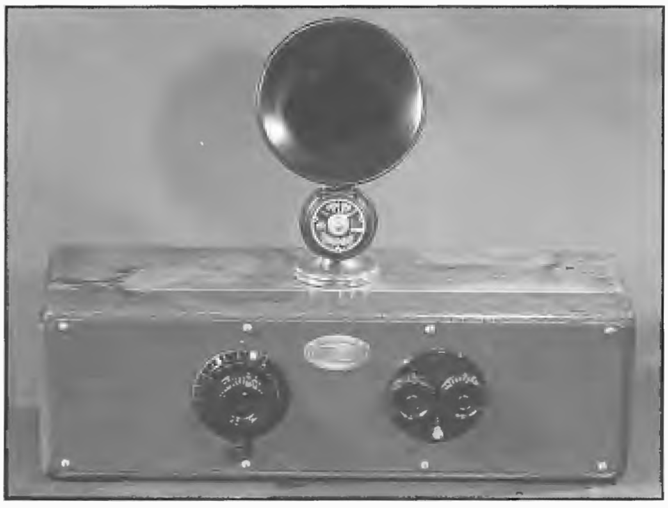
(A)



(B)

Six valve King-Hinners Neutrodyne battery operated receiver manufactured by King Manufacturing Corp., USA and factory tested, according to label, on 15 July 1927. It was imported by Adelaide radio Dealer, Len Harper. The circuit comprised three RF stages, detector and two AF stages. Features included single dial station selector, beautiful Gothic design cabinet and rugged mechanical construction.

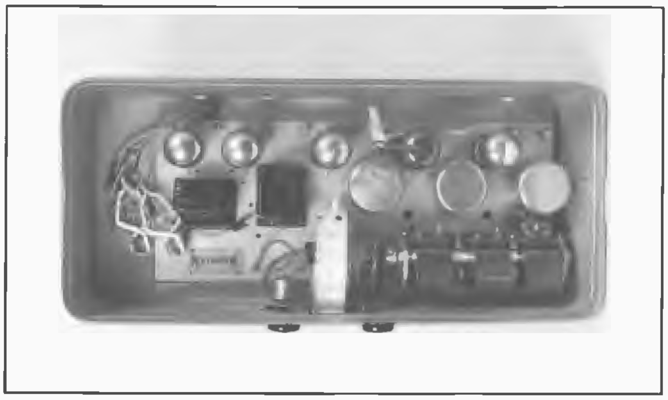
(A) Front view with lid raised. (B) Inside view showing component layout.



Right: Model 48 Atwater Kent six valve battery-powered receiver made by Atwater Kent Manufacturing Co., USA, in 1928. Many were imported by Australian dealers, and are well represented today in vintage radio collections. The receiver was originally produced as Model 30 in 1926, but in 1928 the company updated the receiver, gave it a different colour and called it Model 48. The Model 30 was the company's first one-dial tuning set and the 48 used the same principle of phosphor bronze bands to control rotation of the variable capacitors. It was designed by the company Chief Engineer, John Miller whose name is remembered today for the Miller effect with radio valve circuits. Owner of this receiver was an Announcer at 4QG Brisbane.

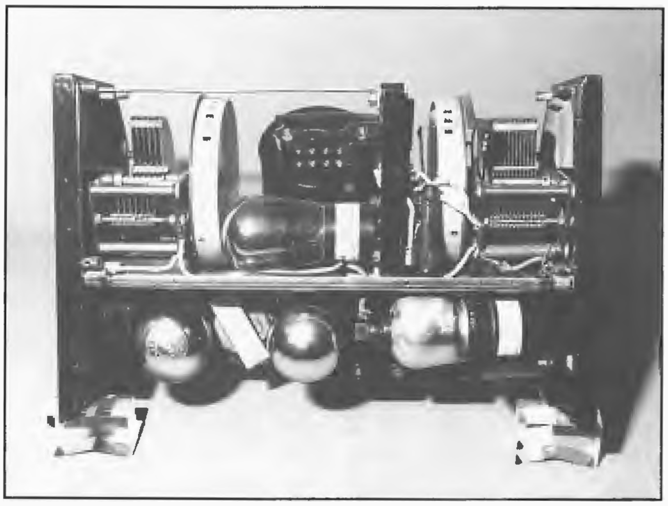
Apex Super Five battery receiver manufactured by Apex Electric Mfg Co., USA and imported by Trackson Bros Pty Ltd, Brisbane, in early 1928. The receiver was a Mail Order purchase by a grazier north of Port Augusta in South Australia. He was a member of the local Quorn Radio Society, one of the oldest Radio Clubs in the State being formed on 25 August 1924. The original loudspeaker was an Apex Entertainer model but was damaged during transit to the purchaser.

(A)



(B)

Astor 'One Control Five' battery-operated table model receiver with Neutrodyne circuit plus screen grid valve. Released about April 1929, a single tuning control operated a three ganged capacitor. The only other controls were volume and a battery switch. The pressed steel cabinet was finished in copper colour. (A) External view with Operatic model loudspeaker. (B) View inside cabinet. The receiver was purchased by a Gawler listener from Louis Coen Wireless Pty Ltd, Grenfell Street, Adelaide, in late 1929.



Philips four valve battery-powered receiver type 2802 displayed with cover removed. It was made by Philips, Holland, in 1929 and employed a screen grid RF stage, 0-180 degree drum drive tuning scales, moulded Philite ends and dark blue rexine covered metal cabinet. This receiver was owned by a railway worker in Port Pirie, South Australia and was purchased with a Philips Concert Grand loudspeaker about 1932 from W H Barber, Radio and Mechanical Devices, Port Pirie. Bill Barber operated experimental station VK5WH and was associated with the establishment of local broadcasting 5PI in 1932.

Philips All Electric Model 2510 Radioplayer with Sevenette loudspeaker. Produced in Holland, 1930, it was housed in metal casing with five Arbolite panels of thin plastic laminated board. The receiver employed two stages of screen grid amplification. The lid was hinged and could be locked. Purchased by a publican in Broken Hill from Philips, Sydney, in mid 1932, shortly after broadcasting stations 5CK and 5PI began operation in Crystal Brook.

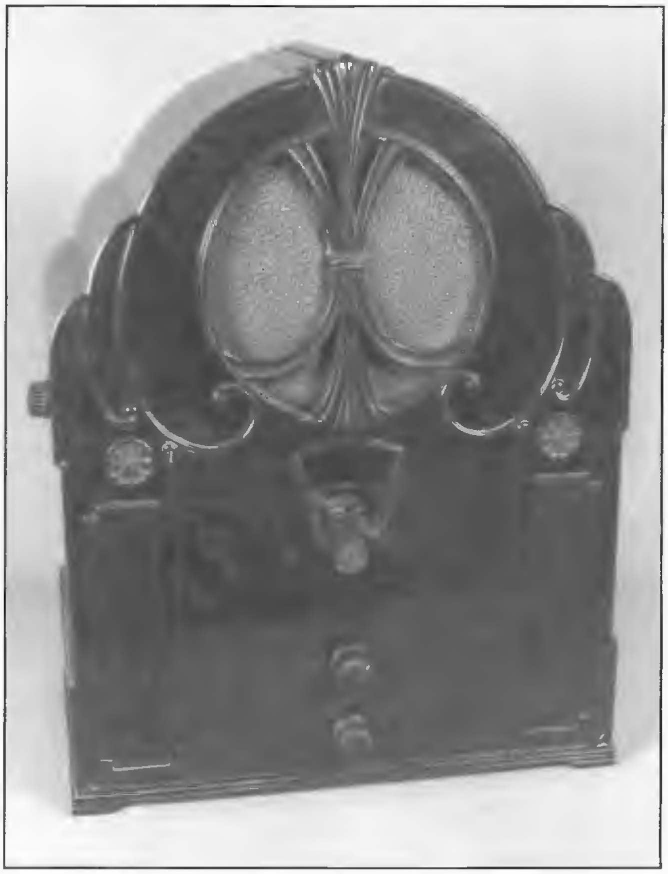
Baby Astor lacquered metal cabinet three valve battery-powered regenerative receiver with screen grid RF amplifier manufactured in 1931 by Radio Corporation Pty Ltd, South Melbourne. Valves comprised Philips A442 screen grid, Philips A415 detector and B409 power amplifier. It had long range reception capability and was popular with country listeners. This receiver purchased by Postmaster Goulburn, a few weeks after 2GN began transmission on 17 December 1931.

Stromberg-Carlson three valve TRF receiver, 1931. Valve types employed were E415 detector and audio; B442 output penthode and 1560 full wave rectifier. Built-in magnetic loudspeaker was mounted on a baffle underneath the cabinet shelf. The Lucan Console cabinet was finished in Queensland walnut and was used to house three and four valve receiver models. It was distributed by Mick Simmons Ltd, Sydney.

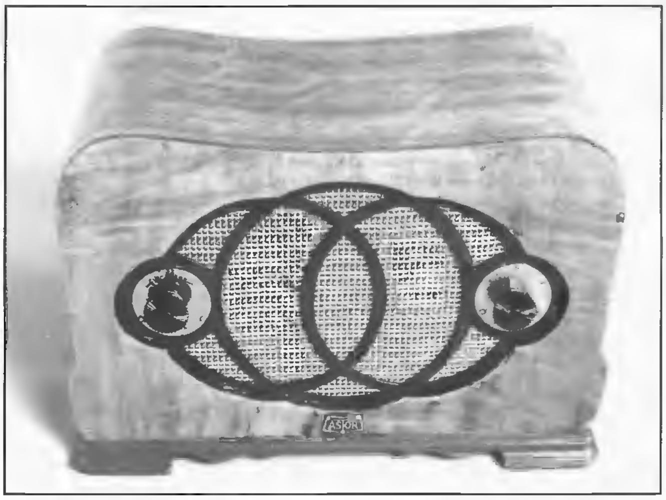
Model 510 Endeavour car radio manufactured in 1934 by Eclipse Radio Pty Ltd. It was a six valve superheterodyne type enclosed in a metal case. AVC was applied to the RF amplifier, IF amplifier and pentagrid converter. Controller attached to the steering wheel column and linked to the receiver with flexible Bowden cables. A selection of remote control units was available. Works Manager, Bill Kerr and Chief Laboratory Engineer, George Williams.

Left: Genalex 5 superheterodyne receiver manufactured for, and distributed by, The British General Electric Co., Ltd, 1933. Genalex receivers were made for BGE by Thom and Smith using Tasma chassis but different cabinet styles. Genalex cabinets of the period featured White Mahogany with walnut cross-banding for many designs with Tasmanian Blackwood being used for the more expensive models. The following year, Genalex receivers were fitted with Osram (Catkin) All-Metal valves advertised as the 'valve with the iron constitution'. Manager BGE Radio and Telephone Department, John Tait.

Philips luxurious Radioplayer five valve Model 1404M AC powered receiver, 1931 featuring the Philips 'stars and waves' motif on the loudspeaker grille. This was the second design produced by Philips when they began manufacture of broadcast receivers in Australia in 1931. The model featured a TRF circuit, cast aluminium chassis, recessed tuning and volume controls on the sides of the cabinet, a pressed metal hood covering the tuning capacitor and Philips type 2118 loudspeaker. Receiver production ceased shortly afterwards and did not resume until 1934.



The first AWA Radiolette Model C87 receiver, 1932. It was a 4 valve design including rectifier with dynamic loudspeaker. The receiver was one of the first Australian receivers to employ a bakelite cabinet. However, bakelite cabinets were discontinued after two years of production. A TRF design, valve types comprised 35, 24, 47 and 80. The owner of this set was a Telephonist at the Mildura Exchange and purchased it in mid 1933, a few weeks after 3MA Mildura began transmissions on 25 May 1933.



Astor Mickey Mouse 5 valve superheterodyne mantle receiver, 1934. The receiver including the plywood cabinet design was carried out in USA in co-operation with the Australian Radio Corporation's Engineer, R Burke. The original design had no transformer in the power supply but from December 1933, a transformer and full wave rectifier were introduced. The receiver label remained in production for at least 26 years and did much to popularise the Astor name.

Right: Model 62E six valve AC powered receiver manufactured by Raycophone Ltd, in 1932. Features included matched Radiotron valves, four gang tuning capacitor, three RF stages employing variable mu valves, screen grid power detector resistance coupled to a pentode output valve. Loudspeaker was Rola Model K12. The Beale manufactured cabinet was constructed of five-ply Grade A veneer maple and provided with a piano finish. Director and Chief Engineer of Raycophone was Ray Allsop who established the company in June 1929.

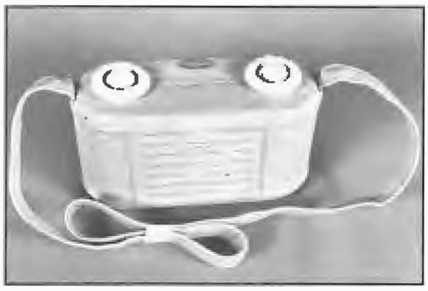
Genalex Bu-Radio, five valve superheterodyne receiver manufactured by Thom and Smith for the British General Electric Co., 1934. Chief Engineer Thom and Smith was Eric Fanker. The unit was a combined radio and writing bureau made to Queen Anne design and constructed of Tasmanian Blackwood and White Mahogany. Two drawers, ink well and lock and key were provided. Originally released in 1933, the 1934 version used Osram catkin valves.

Five valve AC powered Gladiola Radio receiver manufactured by Gladiola Co., Adelaide, 1939, with SA stations being highlighted on the dial. The company made some parts and produced a range of mantle and console models including a radiogram. Cabinets made by the company, a former cabinet maker, were noted for their high quality veneer designs. First receivers using chassis brought in from outside, were released in the late 1920s. Proprietor, William Black. Son, William was responsible for radio aspects of the business.

Five valve battery-powered portable receiver manufactured by Breville Radio Pty Ltd, 1946. It featured 5 inch permag loudspeaker, inbuilt loop aerial and facility for external aerial with on-off switch having a position for either aerial system. Case was covered with leatherette fabric.

Batyphone console receiver circa 1940 on display at the Wireless Hill Museum near Perth. It was manufactured by C S Baty and Co., Perth, who began receiver manufacture in the early 1920s. The proprietor, Stan Baty was one of the first manufacturers to market a package deal for country listeners by providing a complete operational system including aerial and earth systems all installed and set to work on the purchaser's premises.

Four valve AC powered mantle receiver produced by Breville Radio Pty Ltd, 1947. It employed a reflex circuit, post War valves and 5 inch permag loudspeaker. It was housed in 'pick-me-up' cream or chrome metal cabinet with retractable handle. It was fitted with a edgelit perspex dial. The receiver was also available with 'Ace' walnut veneer cabinet.



National Walkabout 4 valve personal portable receiver, 1947. A copper wire aerial was sewn into the shoulder strap. The Adelaide-based National Radio Corporation Ltd commenced manufacture of domestic receivers in 1933 and was the largest organisation outside Sydney and Melbourne. John Allan, who worked with National for 14 years from 1936, was associated with development of this portable.

AWA Radiola 450P Personal Portable, 1948, employing 1.4 volt valves. At the time it was relatively small in size and light in weight. It was completely self-contained and weighed five pounds (0.45 kg). The receiver was housed in a durable moulded case in a selection of colours. The Brisbane ABC studios employed a number of these receivers at outside broadcast points during the visit of Her Majesty Queen Elizabeth to Queensland in 1954 for off-air monitoring where multiple OB points were involved in describing the progress of the Queen's car. This receiver was employed at Queens Park, Toowoomba.

One of the earliest transistor receivers assembled in Australia. It was constructed in 1954 by a local radio enthusiast from a kit set imported from England. The set covered the Long Wave and Medium Wave bands. In 1955, Neville Williams described details of construction of a simple transistor receiver in 'Radio and Hobbies' employing PNP germanium devices released by Philips and Mullard. Many were built to the design.

Above Left and Left: STC Model A6461 six valve radiogram, 1956. It featured MF and extended short wave band operations; 'Heavenly-Twin' 12 inch (30 cm) and 5 inch (125 mm) permag loudspeaker system; high fidelity reproduction; separate bass and treble tone controls; inverse feedback across two circuits; synchrolift doors; cabinet finished in 'Persian' walnut veneer and contrasting blonde interior. STC manufactured its own cabinets.

A program reception and control position at Receiving Station, Cox Peninsula, installed 1969 to provide off-air programs from transmitters at Shepparton, Victoria, for rebroadcast by 250 kW Radio Australia transmitters located at another site on the Peninsula. Booth program and control positions were equipped with Racal RA117-C2 receivers with RA98C-1 independent sideband adaptors set up for dual diversity reception mode. A spare position was set up in the receiver hall. The facility was closed down in 1974 when direct circuits to ABC Radio Australia, Melbourne became available. Installation Engineer, Brian Woodrow.

Broadcast receiver and tape deck installed in Lounge Car of Commonwealth Railways train travelling between South Australia and Western Australia for entertainment of passengers.

The equipment, built in the Port Augusta Workshops of the Commonwealth Railways during the 1960s, comprised a seven valve triple ganged receiver powered by a AC/DC converted feeding a 5V4G rectifier. The set was tuneable across the MF band and four crystal locked frequencies were provided for short wave reception. Jack Strachan played a major role in the design and development of the facility.

Imported miniature solid state receivers marketed as Purse Set (left) and Wrist Set in 1970s. Following the introduction of the first commercially produced all-transistor radio in 1955 under the Sony label, a pocket size version was released the following year.

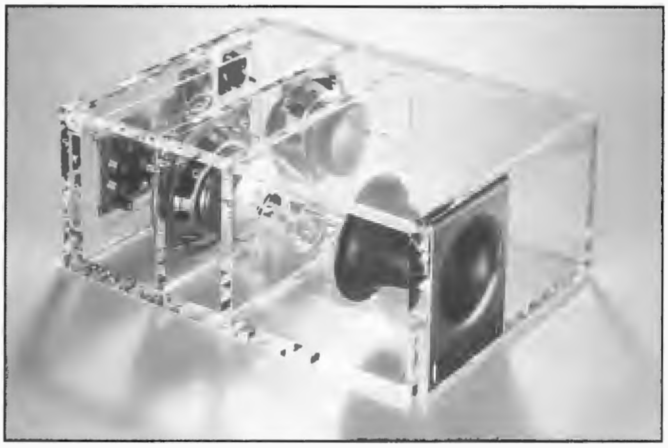
Typical high performance modern receiver. This Sony ICF2000D receiver purchased in 1985, employed a quartz controlled phase locked loop (PLL) synthesiser system with a microcomputer for pin-point tuning. It gave a choice of direct, manual, scan, memory or memory scan tuning. Up to 32 stations could be memorised for instant tuning at the press of a button. It operated from three dry cell batteries.

Reconnaissance position with three Racal HF receivers type RA117-C2 and panoramic adaptor at Receiving Station, Cox Peninsula, 1969. The equipment was used for collection of occupancy data as part of work in preparing Radio Australia transmission frequency schedules. The panoramic adaptor provided a visual representation of transmissions in a band at a particular time. Operator, Mal Stewart.

Acesat Satellite Corporation Pty Ltd receiving dish beamed on Ominicast satellite for programs for Totalisator Administration Board of Queensland, Thursday Island FM transmitter. The station was one of sixteen Queensland country stations commissioned during 1993 for the TAB. Dishes for the network were supplied as 3 or 3.7 metre diameter.

(A)

An example of 1995 technology applied to home hi-fi equipment. It is the Bose Lifestyle 20 Music System featuring very small Jewel Cube loudspeakers, CD changer with a six-CD magazine, stereo AM/FM radio with 30 presets and remote control facility. The Bose system also employed an Acoustimass bass module. Three built-in amplifiers provided 200 watts total audio power.



(B)

Plexiglass display model of Bose Acoustimass bass loudspeaker which launched sound into the room by an air mass, rather than directly from a vibrating surface.

Below and the following pages:
Some early loudspeakers. All except two were imported models sold in Australian Radio Shops or supplied with receivers in the 1920s.

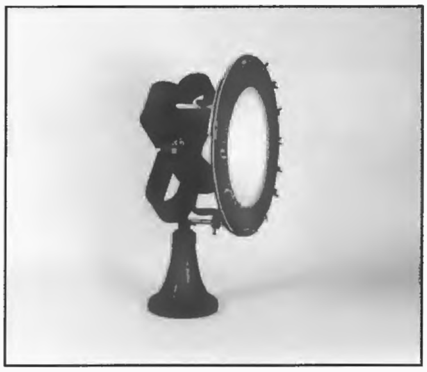
1.
A small vertical horn fixed to a plated brass base which housed an iron diaphragm secured at the edge by a ring. Imported from UK in 1922.

2.
Locally made loudspeaker using a 'jam tim' small straight neck horn on a base of unknown origin. Made in 1922.

3.
BTH Type C2, 1923. Made by British Thomson-Houston Co., Ltd, UK. Aluminium swan neck, painted aluminium flare, brown bakelite base and air gap screw for adjustment of sensitivity.

4.
Burndept Ethovox Type 750, 1923. Made by Burndept Ltd, UK. Sectioned mahogany petal design flare held together with metal ribs. Painted metal swan neck and cast metal base.

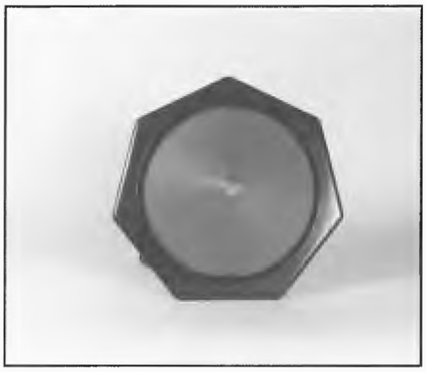
5.
Sterling Baby, 1923. Made by Sterling Telephone and Electric Co., UK. Metal horn with sprayed leaf decoration in antique gold in the flare. Sensitivity control lever in base unit.



6.
Cone loudspeaker made by George Ramsay, Adelaide 1924. Featured eight horse shoe magnets as used in motor cycle ignition system. Heavy cast iron base.

7.
Amplion Dragonfly Type AR102, 1924. Made by Alfred Graham and Co., UK. Spun aluminium flare and cast metal horn. Black crystalline enamel finish.

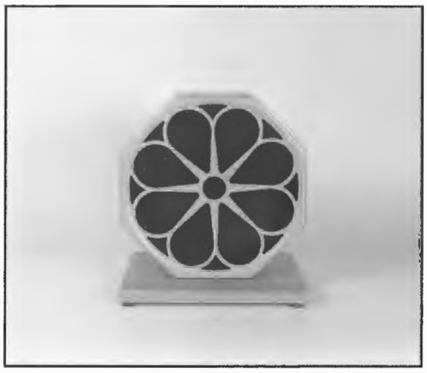
8.
Siemens, 1924. Made by Siemens Bros., UK. Cast metal base, spun aluminium flare and aluminium swan neck. Black enamel finish.



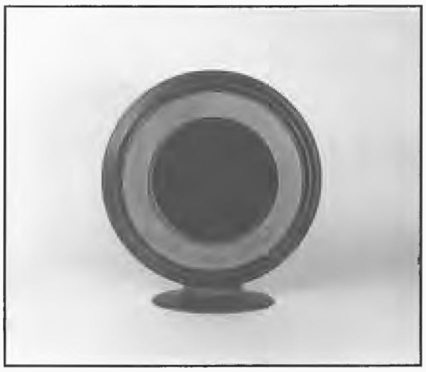
9.
Philips Baby Grand, 1923. Made by Philips, Holland. Septagonal shape with four pole balanced armature drive system. Could be hung on wall or placed on cabinet of set. Two tone switch.

10.
Amplion Radiolux, 1925. Made by Alfred Graham and Co., UK. Folded horn with reflector dish inside cabinet. Mahogany cabinet. Also available in metal cabinet.

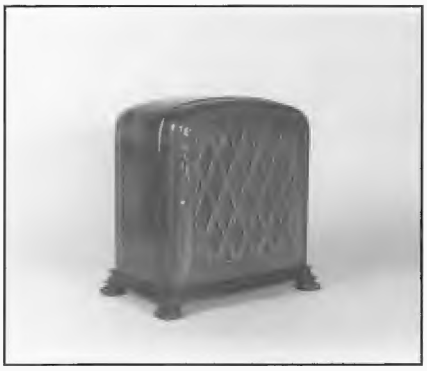
11.
Hegra Cone, 1925. Made in Germany. Single pole drive type with adjustable diaphragm to control sensitivity.



12.
Pausin Cone, 1926. Electromagnetic type with free edge cone. Wooden base.



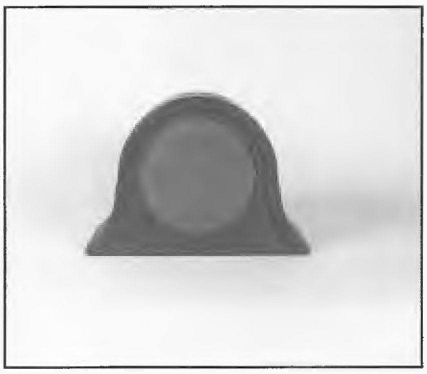
13.
Rola Cone Recreator, 1926. Made by Rola Co., USA. Magnetic cone type and supplied with matching transformer. Hardwood baffle disc and cast base.



14.
Kolster Cone Reproducer Model K6, 1928, Made by Kolster Radio Corpn, USA. Wooden cabinet embossed by a steam heated mould during manufacture.

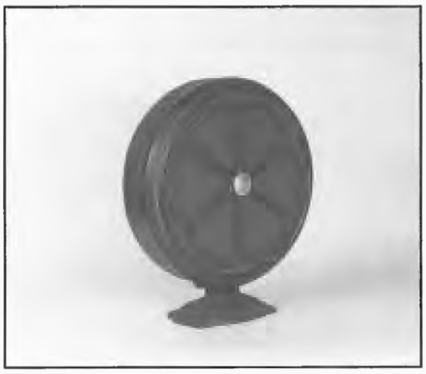
15.
Celestion Cone C12, 1927. Made by Celestion Radio Co., Ltd UK. Piston diaphragm. Both sides of paper cone reinforced with copper wire. Mahogany cabinet.

16.
Reichman-Thorola, 1925. Made by Reichman Co., USA. Burnished bakelite horn with gold coloured throat band. Mica diaphragm with powerful magnet and driving rod.



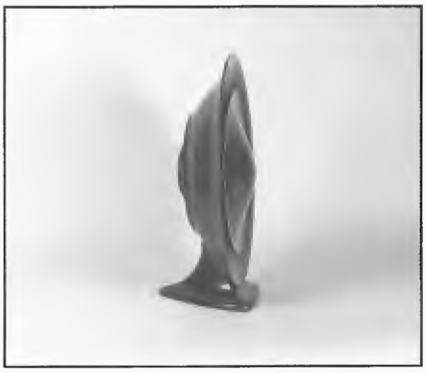
17.
Steward-Warner Magnetic Cone Reproducer, 1927. Made by Stewart Warner Corpn, USA. Bidirectional in cast metal case. Four pole balanced armature system.

18.
Kellogg Symphony Reproducer, 1925. Made by Kellogg Switchboard and Supply Col., USA. Magnetic diaphragm. Moulded non metallic composition body and flare with black and gold crocodile pattern finish.



19.
Atwater Kent Model E, 1926. Made by Atwater Kent Manufacturing Co., USA. Black body with gold colour name disc.

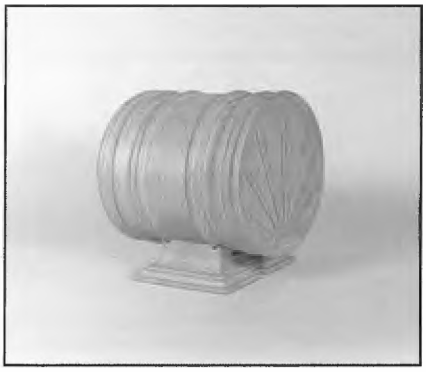
20.
Atwater Kent Model E2, 1927. Made by Atwater Kent Manufacturing Co., USA. Very thin wood veneer cone. Black metal body with gold colour base.



21.
Mullard Pure Music Model E, 1927. Made by Mullard Wireless Service Co., UK. Paper cone driven by moving iron mechanism. Mottled brown bakelite body with cast metal base. Similar model by Philips.

22.
Utah Cone, circa 1926. Made by Utah Radio products Co., USA. All wooden enclosure with elaborate embossing. Utah were the largest manufacturers of loudspeakers in USA at the time.

23.
Philips Sevenette, circa 1927. Made by Philips Holland. Plastic cased and incorporating four pole balanced armature drive system.



24.
Operadio Senior, 1928. Made by Operadio Manufacturing Co., USA. Featured a horn moulded in the shape of a human ear. Drive system acted on an aluminium diaphragm. Patented 1927.

25.
BTH Type E form B, 1928. Made by British Thomson-Houston Co., Ltd, UK. Moving iron drive system. Moulded brown colour bakelite body. Earlier versions made in 1925 featured chrome plated metal body.

Chapter Seven

The Broadcast Manufacturing and Retailing Industry

The Origin

The radio manufacturing industry in Australia had its origin many years before the first broadcast station began transmission in 1923.

The first large scale manufacturing organisation was The Maritime Wireless Company (Shaw System) Ltd, established by Father Archibald Shaw, a Catholic Priest in September 1911 in partnership with Kirkby and Sons who earlier had been in business manufacturing electrical appliance equipment. Shaw had been a former Post Office Telegraphist at Goulburn after leaving school. He was ordained as a Catholic Priest during June 1900.

The factory was located in a large galvanised iron building at 4 Dutruc Street, Randwick, a Sydney suburb. It was directly behind a house on the property known as 'ASCOT' which had been purchased by the Catholic Church in 1907 to house the Procurator and to serve as a Sanatorium for sick missionaries.

The Company produced wireless equipment initially for ships and for planters and traders in New Guinea. An experimental wireless station and a 76 m tower formed part of the facilities for testing the long range efficiency of ship's wireless installations. Callsign was XPO.

It was during this period that the Australian Government became interested in establishing Coast Wireless Stations for communication with ships at sea.

The Naval authorities in particular, were keen on the establishment of Coast Wireless Stations as part of their Defence role and in 1907, a Conference consisting of Admiral Henderson and representatives of the Postmaster General's Department and the Defence Department recommended the construction of a network of stations at strategic locations around the Australian coastline.

Tenders were called for the work the following year but none of the bids was accepted.

In October 1909, tenders were again called, but this time, for the construction of high power stations with a range of 2000 km at Pennant Hills, Sydney and Applecross, Perth only. The tender submitted by Australasian Wireless Limited of Sydney which offered the Telefunken 8 kW RF output quenched spark system produced by the Telefunken Company in Germany was accepted. The Sydney station was commissioned on 19 August 1912. They operated over the band 300 to 3500 metres. However, they were not the first stations to be operational.

Following the letting of contracts for the Sydney and Perth stations, the Government awarded a contract for 17 stations of 5 kW RF output to Father Shaw's Maritime Wireless Company (Shaw System) Ltd in the face of strong overseas competition.

The first station commissioned employing the Australian manufactured equipment was at Melbourne. It went to air on 8 February 1912 followed by a station at Hobart on 30 April 1912. They both preceded the Telefunken stations at Sydney and Perth.

By May 1914, all the 17 stations forming part of the Australian equipment contract had been commissioned. The last station to go to air was at Wyndham when transmissions began on 18 May 1914.

It is not clear as to who deserves credit for the development of the system employed for the Australian constructed stations made in Shaw's factory. In a book written in 1920 by Walter Sweeney who was Construction Engineer of the Commonwealth Wireless Branch and Inspector of Wireless Telegraphy Royal Australian Navy, he refers to the system as the 'Commonwealth or Balsille System' claiming it to be the invention of John Graeme Balsille who at the time was the Government's Engineer for Wireless Telegraphy. Sweeney claimed that the Balsille system was recognised throughout the world as a distinct new system and was the first and only unidirectional impulse system known. With the establishment of broadcasting in the 1920s, Sweeney with a partner manufactured radio receivers under the brand 'Essanay'.

At its peak, Shaw's factory employed some 170 people including trainees. The factory comprised a number of departments or shops including machine, pattern, electrical, punch press, winding, tool and moulding. Each shop was supervised by an experienced Manager or Superintendent.

Many of the workmen who received training and experience at the factory, later became involved in the establishment and operation of broadcasting facilities. Two apprentices who later became well-known in Broadcast Engineering were Raymond Cottom Allsop and Frederick Henry Paton. Allsop became associated with the establishment and operation of 2BL the first broadcast station to go to air, and later, was Director and Chief Engineer of Raycophone Ltd. Paton founded Paton Electrical Pty Ltd, manufacturers of radio test equipment.

In mid 1913, with a change in Government, the new Government switched its support for the purchase of wireless equipment to the newly formed Amalgamated Wireless (A/Asia) Ltd and in the face of declining orders, Shaw's factory scaled down its operations. By this time, the factory was making 18 pounder shells and repairing machine guns as part of the War effort.

Father Shaw offered the factory and patents to the Postmaster General's Department but the Department was not interested. However, after some discussions about purchase price, the Navy purchased the business on 18 July 1916 for 55000 pounds and placed it under control of the Garden Island Naval base. The factory was kept busy producing equipment including transmitters, receivers, telephone equipment, generators and engines for the Armed Forces. It was known as the Randwick Wireless Works and frequently referred to as the Randwick Naval Wireless Station. It included a well-equipped laboratory where special items were developed and trialed for the Navy. Ray Allsop spent several periods in the laboratory, remaining there until the Naval authorities ceased operations at the site. Projects on which Ray worked at the laboratory included a receiving circuit which incorporated a 'weeding out' circuit, an intermediate circuit used when sharp tuning was not necessary, and an 'interference preventer' designed to give high selectivity during reception of signals during difficult conditions. The laboratory also acquired a number of valves from the USA and Ray developed several circuits to employ the valves. One circuit provided for the valve to be shunted across a tuned circuit while another provided for the valve to be located in a closed untuned circuit.

At one stage, the Works were under the control of Albert Cornwall, Chief Mechanic and Works Manager. Fred Henderson, later Director and Manager of Howard Radio Pty Ltd, was one of the Supervisors.

Several items of equipment built at the Works have survived, and are in vintage radio collections. One is a receiver built for the Navy. It is a loose coupler circuit with two fixed crystal detectors and a bias voltage, probably employed with a carborundum detector. All fittings are of brass and ebonite, with equipment mounted on an ebonite panel. The case is solid mahogany.

After the First World War, there was no further need to continue the factory operation for Defence purposes and it was transferred to the Department of Repatriation where it was used to train ex-Servicemen for civilian occupations in wireless. By 1922, it had ceased as a training establishment and the building used for other purposes including construction of Wackett Widgeon trainer planes. In recent times, it was used as an Army storage depot.

BROADCASTING ERA MANUFACTURERS

Even before the official commencement of broadcasting in 1923, there were many stores throughout Australia which sold radio parts and even fully assembled receivers, most of which were imported from Great Britain and the USA. Some enterprising Radio Shop owners assembled their own receivers using imported components. As an example of the extent of availability of radio equipment and components, the following include some of the radio retailers active during 1923 in Sydney and components and equipment stocked:

New System Telephones Pty Ltd, 280 Castlereagh Street, NST Wireless receiver, Everest crystal detector, New System headphones, other components; H.G. Watson and Co., Ltd, 279 Clarence Street, Hellesens dry cell batteries, aerial insulators and wire, battery and lighting switches; The Home Electric, 106A King Street, USA made Federal receivers, Paragon valves, de Forest coils and valves, Federal AF transformers, meters, modulation transformers, grid-leaks, rheostats, capacitors, enamelled and cotton covered wire, spaghetti tubing etc; Ericsson, 7 Macquarie Street, Ericsson headphones; Universal Electric Company, 244 Pitt Street, Armstrong Super-Regenerative Receivers, loudspeakers, vario-couplers, fixed and variable capacitors, grid-leaks, Australian made valve produced by the G & R Company, Thordarson and Federal RF and AF transformers, Radiotron and Cunningham receiving and transmitting valves, Baldwin mica diaphragm headphones, Franco dry batteries, radio magazines, vernier rheostats, loop aerials and many other components; Burgin Electric Co,, 352 Kent Street, de Forest components and equipment including Inter-Panel Audio Control and One-Step Amplifier systems; D. Hamilton and Co., Ltd, 283 Clarence Street, aerial insulators and wire, silk, cotton covered and enamelled wire; Anthony Hordern and Sons Ltd, Brickfield Hill, crystal sets and valve receivers, Murdock headphones, Myers and Expanse valves, accumulators, capacitors, coils, resistors, knobs, terminals, dials, studs, crystal detectors etc., L P R Bean and Co., 229 Castlereagh Street, Stromberg-Carlson headphones, microphones, plugs, jacks, RF and AF transformers, Cotoco inductance units, variable and fixed capacitors, grid-leads etc; Miss F V Wallace, Electrical Engineer, 6 Royal Arcade, a wide range of wireless supplies for the experimenter and hobbyist; Electricity House, 387 George Street, an extensive range of fully assembled crystal and valve receivers, parts, components, wiring diagrams, magazines and catalogues; J J Hoelle and Co., 57 Goulburn Street, crystal sets including American Boy Radiophone, and an extensive range of components; Continental Radio and Electric Co., 165 Kent Street, Australian agent for Graham radio equipment including patented variable capacitors and coils, grid-leaks and transformers; Ramsay Sharp and Co., Ltd, assembled crystal and valve receivers and a range of parts with some parts being manufactured locally.

There were many other agents and distributors in the city and suburbs of Sydney as well as in NSW country centres, indicating the extent of interest by experimenters and hobbyists in radio, even before the establishment of the first A Class broadcasting stations. It was a similar story in other States.

With the commencement of broadcasting, many new companies were formed to manufacture equipment, particularly domestic receivers, and those companies which had already been formed in a small way developed plans to expand their activities.

By 1926, several organisations such as Radio Corporation of Australia, Kriesler, Airzone and Amalgamated Wireless (A/Asia) Ltd, were producing receivers, and other manufacturers soon followed.

Manufacturers were encouraged by the growing demand for receivers as the public interest in broadcasting increased. In 1925, the PMG's Department issued some 63000 listener's licences. In 1926 the number doubled to about 128000 and almost doubled again in 1927 to 225000. From that period, however, demand tapered off as the licences showed only a small growth resulting from the economic downturn conditions facing the nation. Nevertheless, broadcasting popularity was not declining, and it was, in fact, one of the few growth industries in the country during the Depression years.

From about 1932, when the Australian Broadcasting Commission took on responsibility for the provision of programs for the National Broadcasting Service, the increase in listener's licences was evidence of renewed interest in purchasing receivers and demand jumped considerably. About 1933, the number of listener's licences issued reached the half million point and during 1937 doubled, to pass the one million mark. It is estimated that in 1933, there were 243 registered Radio Manufacturers producing receivers and components.

Hundreds of Salesmen earned a living by selling radio receivers during the 1930s. Some were permanent employees based in a Radio Shop or Department Store while others travelled far and wide throughout the nation. The majority were paid a Retainer plus Commission on sales. Typical was an experienced Radio Salesman working from a business in Byron Bay in northern New South Wales. The business stocked a full range of Stromberg-Carlson and AWA receivers. In 1937, the Salesman was paid £2.10.0 Retainer plus 10 % on all sales. Another Salesman working from a business which also sold furniture at Walcha not far from Armidale in New South Wales was paid £2.10.0 Retainer and 7½ % on all sales. Both Salesmen were expected to own a car, be capable of undertaking a complete home installation and to be proficient in test equipment operation.

By the end of the 1930 decade, listeners were being served by some 127 operational stations. It was also a period of great advancement in broadcasting technology with three Australian organisations being actively engaged in major Radio Research activities.

Most of the major manufacturers conducted a program of research and development, at various levels, depending on the available expertise, to improve their products. Even though in many cases, those people working in the company laboratory were not University trained Researchers, they made important contributions to the advancement of Broadcast Engineering. Some inventions were subject to patents. However, the number of patents granted to Australians was only a small fraction of the number granted to overseas radio organisations, particularly such companies as Marconi Wireless Telegraph Co.; Hazeltine Corporation; N V Philips; The General Electric Co., Ltd; Telefunken Co.; Siemens and Halske; Radio A G D S Loewe; Johnson Laboratories and others. For instance, in 1933, of 100 patents granted by the Australian Patents Office, 50 were from USA, 35 from United Kingdom, 15 from Germany and only 5 from Australian individuals or organisations. The Australian patents included a volume control potentiometer, coil formers, valve sockets, resistors and dual capacity fixed capacitors.

Five years later, in 1938, the position had hardly changed with only 8 patents being issued to Australians out of a total of 213 patents. On this occasion, the Australian patents concerned a tuning dial, bias supply, radio cabinet, loudspeaker, resistors, sound records, sound recording apparatus and equipment for ionospheric investigations.

Manufacturers engaged in the design and production of home receivers during the 1930s concentrated their efforts towards improvement in selectivity, noise suppression, automatic volume control, simplified station tuning, band spreading, automatic frequency control, better dial display features, tone compensated volume control, combined radio/record player models, all-wave receivers, lightweight portables, improved loudspeaker systems and enclosures, multifunction valves and better overall receiver fidelity.

Many novel arrangements were produced in simplifying tuning, with such devices as push-button and finger dial systems being widely employed. However, many listeners were disappointed with them. Some did not tune in accurately, the setting varied with temperature and the mechanisms frequently failed. Although high hopes were held for automatic tuning it failed to live up to expectations, and after the War it was seldom seen. On the other hand, automatic volume control was incorporated in most receivers and quickly became commercially acceptable.

With transmitter designs during the same period, manufacturers paid a lot of attention to the series modulation technique and a number of transmitters were installed at Commercial stations. Development in the use of top loaded vertical radiators was actively pursued with much work being undertaking by the PMG's Department staff for the use of this type of aerial in the National Broadcasting Service.

Improvements had also been made in improving the transmitter operating frequency stability by developments in quartz oscillators. During the 1930 decade, 10 kW transmitters designed and manufactured in Australia were introduced into the National service and remained the most powerful medium wave broadcast transmitters in service until 1958 and 50 kW models were progressively installed at some country and metropolitan centres.

One of the most important developments in recent times which brought about major changes in Broadcast Engineering technology was the invention of the transistor and its subsequent solid state off-shoots. In the 1960s, transistors replaced valves in receivers and were gradually introduced into studio and transmitting equipment. Today, even 50 kW MF transmitters employed at National stations are fully solid state designs and the 250 kW Thomson CSF TRE transmitters installed in 1993 at Radio Australia Cox Peninsula were solid state except for the final stage which employed a 500 kW rated TH558 valve.

In the mid to late 1960s, Australian manufacturers were producing about 450000 broadcast receiver and combinations a year, to meet the local market. Slightly less than half of the output were portable designs. Car radios comprised about one third and mantel, radiograms and record player units comprised the remainder.

Many of the large combinations were mixtures of valves and transistors. Typical was the 1967 Kriesler Model 11-110, a six valve, eight transistor and four diode broadcast band stereogram-tape recorder unit housed in a single polished timber cabinet. An 8 inch (200 mm) twin cone loudspeaker Rola type C8MX was provided for each channel. The receiver employed six valves including a full wave rectifier but the tape deck circuitry utilised a printed circuit board with associated components. It contained six silicon NPN and two germanium PNP transistors and two diodes. The silicon transistor section provided two pre-amplifiers — one for channel — which functioned on Record and on Playback. The germanium transistor section constituted a 52 kHz push-pull oscillator for erase head volts and for Record/Playback bias. A diode for each channel rectified the signal output for Recording Level indication.

Stereophonic reproduction was a normal feature of both the radiogram and the tape deck.

Unfortunately, in 1972 the Government of the day removed the tariff that had protected the radio manufacturing industry since the early 1930s, so opening the Australian market to a tidal wave of imported electronics components and fully assembled receivers at a price which the Australian manufacturers could not match.

Local component and receiver manufacturers scaled down their operations and within a few years, the production of broadcast receivers in Australia ceased.

By the time FM radio broadcasting had been firmly established and there was a demand for receivers to receive the FM transmissions there were no manufacturers prepared to invest large capital expenditure and tool up to begin production of FM receivers. Most of the nation's requirements have been supplied from overseas sources.

Three of the major firms of the 1920–70 era still active today, AWA, Philips and STC (now Alcatel) no longer produce domestic receivers or broadcast transmitters in Australia.

AIRZONE (1931) LTD

The large Airzone company grew from facilities established by Claude Plowman. Mr Plowman, educated in Hobart, served on Merchant ships during the First World War and soon after the War served as Chief Instructor at the City Academy of Engineers, London, specialising in Marine Engineering.

In 1920, he moved to the USA where he was connected with Colin B Kennedy Co., one of America's early receiver manufacturers. The Company began by providing short wave receivers for the public in 1919 followed later by broadcast MF band models. The Company established a reputation for high quality expensive equipment which was marketed as 'The Royalty of Radio'.

With this background in receiver manufacturing, Mr Plowman returned to Australia in 1924 and established his own business.

A room was rented in the Wentworth Building in Dalley Street, Sydney and he began assembling crystal sets and making most of the components. Business expanded rapidly, and more space had to be found. A number of critical components were assembled on the spot, and the company became expert in winding coils with high stability properties. They put this to good use and in addition to their own requirements, assembled coil sets for many popular receivers being described in the magazines at the time. These included coil sets for Neutrodyne, Browning-Drake and others which were difficult to make by do-it-yourself receiver constructors with limited machinery or expertise at their disposal.

One of the most popular kit sets produced by the Company was the Swan Neutrodyne kit. It was available from most Radio Shops and was one of the top sellers at Louis Coen Wireless Pty Ltd shops. The coils were wound on green coloured bakelite formers with the wires being space wound. The primary was placed inside the secondary with all terminals being on the secondary former. A bracket was attached to the coil to give the correct mounting angle for the neutroformers (57°). The wires were wound in threads cut in the formers. The kit comprised three coils allowing for two stages of radio frequency amplification. The Neutrodyne circuit was so popular in the United States, that in 1927, it was estimated that there were some 10 million receivers in operation using the Neutrodyne circuit. A large number of these were built using kits.

By 1926, the need for more space and engineering facilities became pressing and a complete existing Engineering Works at Enfield was purchased. Even this move did not fully satisfy growth requirements, so a factory was established at Paddington, where there was a floor space of 400 square metres, more than sufficient to increase output with a workforce approaching 100.

In 1926, the company produced its first Airzone brand battery-powered portable receiver of four valves. It was such a success that very little change to the design was made over a four year period when total sales exceeded 10000 units.

A further change in location took place in 1928 when a large building was acquired at 16–22 Australia Street, Camperdown. Although not fully occupied initially, it was not long before all the space was put to good use. Claude Plowman was Managing

Director; Walter Homewood, Sales Manager; and Philip Parker, Production Manager.

During 1931, the business went through a process of major reorganisation, and the name changed to Airzone (1931) Ltd. At the time, nominal capital was £100000.

One of the major changes of the new organisation was to cease manufacturing unbranded chassis for other firms to market under their own name, and to concentrate on high quality products bearing the Airzone brand name. However, there is some evidence that the company changed this policy in later years. As part of this move, a system of quality control was implemented to ensure that the purchaser would have minimum trouble with the receiver and, hopefully, the firm would build up a reputation of producing reliable receivers.

One of the first receivers produced about August 1931 was the Airzone Cub, a two valve TRF circuit plus rectifier. It featured screen grid-valve and Magnavox dynamic loudspeaker. The little set was a winner, and thousands were sold through Radio Shops.

Models released in early 1932 included:

- Model 320C, a shielded AC powered phono-radio combination in console cabinet and employing six valves. It was also available as a 'radio only' version. The set employed three variable mu screen grid RF stages using 235 type valves; 224 as screen grid anode detector; 247 penthode AF output; and 280 rectifier. Loudspeaker was a Magnavox dynamic type.
- Model 330C, a similar chassis to Model 320C but housed in a different cabinet design.
- Model 310, a four valve AC powered receiver employing variable mu penthodes, screen grid detector and rectifier. Controls included a selectivity switch.
- Model 350, employed a similar chassis to Model 310 but was housed in a different cabinet design.

All cabinets employed selected veneers finished in high quality piano lustre.

Models available during late 1932 and early 1933, included:

- Model 501, a five valve AC powered superheterodyne receiver housed in table type cabinet. Valve types which included the latest six and seven pin types were 57 (two), 58 and 280 rectifier. It featured Magnavox dynamic loudspeaker; Airzone variable capacitor floated on rubber bushes; cadmium plated chassis and gramophone pin jacks.
- Model 909, a high quality nine valve superheterodyne receiver fitted with Magnavox dual loudspeakers and provided with 'free set insurance against fire and burglary'.
- Model 404, a five AC powered TRF set with spotlight full vision dials and employing valve types 57, 58 (two), 59 and 280 rectifier.
- Model 303, a four valve AC powered superheterodyne set with valve types 57, detector oscillator; 58, IF amplifier; 59 detector, amplifier; and 280 rectifier.

Model 305, a four valve superheterodyne set, and Model 510 a five valve superheterodyne set, were also available. They featured cabinets designed and built by Dickin, one of Sydney's leading Cabinet Makers.

Two popular Airzone battery-powered consoles available in Radio Shops in mid 1934, included:

- Model 801, an eight valve superheterodyne receiver with 175 kHz IF and using valve types 34, RF amplifier; 34, detector; 30, oscillator; 34, IF amplifier; 32, second detector, 30, driver; and two 49s Class B push-pull output. A battery was a 2 volt Vespa accumulator while B battery was four 45 volt Diamond Super Service B batteries in series.
- Model 530B, a five valve receiver with 455 kHz IF and using valve types 15, autodyne; 34, IF amplifier; 15, second detector; 30, driver; and 19 Class B output. A battery was a 2 volt Vesta accumulator; B battery comprised three 45 volt Diamond Heavy duty types in series; and C battery was a 22.5 volt Ever-Ready type.

In 1935, the company opened a Branch in Melbourne. Up to that time, Frank Harvey Arco House, Coles Place represented Airzone. One of Frank Harvey's Servicemen was Graeme MacKenzie who continued with Airzone for some time before leaving to work with another retailer. The Managers of the Melbourne Branch were from the Sydney office with Don Gow being one of them. Don became associated with the commercial radio industry soon after his discharge from the AIF following the end of the First World War. He had served in the Signals Corps where he worked on Army wireless telegraphy equipment and operation. He had wide experience in both the managerial and technical aspects of the industry having over a number of years occupied positions in factory management, public relations, engineering and tool making and receiver production activities.

About September 1935, Airzone released a reflex circuit broadcast receiver employing the 6B7S logarithmic duo-diode-pentode as a combined IF and AF amplifier, demodulator and AVC voltage rectifier. Other valve types were 6D6, RF amplifier; 6A7, frequency converter; 42 output pentode; and 80 rectifier.

By 1936, the staff employed exceeded 300 and seventeen different models were being manufactured. The models ranged from four valve to eight valve types and included battery, universal and AC powered units. The majority of mantel cabinets were moulded of zonite at the factory. The top of the range was an eight valve console model featuring two speed tuning, band-spreader, push-pull audio output and 12 inch (30 cm) speaker. It sold for 42 guineas.

In line with trends at the time towards designs featuring mechanical forms of automatic tuning, Airzone produced Model 596 in mid 1938. It was fitted with the Airzone Tele-Dial which provided a means of selecting any eight stations in the MF band. The receiver was an AC powered dual wave type in a solidly constructed veneer wooden cabinet.

Valve types were octal based glass series comprising 6A8G, frequency converter; 6U7G, 465 kHz IF amplifier; 6B6G, detector, AVC rectifier and AF amplifier; 6F6G, output pentode; and 5Y3G, directly heated rectifier.

The Tele-Dial buttons were carried on a slotted bronze ring attached to the dial scale. A station was tuned-in by depressing the desired station's button, and carrying it around to a spring-loaded locking position. The receiver output was automatically muted during the tuning operation. Because the Tele-Dial was also fitted with a tuning knob, stations not automatically tuned, and short wave band stations, could be tuned-in in the usual manner.

Just prior to the Second World War, 30 different models were in production. Mr Plowman was still Managing Director of the company and Chief Engineer was Geoffrey Menon, who had previously worked with the Stewart Warner Corporation in USA and Firth Bros., Pty Ltd, in Sydney before joining Airzone in 1934. Others who served with the company include:

W Godrey, K H Chittock, W E Gill and Philip Parker. Philip Parker who was Works Manager, presented a paper at the World Radio Conference held in Sydney in 1938 in which he outlined new types of coils being developed by the company for broadcast receiver application, new materials being employed and machinery being developed to allow the production of high quality coils. The work done resulted in the coils being manufactured, being equal to those produced anywhere in the world.

During the War, in line with other companies, Airzone produced equipment for the Services, including radar equipment, cathode ray oscillographs, wavemeters and many non-radio items such as carburettors and hand grenade casings, using their well-equipped engineering workshop to maximum advantage.

During 1940, Airzone produced two dual wave models aimed at a buying public that had become increasingly interested in events taking place in Europe because of the War. The models were Model 1052A, a five valve receiver, and Model 1062A, a six valve receiver. Both models covered bands 1600 kHz to 550 kHz and 13 to 42 metres.

Valve types employed in model 1052A were 6J8G, 6U7G, 6G8G, 6V6G and 5Y3G. The Model 1062A had the same valve lineup but with the addition of a 6U7G RF amplifier.

Both models were enclosed in a veneered wooden console type cabinet. Table models available at the same time, were the Radio Star Model 550A, a five valve AC powered MF band receiver; and Model 542A, a four valve AC powered MF band receiver.

Early the following year, models released included Model 6851V, a five valve vibrator/battery-powered receiver; Model 6521A, a five valve AC powered MF band receiver; and Model 6252A, a five valve AC powered dual wave receiver.

Model 6851V was housed in a Concert Star mantel cabinet. Valve types comprised 1C7G, frequency converter; two 1M5Gs, 456 kHz IF amplifier; 1K7G, detector, AVC rectifier and AF amplifier; and 1L5G, output pentode. The valve filaments were wired in a series-parallel network to enable operation from the 6 volt accumulator which also fed the synchronous vibrator/converter unit. Total drain from the accumulator was 1.05 ampere.

By mid 1941, Airzone receivers available in Radio Shops included:

- Model 1452A, a five valve AC powered dual wave receiver in a console cabinet.
- Model 1552V, a five valve dual wave receiver in console cabinet powered by vibrator/battery system.
- Model 458, a four valve AC powered receiver covering the MF band in Junior Star mantel cabinet with walnut finish.
- Model 459, a four valve battery-powered receiver using 1.4 volt filament valves and housed in the Junior Star cabinet.
- Model 1362A, a six valve AC powered dual wave receiver in console cabinet.
- Model 1652A, a five valve AC powered dual wave receiver housed in a console cabinet.

The Model 1652A featured a large square edgelit dial of the inertia drive type providing 330 degree movement; negative feedback; and 12 inch (30 cm) loudspeaker. The valve lineup comprised 6J8G, converter; 6U7G, IF amplifier; 6G8G, detector; 6V6G, output tetrode and 5Y3G rectifier.

The Model 1362A, had a similar valve lineup to the 1652A but with the addition of a 6U7G RF stage ahead of the converter.

- Model 458, a four valve receiver in a moulded cabinet powered from 200–250 volt AC mains. It was known as the Airzone Cub and employed valve types 6A8G, frequency converter; 6G8G, IF amplifier and detector; 6V6G, beam power output tetrode and 6X6GT rectifier.

During 1940, Airzone produced a range of about 25 models for Peal Products Ltd under the Peal label. Others under the same label were manufactured during 1948.

After the War, the company became part of the Electricity Meter Manufacturing Co. (EMMCO), a firm which had been in the radio component manufacturing business since 1925. In the mid 1930s the company produced a range of EMMCO receivers as well as manufacturing models for other organisations. The EMMCO company had itself in 1937 become part of a holding company known as Electricity Meter and Allied Industries Ltd (EMAIL).

AMALGAMATED WIRELESS (AUSTRALASIA) LTD

The Australian Government's decision before the First World War to construct a chain of Coast Radio Stations led to the establishment of a second Radio Manufacturing company during the period.

A number of major overseas companies had tendered for installation of the stations, and when it was announced that Father Shaw's Maritime Wireless Company had been given the contract using a design by John Graeme Balsillie, an Australian, there was enraged outcry from international firms, including Marconi's Wireless Telegraph Company Ltd, in England. Complex legal manoeuvres ensued, regarding patent infringements and the end result was the formation of an Australian company to represent the world's leading systems in Australia and New Zealand.

The company, Amalgamated Wireless (Australasia) Limited was incorporated on 11 July 1913 and acquired the Australian good-will, including Patent rights of Marconi's Wireless Telegraph Co., Ltd and Australasian Wireless Limited which represented the German Telefunken Company and also associated companies in France, USA and elsewhere.

Sir Hugh Denison was the first Managing Director, and Ernest Fisk was appointed Technical Director and General Manager. The paid up capital of the company was 140000 one pound ordinary shares. The registered office was at 'Wireless House', 97 Clarence Street, Sydney. Principal shareholders were Marconi Wireless, London; International Marconi Communications Company, London; Telefunken Company, Germany; together with E T Fisk, W H Payne, H R Denison, C P Bartholomew and W McLeod. All these latter gentlemen were from Sydney. Denison and McLeod were proprietors of 'The Bulletin' and principal promoters of the magazine, 'Australasian Wireless Ltd' established on 27 May 1910. Charles Percy Bartholomew, an executive of Beard, Watson and Company, a Sydney retailer, like Fisk had a background in Wireless Engineering. He had operated spark wireless telegraphy station XBM at Mosman since 1906.

The first Directors of AWA were Hugh Denison, John Jolly, Charles Bartholomew, Ernest Fisk and John Forrest. John Forrest was company Secretary. The first Annual General Meeting was held at BMA House, Elizabeth Street, Sydney on 27 August 1914.

During the War years, Denison, Jolly and Forrest resigned from the Board and in 1918, the Directors comprised Hon. Sir Thomas Hughes MLC, Chairman; Ernest Fisk, Managing Director; Charles Bartholomew; Alfred Goninan; Jas Taylor; and Capt J Langley Webb. Mr J F Wilson was acting Secretary. He was subsequently appointed to the position on a permanent basis.

Hugh Denison later acquired shares in Broadcasters (Sydney) Ltd 2BL, through his newspaper interests and in 1936, purchased a controlling interest in 2GB. He set up a group known as the BSA Players in order to promote broadcasting dramas written in Australia about Australian subjects and using Australian players. The letters BSA stood for Broadcasting Service Association. In 1938 he formed the Macquarie Network comprising 2GB and 13 other stations. It was the most powerful network in Australia and by about 1940 was the largest producer of radio drama in the British Commonwealth.

John Francis Wilson, although appointed as Secretary had a technical background. He joined Marconi's Wireless Telegraph Company in England in 1909 as Marine Engineer-Operator and was involved in the construction of wireless land stations and shipboard wireless telegraphy installations in United Kingdom, Brazil, South Africa and Canada. He joined the Australian Branch in Sydney in 1911 with Ernest Fisk and joined AWA on formation of that company. In 1922, he became Secretary and Assistant Manager and in 1945 was appointed Assistant General Manager and Secretary.

Charles Bartholomew remained on the Board until 27 July 1942 and during his long association with the company acted as Chairman on several occasions. At the 1922 General Meeting at which he acted as Chairman he announced that the Authorised Capital of the company had been increased to £1 million with the Subscribed Capital having increased by over £90307. At the time, the Board comprised Charles Bartholomew (Actg Chairman), Ernest Fisk, Capt T Langley Webb, Sir W M Vicars, G Mason Allard and J Stinson with company Executive Officers including Ernest Fisk, Managing Director; John Wilson, Assistant Manager and Secretary; Fred Larkins, Chief Accountant; John Mulholland, Traffic Manager; D Campbell, Equipment Manager; Stan Grime, Factory Manager; George Apperley, Technical Superintendent; Sydney Tatham, Manager Wireless Press; A R Mancer, Superintendent Wireless School; V Gardiner, Sales Manager; Lionel Hooke, Melbourne Branch Manager and G Robertson, New Zealand Branch Manager.

Frederick William Larkins the Chief Accountant, had been associated with wireless activities before the formation of AWA.

He was an Associate of the Commonwealth Institute of Accountants, Associate of the Chartered Institute of Secretaries and holder of a Diploma in Economics and Commerce from Sydney University. He joined the Australasian Wireless Co., Ltd as Accountant in July 1912 and was appointed Accountant with AWA on formation of the company in July 1913. In 1923, he was appointed Publicity and Advertising Manager on creation of a new section to handle those activities.

Fred Larkins was a skilled public speaker and did much to enhance the image of the company. He also wrote articles on the company activities, some of which were published in technical magazines. One article published in the 'South Australian Wireless and Radio Monthly' of 1 December 1924 was titled 'The Romance of Wireless' and gave an outline up to that point in time of the development of wireless in Australia from 1913 when AWA was formed, including the company's role in the manufacture of transmitters for the establishment of broadcasting in Australia. Fred was still head of Publicity and Advertising at the end of the Second World War in 1945.

On its formation in 1913, the company lost no time in building up a viable organisation and in actively seeking business in the rapidly expanding wireless field. Establishment of workshops, research and technical training facilities for the manufacture of wireless equipment and training of Ship's Wireless Operators were high on the agenda.

One of the first major works was the installation of Naval Wireless Station VKQ for the Sydney Garden Island Dockyard. The station was commissioned during August 1914. During the War years the Garden Island Station carried out the duties of a Coast Radio Station. One of the operators was Hugh Taylor who transferred to the station in 1918 from the Sydney Coast Radio Station VIS. Hugh was one of the first people to employ the AWA manufactured Expanse B valves when they became available for receiver application.

Prior to the availability of the AWA manufactured Expanse B valve, valves imported from various USA sources were employed with varying degrees of success. They included types manufactured by de Forest, Cunningham and Roome.

Hugh served at sea as a Ship's Wireless Operator from 1919 until he joined the Island Radio Service in 1936. During the Second World War he was at Manus Island when the radio station was bombed by the Japanese in 1942. When the Japanese landed, he and a party of station staff escaped to New Guinea. In later years, Hugh was on the staff of Adelaide Coast Radio Station and transferred to the new station at McLaren Vale when the station was commissioned in 1963 to replace the original Rosewater Station.

To meet production and service demands, AWA staff numbers increased considerably over the years. In 1915, only two years after formation of the company, 100 people were on the pay roll. By 1922, the number had grown to 400 and by 1926, when output of broadcasting transmitters and receivers were at high levels, the number of people in the work force had doubled to 800. Fifty years after establishment, the staff level had passed 5500 with about half being employed at the main Ashfield works.

Equipment was initially made under licence but it was not long before local designs were being manufactured. At the time the company began operations, there were about 75 ships fitted with wireless equipment. This was only a small proportion of ships in service so the company quickly geared itself to design and manufacture equipment to fit out ships not already equipped and to train staff to operate the equipment. AWA subsequently increased its role in the Australian maritime service by taking over responsibility for the Coast Radio Stations which served the ships.

At the conclusion of the First World War, the company increased its staff level to meet expected high demand for wireless equipment. Two of those people who joined AWA during 1918 were Ern Horner and Stan Grime.

Ern Horner began his working life in Engineering as an Apprentice Electrical Fitter in the NSW Railways and Tramways Workshops at Randwick in 1908. Following completion of the Apprenticeship in 1913, he spent five years working with a number of organisations on various duties including armature winding and work as an Electrical and Mechanical Fitter. One of these organisations was the Naval Wireless Workshops at Randwick previously operated by the Maritime Wireless Company.

When he joined AWA, his first position was as Electrical Draftsman. He later occupied positions of Estimating Engineer, Chief Draftsman, Assistant Works Manager and in 1923, Ern was appointed Works Manager. In this role, he played a major part in the manufacture of broadcast receivers and transmitters.

In 1926, he visited England and USA to study advances in the broadcast manufacturing industry at major organisations. A further visit was made in 1932-33 prior to AWA expanding its manufacturing facilities at the new Ashfield site.

In 1939, when AWA geared up for wartime activities, Ern Horner was Production Manager and by 1945 was Assistant General Manager (Manufacturing). In 1956, he became Deputy-General Manager.

Stan Grime joined AWA after being trained as an Apprentice Electrical Engineer with the Strand Electric Light Company in 1904. He later became Superintendent of the Electric Workshops of the Sydney Municipal Council Electric Light Department.

When he joined AWA, he was appointed to a senior position in the factory, and in 1922, when he was Factory Manager, in pursuance of company policy of sending Engineers abroad for experience and study, Stan together with several Engineers, visited England and the Continent to investigate the latest developments in the manufacture of wireless components and equipment. The group visited major wireless manufacturing organisations in England, France, Germany, Norway, Sweden and Belgium.

On his return, he reorganised the manufacturing facilities on the most modern lines, installing the latest in production equipment and test instruments. In 1924, he was appointed Production Manager and in 1928, became Assistant Manager.

When AWA decided to establish a large valve manufacturing industry, the company sent Stan to the USA to obtain information to assist in planning the facility employing the latest technology.

A subsidiary company Amalgamated Wireless Valve Co., Pty Ltd was registered on 18 April 1932, and valves produced from 1933. In addition to his position with AWA, he was the first Chairman of the Examinations Board of the Institution of Radio Engineers (Aust) in 1933, President of the Radio and Telephone Manufacturers Association, and Chairman of the Radio Panel of the Standards Association of Australia.

Another Engineer associated with works activities for many years was Ernest Parkinson. He was educated in England and Apprenticed to J Parkinson & Son, machine tool makers. Following a term of teaching at Bradford Technical College he returned to J Parkinson & Son as jig and machine tool designer until 1923 when he came to Australia to work at various engineering establishments before joining AWA in 1929 as Works Production Superintendent. He later became Works Manager and in 1956 was appointed Assistant General Manager.

Before the Government granted licences for the establishment of broadcasting stations, AWA was actively involved in demonstrating the advantages and possibilities of broadcasting.

In August 1919, a demonstration was performed for the benefit of about 100 members of the Royal Society in Elizabeth Street, Sydney, and in October 1920, some 400 people were entertained in Queens Hall, Federal Parliament House, Melbourne with speech and music transmitted from a 500 watt station some distance away at Brighton.

In January 1921, a regular weekly broadcast using callsign VK3ME on 1100 metres and later 400 metres was conducted from the company's office in Little Collins Street, Melbourne by Syd Newman. It did much to encourage interest not only by listeners, but by people interested in the technical aspects of broadcast transmission and reception. The service continued up to about the time that regular broadcasting was provided by stations licensed for the purpose.

A similar service was provided in Sydney using callsign VK2ME from facilities located at the AWA Knox Street factory and operated by Alton Vipan.

With the official licensing of broadcasting stations, the company designed, manufactured and installed transmitters for A Class stations 2FC, 3LO, 5CL, 6WF and 4QG over the period 1923 to 1925. With this start in the broadcast transmitter field, AWA continued active involvement to recent times, even to the extent of establishing its own stations.

AWA was also instrumental in building transmitters which it owned and operated to provide Australia's first overseas short wave broadcasting service with station VK2ME in Sydney and others in Melbourne and Perth. The service commenced in 1927, and continued to be operated by the company until the outbreak of the War in 1939.

The advent of broadcasting 10 years after formation of the company gave great stimulus to the manufacture of domestic broadcast receivers and components for manufacture of the receivers resulting in thousands of people being employed to meet the demand. With this activity, the company became for the first time, involved in consumer products.

By the early 1920s, AWA had a well-equipped Technical and Research Laboratory, making substantial contributions to the advancement of Radio Engineering technology.

In 1922, George (later Sir George) Mason Allard was appointed Chairman of the Board with Rt Hon. W M Hughes KC former Primer Minister joining the Board to fill the vacancy left by the promotion of Mr Mason Allard. Sir George remained Chairman until 1931.

In 1925, AWA began the production of a range of broadcast receivers including crystal sets; a four valve Radiola TRF receiver featuring a tuned anode regenerative circuit using valve type AWA109X which was interchangeable with AWA101A and Radiotron UV or UX201A; a two valve Radiophone receiver; a three valve Radiola model consisting of one stage of radio frequency amplification, a detector and one stage of audio frequency amplification and the Radiola Super Six, a six valve superheterodyne circuit receiver with loop aerial and produced as both console and table models with Tasmanian blackwood cabinets. Intermediate frequency was 50 kHz.

Production of these models, updated to take advantage of new technology and components, continued through 1927 when an eight valve superheterodyne circuit model was introduced. In the same year, a TRF Browning-Drake circuit model was added to the range. Up to this point, the company employed many valves it manufactured locally in its own factory. However, production of valves ceased in 1927, and valve requirements were imported from overseas manufacturers.

The production of receivers employing superheterodyne circuits was discontinued after 1927 and not manufactured again by AWA until 1933. The first AC mains powered receiver, a seven valve TRF circuit model came off the production line in 1928 as console and table models. Six valve battery-powered models were also produced in the same year.

The first radiogram was manufactured in 1929 as the Duoforte model. It employed a TRF circuit with valve types 26, 27, 71A (two) and 80 rectifier. The two 71A valves were in push-pull configuration. An electromagnetic loudspeaker was employed for the first time by the company. Prior to that, magnetic types had been employed with all receiver models. An alternative Duoforte was produced employing type 45s in push-pull in the output stage feeding a Magnavox 405 loudspeaker.

A driving force behind marketing and sales of AWA receivers was William (Bill) Wing. He received training in wireless at the Marconi School, England in 1911 and following service as Ship's Wireless Operator on a number of ships, came to Australia and joined the Commonwealth Radio Service in 1913 serving at a number of Coast Radio Stations. In 1922, he joined AWA commercial business activities and in 1924 was appointed as Sales Manager of the company. He held that position until 1950 when he was appointed AWA Victorian Manager. For many years he was prominent in many radio trade organisations.

One of the company's Commercial Engineers of the 1930s was James Draffin. He had been trained as a Radio Telegraphist during the First World War and served in New Guinea remaining there after the War and becoming Officer-in-Charge of one of the New Guinea radio stations. In 1927 he moved to the Fiskville Beam Station as Engineer-in-Charge remaining there until 1935 when he transferred to AWA Head Office in Sydney where he became an Engineer in the Broadcasting Department. In the late 1930s, he became Commercial Engineer and subsequently was appointed Engineering Sales Manager, a position he held until 1956 when he took up the position of Assistant General Manager.

Although AWA had designed and constructed the transmitters for five of the first A Class stations which went to air during 1923–25, and operated two of them on a contract basis, none of them was owned by the company. In addition to plans to become leader in the entire broadcasting technical field, to include design, manufacture, installation and consultancy of studios, transmitters and home receivers, AWA had plans to own a network of Commercial stations. However, it was not until 17 December 1930 with the commissioning of 2AY Albury that involvement in this field was achieved. This was followed by others with the company holding the licences for 3BO Bendigo, 4TO Townsville and 4CA Cairns. It was also a shareholder in other stations including 2GF Grafton, 2GN Goulburn, 4WK Warwick, 7LA Launceston, 2SM Sydney, 2CH Sydney, 2KA Katoomba, 3HA Hamilton, 3CV Maryborough, 3SH Swan Hill and 3TR Sale. With the establishment of television, AWA became a major shareholder in United Telecasters Sydney Ltd.

One member of the staff who had extensive experience at AWA broadcasting stations in both technical and managerial roles was Hamilton Reynolds Huntley. He was educated at Sydney Technical College and joined AWA as a Cadet Engineer working at the Radio Electrical Works 1932–33. He then transferred to AWA broadcast station network serving as Technician-Announcer-Salesman at 2AY Albury and 3BO Bendigo 1933–34. In 1935, he moved to 2GF Grafton where he acted as Manager. Hamilton was appointed Assistant Manager at 4TO Townsville where he served from 1935 to 1936. His next assignment was to ZJV and VDP2 Fiji from 1936 until 1952 carrying out various duties including Engineer, Announcer, Secretary and Director. In 1952, he returned to Australia to become Assistant Manager 3BO Bendigo and being appointed Manager in 1954. In 1957, he took up a position at 2CH Sydney as Manager until 1971 when he became Radio Network Communications Manager. In 1943, he became a Member of the Institution of Radio and Electronics Engineers, Australia.

Another employee who served in the Radio Network was William Kinane. He joined AWA Accounts Department in 1936 and following attendance at the Marconi School of Wireless obtained a First Class Commercial Operators Certificate of Proficiency and transferred to the Marine Department as Radio Officer. He later moved to the Broadcast Department where he served at 2GF Grafton. Following service during the Second World War as Radio Officer in the Marine Navy he was appointed Assistant Manager 2CH Sydney, later transferring to 4WK Warwick as station Manager in the early 1970s.

The first factory operated by AWA was at Wireless House, 97–99 Clarence Street, Sydney with a staff of about 25. With the outbreak of the First World War, activities were geared up to produce and install ship's radio equipment for ships built in the Far East for the British Government. The local factory manufactured Marconi 1½ kW spark transmitters and crystal receivers which were sent to China and Japan with AWA Marconi School trained staff who installed and operated the equipment. The factory also produced pack sets for the Armed Forces with one of these sets going to the 22nd Signal Troop in South Australia where one of the operators was Signalman Roy Cook who, later in the early 1920s, played a leading role in popularising broadcasting in that State.

Later, AWA designed Type F transmitters were manufactured and subsequently put into operation by Service personnel.

Australectric Ltd, the product distribution arm of AWA, marketed a range of products under the Expanse label. One popular product available about 1923 was the Panel Unit or PX receiver. It was intended for experimental work by radio enthusiasts being adaptable to various circuits whilst retaining a symmetrical appearance. The receiver was constructed on the unit principle employing small bakelite panels each having certain parts mounted on them, the whole being assembled on highly polished framework. It was a three coil design taking standard honeycomb coils. The detector mounting was arranged to take an R type valve and the amplifier arranged for V24 or QX type valve.

Australectric Ltd also distributed AWA manufactured Expanse valves and Marconi brand valves.

In addition the main outlet at 97 Clarence Street, Sydney Australectric Ltd had an outlet at 122–4 Little Collins Street, Melbourne.

The PX receiver was very popular among experimenters and many were in service during the early 1920s. One was purchased by Roy Cook of Adelaide in 1927 and used with various modifications until about 1933. Although not operational because of the non-availability of suitable valves it was still amongst his VK5AC radio station equipment in 1964.

The Manager of Australectric Ltd, Experimental Wireless Sales Department was Malcolm Perry. He was one of the early wireless telegraphy experimenters having been involved from about 1904 with emphasis on improving transmitter/aerial coupling arrangements to improve radiation efficiency.

During 1905, he gave a demonstration of wireless telegraphy operation at the Sydney Grammar School employing a large inductor loosely coupled to a spirally wound loop type aerial. Three Leyden jars made with metal foil on inside and outside of large pickle bottles provided capacitance for the resonating circuit. According to an essay later written by one of the School students about the visit, 'the roar of the sparking was deafening and there was a strange smell in the room from the spark breaking down the oxygen in the air. The Headmaster closed all the room doors and windows to make sure that the wireless signals did not escape from the room. Mr Perry sent a secret message in Morse Code'.

The receiver employed in the demonstration used a Marconi type coherer with metal filings in an evacuated glass tube. A vibrating bell with a cork hammer was used for decohering purposes.

By 1910, Malcolm had an elaborate installation at his home capable of operation from any one of three different resonating and coupling circuit arrangements. His receiving equipment comprised two crystal detectors and a mercury type. Although he found the mercury type to be more difficult to adjust, it was more sensitive than the crystal types.

The aerial was about 150 ft (45 m) long supported by one pole 75 ft (45 m) high and another 25 ft (8 m) high.

In 1911, he became the second Secretary of the NSW Wireless Institute, occupying the position until 1920 when he took over as Treasurer.

With the availability of valves after the War, he obtained one of the early Audiotrons from USA and built a receiver to put it to use, with good results. At the same time, AWA was investigating arrangements to make valves in Australia.

To meet increasing demands for its equipment and services, and to take account of the Government's intention to allow the establishment of broadcasting stations in Australia, company management realised that the Clarence Street premises would be too small to meet future needs, and larger premises were acquired in Knox Street, Darlington in 1922. The building was equipped with the latest production facilities including automatic turret lathes, screw cutting machines, power presses, milling machines, multiple drilling equipment as well as a multiplicity of special purpose machines such as coil winding, stamping and die casting machines. Electroplating equipment was also installed.

The Knox Street works produced a wide range of wireless apparatus including broadcast transmitters for the A Class stations and later for Commercial stations, home radio receivers, wireless apparatus for use on ships and the Coast Radio service and radio telephone equipment for use by settlements in the outback. Radio receivers were made in several models from the small crystal sets to the professionally finished Radiola Super Sherton cabinet type which was capable of operation with a loop aerial. It was a six valve receiver with the cabinet being made of Tasmanian fiddleback blackwood of exceptionally distinctive design. Other models produced at the time included an Experimental PX receiver with R type detector and V24 or QX type valves as amplifiers; the Radiophone, a simple two valve receiver; an unassembled three valve receiver for the hobbyist or home constructor; the Radiola 3A receiver, a three valve model employing one RF stage, a detector and one AF stage, and the Radiola Special IV A an entirely new receiver of the period, featuring a tuned anode regenerative circuit having only two controls and employing four AWA 109X valves.

The company prided itself in the fact that in 1925, when the Knox Street plant was in full scale production, every one of the company staff of about 800 employees, with the exception of the Managing Director, Ernest Fisk, had been recruited in Australia, with many of the technical staff being trained using company resources.

In 1926, negotiations were completed for the purchase by AWA of premises occupied by Messrs W E Ward and Co., Ltd at 47 York Street. The building was altered to accommodate the city accepting office for the proposed Beam Wireless Service and other services, and also as headquarters for numerous activities of the company.

By the end of the 1920s, it became evident that new larger factory premises were required to meet expected demand for home radio receivers and the many Commercial broadcasting transmitters and studios being planned by entrepreneurs. The area being used for the manufacture of receivers was severely congested and left no room for expanded production.

In producing the 1928 Radiola models, more than 4 million parts were used, involving some 10 million operations in their manufacture.

The production of variable capacitors and audio transformers is typical of the extent of activities. For the logarithmic variable tuning capacitor, 1860000 parts and 5630000 operations were involved. About 8 tonnes of brass and 2 tonnes of aluminium were used in making the plates and frames. For the Ideal audio transformers, three tonnes of copper wire and 32 tonnes of sheet steel for laminations and case pressings were used, with the total parts produced being some 4069000, involving 5686000 operations. At the time, AWA employees numbered about 1000.

In 1930, the company produced a wide range of all-electric and battery-operated receivers incorporating the most advanced technology available at the time. They included:

- Radiola 90, a six valve all-electric screen grid receiver available in floor and table models with shielded stabilised RF amplifier utilising three screen grid UY224 type valves with a screen grid linear power detector. An indirectly heated cathode valve was used in the first audio stage and a UX245 type power valve in the output stage. The console used a built-in corrugated cone moving coil loudspeaker, while the table model employed either magnetic or dynamic types.
- Radiola 80, a six valve screen grid battery-powered receiver employing UX222 type valves in the RF stages, DEL40 type as detector and DEP425 as output valve.
- Radiola 70, a straight six all-electric model employing three UY227 type valves in the RF amplifier, with UY227 type valves also in the detector and audio stages. The output valve was a UX171 type.
- Radiola 50, a six valve battery-powered receiver with three stage RF amplifier employing DEL410 type valves with a sensitive detector and a DEP410 type valve in the power stage with provision for use of a DEP425 type valve if required.

- Radiola 40, a four valve all-electric screen grid receiver with stabilised RF stage utilising UY224 screen grid type valve and a screen grid power detector UY224 type valve. The first audio stage employed a UY227 type valve with a UX171A type power valve in the output stage.
- Duoforte 90, a combination all-electric eight valve screen grid model for broadcast reception and reproduction of records. It was based on the Radiola 40 model with the addition of push-pull first audio stage utilising UY227 type valve. The power amplifier comprised an output stage of two UX245 type super power valves in push-pull. Special features included Model 106 corrugated cone dynamic loudspeaker, RCA pick-up, a 20 cm diameter turntable fitted with automatic cut-out feature and driven by a noiseless induction motor, remote volume control and tone control, and a magnificent cabinet of lacquered Queensland Maple.
- Duoforte 40, based on the Radiola 40 with the addition of a power output stage employing a UX245 valve.

At the time, the rectifier in AC powered receivers was not counted as a valve. However, by 1934, the rectifier was included.

In April 1930, AWA purchased a complex of three factory buildings at Dodge Park on Parramatta Road, Ashfield. The total factory floor area was 75000 square feet (7000 sq m) with the buildings being located in an area well laid out with lawns and gardens.

The premises were officially opened by Prime Minister Scullin on 31 March 1931, the year AWA introduced the 'Fisk' series of receivers. The factory was referred to as a 'Factory in a Garden' and known as AWA Radio-Electric Works. Expansion was carried out to bring together Consumer Products Division, Engineering Products Division, Broadcasting Division, Aviation and Marine Services, the valve and semi-conductor subsidiary Amalgamated Wireless Valve Co., Pty Ltd and operation activities.

During 1933, the manufacture of receivers employing TRF circuits was discontinued by AWA. Superheterodyne circuits employing an intermediate frequency of 175 kHz were used with all models. Eight models were produced during the year and included 4 valve AC mantel; 4 valve AC console; 6 valve AC console; 6 valve battery-operated console with push-pull output; 8 valve battery-operated console with push-pull output; 5 valve DC powered console; 6 valve AC operated console with push-pull output; 5 valve AC operated console. The two battery-powered receivers employed Permag loudspeakers while all others employed Electromagnetic types.

In 1934, a range of mantel receivers under the Radiolette label were manufactured in battery, AC and Universal AC/DC powered models. All receivers employed an IF of 175 kHz with the exception of Model 240, a 7 valve three band receiver and model 301, a 9 valve Phono Radio three band receiver, both of which employed an IF of 460 kHz.

A console model of interest produced during the year was The Fisk Radiola seven valve Model 240. It featured all-wave reception with direct sight rotovision tuning. Direct sight tuning was made possible by a specially designed cabinet with dials and controls mounted on a sloping top so that tuning could be carried out without stooping or bending the body. The rotovision tuning was provided by a specially designed circular dial which displayed at a glance all station callsigns clearly and boldly marked through the highly illuminated dial. The dial was fitted with a double ended pointer driven from the tuning capacitor shaft which in turn was driven through a high ratio drive system enabling precision tuning.

The circuit of the Radiola 240 comprised 6D6 short wave RF amplifier; 6D6 RF amplifier; 6A7 detector oscillator; 6D6 IF amplifier; 6B7 detector and AVC; 42 output pentode and 80 full wave rectifier.

On 11 July 1934, Amalgamated Wireless (A/Asia) Ltd celebrated the 21st Anniversary of incorporation of the company with simultaneous celebrations being conducted at Wentworth Ballroom, Sydney and the Masonic Hall, Melbourne. The two venues were linked by landline and loudspeaker systems installed to hear the various speakers.

Ernest Fisk presided over the Sydney gathering and was presented with a paperweight carved from Queensland maple in the form of a golden key. Mrs Fisk cut a three tiered birthday cake, on which was mounted 21 candles, with an inscribed silver knife.

By 1938, the total factory floor area was 20700 sq m with the property area exceeding 2.8 hectares. Employees working on the site at the time exceeded 1700.

So great was company expansion, that even this huge complex could not accommodate all activities. By 1963 — 50 years after formation of the company — the AWV group had moved to its own factory at Rydalmere and in addition to the large floor area occupied by Head Office in York Street, other premises were occupied at suburban sites at Alexandria, Belmore, Darlinghurst, Glebe, Mascot, Petersham, Silverwater, and Summer Hill, together with city sites at 72 Clarence Street, 158 Goulburn Street and 215 Bourke Street.

The company also had a subsidiary in New Zealand — Amalgamated Wireless (A/Asia) NZ Ltd — which handled AWA products and manufactured a range of equipment for the New Zealand market.

The company endeavoured to be self-supporting as far as possible, and during 1937 when it produced some 50000 Radiola and Radiolette receivers, it manufactured 60 million small parts and components such as fixed capacitors, tuning ganged capacitors, power and audio transformers and complete dial assemblies.

The production of nearly 50000 receivers comprising 20 models in 1937 contrasted with the output of Radiolas in 1924 when they were first produced. In that year, 200 receivers of only a few models were produced. Since then, the peak output of receivers for one week was 1650 which was more than eight times the quantity produced during the whole of the first year. A single receiver required about 1285 piece parts for its manufacture and this meant that for an average chassis, over two million separate pieces had to be kept moving between manufacturing sections, to a definite daily time schedule each week.

Athol Cave was of the many employees associated with receiver production activities. He joined AWA in 1938, spending seven years in receiver test rooms followed by a further seven years as Technical Expert in receiver Sales Department. In 1955, he was appointed Commercial Manager at 2CH Sydney and in 1957 to a similar position at 4TO Townsville. During 1959 to 1964 he was Manager of 2GF Grafton and then moved into television management posts.

Among the 30 receiver models manufactured during 1938, were the 171 and 173 models which incorporated automatic tuning facilities. The model 171 was a medium wave band model while the 173 was a medium/short wave band model.

The receivers employed a reflex superheterodyne circuit with valve types comprising 6K8G frequency converter; 6U7G intermediate frequency amplifier; 6G8G IF amplifier, and automatic gain control; 6F6 output pentode; 5Y3 full wave rectifier and 6U5 visual tuning indicator. The reflex superheterodyne circuit was widely used in AWA receivers of the period with plate reflexing and fractional AVC on both controlled stages being popular.

The facility which enabled automatic tuning operation comprised a set of pretuned slugged inductors and trimmer capacitors. A row of six push buttons enabled individual selection of the inductor/trimmer sets.

The 171 and 173 models were console types. Models manufactured during the same year included 16 consoles, 5 radiograms and 9 mantel types. All employed superheterodyne circuits with intermediate frequency of 460 kHz. The designs ranged from four valve to seven valve and included AC, battery and vibrator powered models. Ten of the models were fitted with visual tuning indicators.

One receiver of interest produced by AWA was the Model 281, a 13 valve three band AC operated receiver with automatic tuning. The receiver covered the MF band and short wave bands 35–105 metres and 13–39 metres. Valve complement comprised 6U7G RF amplifier; 6K8G mixer; 6J7G oscillator; 6J7G oscillator control; 6U7G 1st IF amplifier; 6U7G 2nd IF amplifier; 6H6G 2nd detector, AVC and AFC; 6R7G 1st AF amplifier; 6J7G 2nd AF amplifier; 6J7G phase inverter; pair 6V6G output; 5V4G rectifier plus a 6U5 visual tuning indicator. The undistorted power output was 13 watts. Loudspeaker employed was type AS3, 12 inch dustproof electromagnetic unit.

The receiver was constructed in two units with the audio amplifier being separate from the RF unit and mounted in the lower compartment of the cabinet.

Features of the design included automatic keyboard tuning for eight broadcast stations, scanning by which the dial pointer could be shifted automatically to any position on the dial controlled from the keyboard, phono switch operated from the keyboard, magnetite core tuned IF transformers and oscillator coil, temperature compensated circuits, seven point high fidelity and high frequency tone control, provision for attachment of Armchair Control Unit and many other unique features.

At the time, Albert Martin was Engineer-in-Charge, Broadcast Receiver Development. He was educated at Wesley College, Melbourne and graduated with BEE Degree from University of Melbourne in 1923. Albert then worked with Melbourne Electric Supply Company for 12 months before going to USA to widen his experience with Westinghouse Electric and Manufacturing Company at East Pittsburg. The company was a leader in the rapidly expanding broadcasting industry. It had established broadcasting stations KDKA at East Pittsburgh and KYW at Chicago and had a radio receiver manufacturing arm which was hard-pressed to keep up with public demand. Albert took a great interest in the technology, not only at Westinghouse but at Radio Corporation of America and General Electric all three of which were closely linked in the design, production and sales of domestic radio receivers. On return to Australia he took up a position with AWA in 1928.

In August 1938, AWA formed Manufacturers Special Products Pty Ltd (MSP) to market AWA products which it manufactured for its own receivers. The first components made available included variable capacitors, wafer switches, paper capacitors, vibrators and magnetic cores. Sales volume rose rapidly until entry of Japan into the War in 1941 when the company reduced substantially, production of domestic radio receivers.

During 1941, 23 models were manufactured comprising 1 portable, 1 transportable, 9 mantels and 12 consoles.

The portable, model 65–65Z employed four valve types 1A7GT, 1P5GT, 1H5GT, 1Q5GT and 5V4G in power unit. The receiver operated from dry cell batteries or AC mains.

The transportable was a five valve two band receiver operated from dry cell batteries, vibrator or AC mains and employed valve types 1P5GT, 1A7GT, 1H5GT, 1Q5GT, 5V4G in power unit.

The consoles included models 317 and 318 employing nine valves and incorporated record playing facilities, with model 318 being fitted with an automatic record changer. A nine valve receiver, model 284 was also available, but without record playing facilities. The three receivers employed valve types 2–6U7G, 6J8G, 6B8G, 2–6J7G, 2–6V6G and 5V4G. Models 276 and 284 were fitted with tuning indicator 6U5.

Highlights of the range included newly styled cabinets; improved tuning mechanisms; acoustically matched loudspeakers; improved dial calibration technique; employment of newly introduced 6X5GT rectifier in table models; freedom from drift during temperature variations; use of air dielectric trimmers and trolitul insulation contributing to improved reliability and general circuit efficiency; use of new coil impregnation process to ensure freedom from effects of atmospheric humidity, plus other features.

At the time, there were some 3900 people at the Ashfield Radio-Electric Works. The Works operated on a continuous basis and 44 people staffed the huge cafeteria to provide meals. It catered for twelve meal breaks each day with about 3600 meals being served daily.

Large numbers of receivers were produced for the Services as part of the company War effort. The Series C6940 general purpose communications receiver was widely employed by the RAN for both shipboard and land station operations. Several variants of the design were manufactured to meet special requirements. One model, the 3C6940 covered the range 100 kHz to 3.1 MHz.

A model built for the requirements of the USA Forces was the AMR100 which used plug-in coil assemblies to cover the range 550 kHz to 24 MHz. The plug-in coil arrangement was widely employed with many communications receivers manufactured in the USA even before the War. The receivers were powered from 12 volt DC or 110/240 volt AC supplies. A rack mounted version, the AMR101 was installed at a number of fixed receiving stations set up for diversity reception.

The C1702, a fully tropicalised set designed for battery or AC operation was manufactured for the Australian Army Amenities Service and used at Army bases throughout Australia and the Pacific region.

After the War, when the factory resumed normal production, MSP marketed its prewar products and later added under its own brand name, other items including loudspeakers. Activities expanded greatly with the introduction of television and computers.

By 1939, the company had diversified into a wide range of Radio Engineering activities. These included Beam Wireless Service, Wireless Telephone Service, Wireless Service to Ships, New Guinea Wireless Service, Fiji Wireless Service, Broadcasting Services, Aircraft Radio Services, Picturegram Services, Wireless Manufacture, Wireless Research, The Fisk Radiola, Broadcasting Stations and others. Broadcasting stations which under AWA control included experimental Short Wave stations VK2ME Sydney, VK3ME Melbourne, VK6ME Perth and VPD2 Suva together with MF stations 2CH, 2GF, 2AY, 3BO, 4CA, 4TO, 4PM and 4WK.

It was also 1939, that AWA erected a new 14 storey headquarters building and tower at 47 York Street, Sydney. It was a landmark for many years with the 40 metre lattice steel tower being used for some time as the radiator for 2CH located in the same building. The building was of reinforced concrete construction and had a high power flashing beacon mounted on top of the tower, the top of which was 368 ft (112 m) above street level.

The 2CH studios were damaged when a fire started on the 13th floor. Although the studios were located on the 11th floor they were affected because the ventilation system supplying inlet air to the studios was not equipped with smoke detectors and automatic shutdown facilities. Heat or flame coming down the inlet and ducts from the two floors above, ignited acoustic and other materials, and set alight to one of the walls. Equipment interwiring located in floor ducts and chases, suffered damage and required replacement. At the time of the fire, the tower was not being used as the 2CH radiator. The transmitting facilities had been transferred to Pennant Hills.

The firemen's task of dealing with the fire was made difficult when the two lifts in the building failed soon after the fire started. They had to carry heavy portable extinguishers up 13 floors to reach the fire.

When the art deco building was opened on 1 September 1939, the tower made the AWA building the tallest building in Australia, and remained so until 1965.

Although AWA sold the building in 1988, the company still leases the tower.

In May 1994, the tower was dismantled for refurbishment at a cost of several hundred thousand dollars. The work which included regalvanising all steel members and painting the structure in its traditional white colour, was undertaken by Transfield. The structure was re-erected during May 1995.

During the War years, the resources of the company were directed towards providing equipment, services and facilities for the Services. The major production centre remained at the Radio-

Electric Works at Ashfield but several branch factories were established in dispersed locations for security reasons. At peak, there were more than 5000 people on the pay roll.

War production included at least 20000 radio receivers, transceivers and transmitters of all kinds valued at more than £13 million ($26 million).

With the outbreak of the War against the Japanese in 1941 it soon became evident with radio equipment despatched to tropical areas that there was a major problem with equipment reliability. The equipment deteriorated rapidly under hot humid tropical conditions due mainly to breakdown of insulation or condensation on the surface of components particularly switch contacts, plugs and sockets.

Although a number of Government Departments through the Scientific Liasion Bureau began to tackle the probe, civilian radio manufacturers were anxious to solve the problem to improve reliability of their equipment.

AWA had at least three Scientists investigating the effects of tropical conditions on radio apparatus with one of these staff members being Miss Marie Clark a former School Teacher and graduate in Science from Sydney University. Although an expert in the scientific field, Marie felt disadvantaged when discussing her work with Radio Engineers and resolved to learn their language by attending night classes in Radio Engineering. She subsequently obtained a Diploma in Radio Engineering in 1946 and at the time was only the second woman in New South Wales to be granted such a Diploma.

One of the major subsidiaries of the company was Amalgamated Wireless Valve Co., Pty Ltd which commenced the manufacture of Radiotron valves in 1933 in premises at the Ashfield site. Although at first, only receiving valves were produced, development of transmitting valves was commenced in 1938 with first deliveries being made during 1939. During the War, new types were introduced and production facilities expanded. During 1942, over 2 million valves were manufactured and staff numbered about 800. Although the valve factory was extensively damaged during a fire in 1944, production was quickly resumed. However, production ceased in December 1989 due to a shrinking market for transmitting valves and expiration of the building lease.

Towards the end of the War, AWA combined with STC to produce two 100 kW short wave transmitters for Radio Australia Shepparton.

The manufacture of broadcast transmitters was for many years a major part of company activities. By 1963, when AWA celebrated its Golden Jubilee it had been in the broadcast transmitter manufacturing business for 40 years and over that period had supplied about 65% of transmitting stations throughout Australia and New Zealand. They included a 60 kW MF transmitter to New Zealand and a 50 kW MF transmitter for 2CR Cumnock in Australia. Many units were also supplied to overseas organisations including Radio Malaya, Radio Singapore, All India Radio, Radio Pakistan and stations in Hong Kong and Fiji.

After the end of the Second World War, AWA rearranged its production line to manufacture many new models of domestic receivers taking into account developments which had taken place in radio technology and materials during the War years.

Technical Superintendent of the Consumer Products and Special Products Divisions at that stage was Dick Huey who had resumed duty with AWA following service with the Army where he was Assistant Director of Signals and Radar Equipment.

Dick joined the AWA Research Laboratories following graduation from the University of Sydney in 1935. He later transferred to the Production Factory as Senior Testing Officer where he worked until 1938 when he left to take up a position with Swinburne Technical College before joining the Army in 1940.

In 1948, Dick left AWA to join EMI (Australia) serving in Australia and England until 1950 when he left to take up an appointment with the NSW University of Technology. While at the University, he was joint author of a paper, presented at The Institution of Radio and Electronics Engineers Australia, National Radio and Electronics Engineering Convention held in Sydney 22–26 May 1967, on the subject 'The Oblate hemi-spheroidal P-N Junction'.

New domestic receivers produced by AWA in 1947 included:

- Radiola 510M, a five valve dual wave model for AC operation, available in moulded cabinet in ivory, green or walnut colours.
- Radiola 511M, a five valve dual wave mantel receiver for battery or vibrator operation.
- Radiola 712C, a five valve dual wave console for AC operation.
- Radiola 713C, a five valve dual wave console for battery or vibrator operation.
- Radiolette model with moulded cabinet available in three colours.
- Radiola 801G, a five valve dual wave radio-phonograph combination in table cabinet.
- Radiola 802G-Y deluxe radio-phonograph combination for AC operation featuring eight valves, dual wave capability, bandspreading operation and automatic Oak record changing phonograph with crystal pick-up and permapoint needle.

The following year, 1948, resulted in production of a range of mantel, console, table and radiogram models with a greater selection of models being available compared with the previous year. Models included:

- Radiolette 516M, a four valve AC operated medium wave receiver with moulded cabinet.
- Radiolette 514M, a four valve battery-operated medium wave receiver with moulded cabinet.
- Radiola 517M, a four valve AC operated medium wave receiver with moulded cabinet.
- Radiola 513M, a five valve AC/DC Universal operation receiver covering three bands and fitted in a moulded cabinet.
- Radiola 518M, an AC operated dual wave receiver in moulded cabinet.
- Radiola 519M, a five valve dual wave receiver covering three bands and fitted in a moulded cabinet.
- Radiola 612T, a five valve battery operation receiver covering all broadcast bands and housed in a cabinet of selected veneers.
- Radiola 615T, a five valve AC operated dual wave receiver covering bands 185 to 555 metres and 16.6 to 50 metres and enclosed in a cabinet of selected veneers.
- Radiola 616T, a five valve battery-operated dual wave receiver in a cabinet of wood veneers.
- Radiola 617T, a six valve AC operated all-wave receiver with band-spreading and housed in a cabinet of selected veneers.
- Radiola 710C, a five valve battery-operated receiver with band-spreading and covering all bands 13.5 to 555 metres and housed in a console veneer cabinet.
- Radiola 715CZ, a five valve AC operated dual wave receiver in console veneer cabinet.
- Radiola 716C, a five valve battery-operated dual wave receiver in console veneer cabinet.
- Radiola 717C, a four valve AC operated medium wave receiver housed in a console veneer cabinet.
- Radiola 718C, a four valve battery-operated medium wave console receiver.
- Radiola 719C, a six valve AC operated all-wave receiver with band-spreading and housed in a console veneer cabinet.
- Radiola 801G, a five valve dual wave table receiver covering the range 185 to 555 metres and 16.6 to 50 metres with automatic record changer and housed in a table veneer cabinet.
- Radiola 802GX, an eight valve AC operated all-wave receiver covering bands 13.5 to 555 metres and fitted with automatic record change system and housed in a console veneer cabinet.
- Radiola 804G, a five valve AC operated dual wave receiver with automatic record changer and housed in a console veneer cabinet.
- Radiola 450P, a personal portable battery-operated medium wave band receiver in moulded case in selected colours and provided with carrying handle and shoulder strap.

The eight valve deluxe radiogram Models 802G-Y and 802GX were followed by the Model 805G(Z/Y), a nine valve AC powered set popular for about four years following its release about 1948. Valve line up comprised 6U7G, RF amplifier; 6J8GA, converter; 6G8G, IF amplifier, detector and AVC; 6SJ7, 1st IF amplifier; 6SJ7, 2nd IF amplifier; 6J5GT, phase splitter; 6V6GT (pair) push-pull output; 5Y3GT full wave rectifier and Y61 or Y63 visual tuning indicator. Loudspeaker was 12 inch (30 cm) permag type producing 8 watts output. A seven position switch enabled reception of MF band 540–1600 kHz and HF bands 1.5 MHz to 22.3 MHz (555 to 13.5 metres).

When television was established in Australia, AWA was the only local company to design and manufacture TV transmitters. The first two units were supplied to Commercial stations at Bendigo and Shepparton. The Broadcasting Division which was responsible for transmitter manufacture also undertook commercial recording work under Radiola label and AWA Custom label with two recording studios in Sydney and one in Melbourne. Two Managers who played major roles in the development and expansion of the company broadcasting and recording facilities were Vivian Brooker and Reg Fox.

Vivian Brooker joined AWA in 1917. In 1920, he participated in the long wave experimental work at Koo-wee-rup and in 1926 operated the first shipboard short wave station set up in the UK to transmit commercial messages to Australia. In 1927, he transferred to the AWA Engineering staff and following construction of 7LA Launceston was Manager and Chief Engineer from 1931 until 1933. He then became Manager Broadcasting Department, a position he held until 1946.

At the World Radio Convention held in Sydney during 1938, he delivered a paper 'The Technology of Recording Sound on Disc'. In 1945, he became AWA's Chief Recording Manager.

Reg Fox began his career in radio in 1926 when he took up a position with the Telegraphs and Wireless Branch of the PMG's Department in Melbourne. While there, he attended the Marconi School of Wireless. When the Department took over the A Class stations 3LO and 3AR to form part of the National Broadcasting Service in 1929, he worked on the operation and maintenance of studio and transmitting facilities of those stations until 1933 when he transferred to the Radio Division of the Victoria Police. In 1935, Reg joined the Marine Department of AWA being engaged in Far East and Island services. At the end of 1936, he transferred to the Broadcasting Department becoming Manager of AWA's station 2GF Grafton in 1937 and later, in 1939, Manager of 3BO Bendigo. In 1940, he became Manager of 2CH Sydney which AWA operated under agreement with the NSW Council of Churches.

During the War years, he served as Commissioned Officer in the Navy rising to the rank of Lieutenant-Commander. After the War, Reg rejoiced AWA becoming Manager Broadcasting and Recording in 1950 and Assistant General Manager in 1956 in charge of the Broadcasting Division. He remained in that position until July 1963 when he transferred to United Telecasters Sydney Ltd which operated Channel 10, as General Manager and Director until 1969 when he left to form Video-Tape Corporation which became one of the largest TV production companies in Australia.

Reg became an Associate Member of the Institution of Radio Engineers (Australia) in 1935 and Member in 1946. During 1951 to 1952, he served as President of the Federation of Australian Commercial Broadcasting Stations.

Another employee of the Broadcasting Department with long service with AWA was Frank McManus who worked on broadcasting activities from 1937 until 1960. During the War years, he took leave from the company to serve with the AIF from 1940 to 1945 occupying the position of Communications Officer, Royal Corps of Signals from 1942 to 1945.

On return from War service, he was Salesman at 2AY and 3BO 1946–48, Manager of 3BO 1948–54 and then Sales Manager AWA country stations.

After leaving AWA in 1960, he played a major role in the establishment and expansion of television services particularly Bendigo and Central Victoria Telecasters Ltd (BCV8) where he was station General Manager and Director. Frank was a member of The Institution of Radio and Electronics Engineers, Australia having joined as Student in 1936 and upgraded to Member in 1954.

The company had a policy dating from the early 1920s of building up its engineering strength and to manufacture from raw materials the majority of components required for equipment and products manufactured on the premises. In addition to cost factors, the practice enabled the company to provide components of the highest quality and reliability for its products. The range of components was very large and included such items as variable and fixed capacitors; coils; coil formers; loudspeakers; switches; AF, RF, IF and power transformers; AF, RF and power chokes; knobs; escutcheon plates; mouldings; valves; TV picture tubes; transistors and many more, all produced under tight quality control conditions by AWA or its subsidiary companies.

The Material Testing Laboratory staff under Clarrie Healy in the 1960s played a major role in oversighting quality of the products. Engineer Albert Martin took testing operations a stage further by subjecting completed items coming off the assembly line to further rigorous testing.

Clarrie Healy joined AWA in March 1936 as Development Engineer having previously worked in a number of broadcasting and associated areas. Following studies at Melbourne Technical College and University of Melbourne, he became Senior Technical Instructor in the Victorian Education Department in 1925. He then obtained experience with several organisations including Airzone 1929–32, Raycophone 1932–34, Ducon 1934–35 and Continental Carbon 1935–36.

Because design has two requirements, that of the functional design of the component layout and interconnection, and that which is visible to the purchaser, close co-ordination was an ongoing operation between the separate groups concerned. The Industrial Design Department under Bill Moody worked in close collaboration with the Customer Products Division's Design and Development Department headed in the 1960s by Ron Stewart, and others in specific areas such as Eric Phillips, Components and Les Bubb, Radio Design. The Division's Manufacturing Engineering Department was controlled by Works Manager Fred White with Ron Piggin as Assistant Works Manager and John Hall being responsible for Process Information to the manufacturing units. Kel Gibbs was in charge of the Division's parts making unit while Tom Sneddon controlled components and Don Morris was responsible for main assembly work. Components Design Engineer was Eric Phillips.

The Engineering Products Division was particularly active during the 1960s. It was under the control of Chief Engineer Wilf Honnor who had been with AWA since 1937. Before joining AWA, Wilf was on the staff of the South Australian School of Mines as Assistant 1921–25; Instructor, Mathematics and Physics Department 1925–33 and Lecturer Wireless and Electronics 1933–37. During leave from the School in 1935, he visited England and gained work experience with the British Broadcasting Corporation and the Marconi Wireless Telegraph Company Ltd. He left the School to join AWA in 1937. In 1947, he became Chief of Research and in 1960 was appointed Chief Engineer of the company. He served as President of the Institution of Radio Engineers (Australia) 1953–54.

The Engineering Products Division was divided into a number of Departments including Broadcasting and TV Equipment with Jack Davis in charge; Communications Equipment with Jim Gilchrist in charge; General Electronics with Jim Telfer in charge; Data Handling Equipment with Jim Trick in charge; Traffic Signals with Bob Filmer in charge and Space Tracking with Theo Nyser in charge.

In the 1930s, AWA established a recording service and manufactured 'AWA High Fidelity' disc recording equipment which was installed at many broadcast studios and radio production companies. In 1937–38 its productions included 'Coronets of England', 'Fred and Maggie Everybody', 'Masked

Masqueraders', 'Personal Column'. 'Blue Danube', 'The Minstrel Show', 'News in a Nutshell', 'Ali Baba Pantomine', 'Radiola Celebrity Concert' and others. The recording studios were located at 72 Clarence Street, Sydney.

By the 1970s, when tape recording technology had been well-established, the company was producing both discs and tapes, although disc production was on the decline at the expense of tapes. The Recording Department was located at 47 York Street and output included transcriptions, radio commercials, TV film sound tracks and gramophone records. Recording Manager was Kenneth Johns who had joined AWA in 1932 as Beam Wireless Messenger. He worked at the Marconi School of Wireless and Sales and Publicity Departments before transferring to the Recording Department in 1937. During the Second World War, he served with the Royal Australian Navy.

The York Street facilities included two studios specially designed and equipped for dramatic, oral and music recording. Tape machines included Ampex mono, stereo and multi-track recorders. The control console catered for 12 input channels and three output channels. Tape duplication was carried out using a high speed Ampex machine. For disc work, Neumann mono and stereo disc cutting lathes were used. A comprehensive music and sound effects library was available for use during production and dubbing work. Mobile OB mono and stereo recording equipment was also available for work away from the studio.

In later years, AWA established its main activities at Lane Cove Road, North Ryde and by the early 1790s products included radio and television broadcasting station and studio equipment, communications transmitters and receivers, radio aids to navigation, distance measuring equipment, aeradio stations, telephone terminal equipment, microwave links, radio components and parts, quartz crystal units, military communication equipment, test and measuring instruments, traffic signalling equipment, deep image TV, stereo-player and stereo-gram equipment, transistor portable receivers, clock radio and mantel receivers, hi-fi stereo amplifiers, tape and cassette recorders, car radio, inter-office communications systems, loud-hailers, audio amplifiers, loudspeakers, microphones, background music systems and many others.

In December 1987, the company name Amalgamated Wireless (Australasia) Limited was dropped and the name AWA Limited became the official name of the company.

The company sold the Ashfield site and facilities about 1989 and it was demolished in early 1993. In its hey day, it was the largest Radio Factory in Australia in which thousands of people were employed. They included Engineers, Scientists, Technicians, Mechanics, Assistants, Draftsmen, Trainees, Cadets, Toolmakers, Fitters and Turners, Electricians, Electroplaters, Chemists, Painters, French Polishers, Cabinet Makers, Carpenters, Welders, Sheet Metal Workers, Process Workers, Administrative Staff and many others. They worked multi-shift production lines to produce a wide range of components, parts and complete radio and television receivers, transmitters, electronic equipment, telecommunications equipment, test equipment and many others.

Major subsidiary companies have included AWA Defence Industries Pty Ltd; AWA Defence Trust; AWA Media Ltd; AWA Microelectronics Pty Ltd; AWA New Zealand Ltd; AWA Universal Totalisator Pty Ltd; AWASCO Pty Ltd and others. At one stage Radio Broadcasting accounted for 6% of the company business.

In the 1980s, AWA divested itself of its Radio Broadcasting, Radiocommunications, Telephone, and Computer Divisions to focus on high technology, defence and aerospace, and communications systems such as traffic signals. In 1991, it was awarded a contract worth $27 million to install traffic lights in Hong Kong.

In 1996, the Microelectronics business and Defence arm were sold, followed by the sale of the Traffic, Rural and Aerospace Divisions to the South African Plessey Corporation.

In recent times, the company has changed its role from being a great pioneering company in Radio and Electronic Engineering to focus on gaming, wagering and service and distribution as its key business activities. The Board was of the view that gaming and wagering was a growth market where the company could use its service, distribution and technological background to advantage.

By December 1996, AWA posted an interim net loss of $15.7 million and staff levels had fallen to just under 500 compared with about 1500 two years previously and more than 5000 during the years of the Second World War.

A great many employees of AWA made significant contributions to research, design, development, installation, operation, manufacture and administration of Broadcast Engineering technology over a period of more than 80 years and it would not be possible to list all those people involved. However, in a listing, the following would be included:

J G Abel, Ron Aitchison, Joe Allen, Jack Anderson, Vivian Anthony, George Apperley, Vic Audet, Fred Audsley, Gordon Bailey, John Bailey, Reg Baird, William Baird, Dr William Baker, Cec Bardwell, D Barnett, Hugh Bartlett, Frank Basden, Tom Bearup, Dr Ernest Benson, Ron Blades, J P Blom, Kevin Borthwick, William Bostock, Francis Bourne, Viv Brooker, Stafford Brown, Harold Brown, Les Bubb, Harold Buik, Dr Geoffrey Builder, Eric Burbury, Eric Burgess, Tom Busby, I J Cafe, J Calder, D Campbell, Fred Canning, N V C Cansick, Robert Casey, Athol Cave, Bill Challier, Mort Chambers, Frank Chandler, Jack Chesterfield, George Chilton, Wilbur Christiansen, Marie Clark, W G Clark, F P Clapp, Graeme Cohen, Richard Collins, Robert Colsell, Bill Conry, George Cookson, Len Cookson, Stanley Cooper, Harold Cox, Donald Craig, John Crocker, Ken Crossman, George Dale, Dr Lou Davies, Allan Davis, Jack Davis, Ross Davis, Dr E R Daziel, Ken Dean, Harry de Dassel, Arthur Dixon, Leonard Dobbie, John Dougall, H L Downing, Jim Draffin, Bill Eades, Beryl Evans, Bill Evans, Arthur Everitt, J G Ewing, Frank Exon, Len Farrer, W M (Chum) Ferris, Bob Filmer, Keith Finney, Sir Ernest Fisk, Joan Forwood, Reg Fox, Arthur Freeman, Harry Freeman, Arthur Gabb, Bill Gamble, Philip Geeves, Kel Gibbs, Jim Gilchirst, Jack Gostalow, Christine Graham, Dr Alfred Green, R M Griffith, Stan Grime, Graham Hall, John Hall, Ian Hansen, Robert Harris, Joseph Hawkins, Stan Haworth, Leila Head, Clarrie Healy, Geoffrey Healy, R H Healy, P R Hellyar, Doug Henderson, R Herbert, Jack Herrick, Owen Hill, William Hill, John Holland, F Holloway, Wilf Honnor, I Hood, John Hooke, Sir Lionel Hooke, Ern Horner, A P Hosking, John Howell, Richard Huey, Ron Hugo, R C V Humphery, Hamilton Huntley, C A Hurndell, Ken Johns, Murray Johnson, Brian Johnson, Hector Johnstone, Tom Kaldor, Noel King, William Kinane, Harry Lamb, Dick Lambie, Hazel Lambie, Fritz Langford-Smith, Arnold Lawrence, M W Lawrence, Ward Leopold, Herbert Lewis, Donald Lindsay, James Lindsay, Dulcie Lonergan, Alan Longstaff, A R Mancer, Arthur Martin, Albert Martin, E Matheson, Don Macdonald, F Maynard, Arthur McDonald, Bill McGuire, Ray McIntosh, Frank McManus, Roy McMaster, Tom McNeill, Gil Miles, P Montague, Bill Moody, Bill Moore, David Morris, Don Morris, M Mortimer, John Mulholland, Dr A H Nash, Bill Nash, Bruce Neal, Sydney Newman, Frank Noar, George Nolfe, Dorothy Norquay, Theo Nysen, Didley Ogg, Alan Omant, Dennis O'Reilly, S W Owen, E J Packer, Les Page, Ernest Parkinson, L G Palmer, Fred Pearce, Hugh Peaston, Neville Pellitt, Eric Pernase, Eric Phillips, William Phillips, Ron Piggin, Wal Pulford, Albert Pringle, J Pritchard, Dr Oliver Pulley, H N Quodling, R J Rawlings, Joe Reed, S R Reichard, Bill Richards, Graham Rigby, Ted Rogerson, H A Ross, Dr James Rudd, B Sandel, C A Saxby, Albert Scown, H R Sharpe, John Simpson, Geoffrey Sizer, Alan Smith, Grenfall Smith, Tom Sneddon, F W Sparkes, J G Spence, John Spencer, Norm Spratt, J Stacey, Vin Stanley, Jim Stanoulis, Fred Stevens, Alex Stewart, Ron Stewart, Colin Stockbridge, Doug Sutherland, Charles Tapp, Sydney Tatham, John Telfer, Fred Thom, Ray Thomas, Ray Tonks, Captain S Toombs, Henry Trick, Jim Trick, Sid Trim, Harry Tuson, V J Tyler, R Vine, Alton Vipan, Valerie

Visner, Bill Wainwright, G R Walters, T R Walton, Kevin Ward, Eric Watkinson, M S Wells, R G Westmore, Neville Williams, Derrick Williamson, N Williamson, Fred White, Margaret White, Robert White, John Wilson, Bruce Wilkinson, Bill Wing, John Woodward, H T Wright, Margaret Wykes, David Wyles, T M Yates, John Young and many others.

Ernest Fisk, the 'father of AWA' was a man of many talents. He was a Radio Pioneer, an Inventor, a Businessman, an Advisor to Governments and was involved with many civic bodies throughout his long working life.

He joined the Marconi Company in England in 1905 after having worked in the British Post Office where he became an expert Telegraphist. At the time, the company was expanding at a rapid rate to meet commitments for equipping ships and shore stations with wireless telegraphy equipment. The company was so confident of its ability in the development of the new technology, even at this early stage, that it put forward a revolutionary scheme to the British Colonial Office to link Britain with its Dominions by means of 1000 mile (1600 km) wireless links. It was also the time when the Australian Government became interested in the possibility of linking the mainland and Tasmania by wireless as an alternative to the unreliable Bass Strait submarine cable. Although Marconi Company experts came to Australia and successfully demonstrated the technology with installations at Queenscliff and Davenport in July 1906, the Government deferred any action.

It was in this exciting period that Ernest Fisk, only 19 years of age embarked on his career in wireless. He received a good training in the company including experience with land based installations in the UK and USA and experience as a Ship's Wireless Operator.

In 1910, he visited Australia on board 'SS Otranto' and the following year returned, this time as representative of Marconi's Wireless Telegraph Company Ltd with an office in Bond Street, Sydney and, later Challis House, Martin Square.

In 1913, Amalgamated Wireless (Australasia) Ltd was incorporated and he was appointed General Manager with a seat on the Board. Three years later, he became Managing Director. From that time, he steered the company on a path that made it the premier Radio Engineering organisation in Australia.

He was closely associated with many major milestones in Radio Engineering in Australia. These included:

- Establishment of the Marconi School of Wireless.
- Establishment of the AWA Research Laboratories.
- Reception of the first direct wireless telegraphic messages transmitted from England, September 1918.
- First public demonstration of broadcasting, at the Royal Society meeting in Sydney, August 1919.
- Establishment of the Australian terminals of the Beam Wireless Service.
- Invention of Fisk Sound Proof Windows, and many others.

He also played a leading role in convincing the Government that a system of broadcasting should be established in Australia. He was the only speaker at a Conference called by the Government in 1923 to put forward a workable proposal.

In 1924, he took the initiative together with some AWA colleagues to register the name 'The Institution of Radio Engineers Australia' with the Registrar-General of NSW and it was fitting that when the Institution was eventually established as a working body in 1932, that Fisk was elected to be its first President. He was President on four occasions between 1932 and 1943.

In 1937, the Coronation Honours List included a knighthood for Ernest Fisk for his outstanding contribution to the wireless industry in Australia. He travelled to England to attend the Coronation and was among a large contingent of Radio Executives. Others included Harry Brown, Director General Postmaster General's Department; Al Freedman, Sales Director Stromberg-Carlson; Eric Moore, Chief Radio Design Engineer Philips; Charles Norville, late partner Breville Radio; Arthur Veal and Herbert Prior, Veales Melbourne; Arthur Allen, Vesta Batteries and Arthur McDonald, Chief Engineer, AWA.

In 1944, he left AWA to join Electrical and Musical Industries in England as Managing Director. After seven years with the company he returned to Australia where he lived in retirement undertaking some work as a Consultant in Technology, Industry and Commerce. Sir Ernest Fisk died on 5 July 1965 at age 78 years.

Lionel (later Sir Lionel) Hooke succeeded Sir Ernest Fisk. He joined AWA in 1913, the year the company was founded and in 1963 when the company celebrated its Golden Jubilee he was the only employee who had served 50 years and was still with the company.

After being educated at Brighton Grammar School, he joined AWA and was selected to accompany Sir Ernest Shackelton's Polar Expedition to Antarctica in 1914 as the party's Wireless Operator. During the First World War, he was commissioned in the New Zealand Royal Naval Volunteer Reserve serving in submarine chasers and later transferring as a Pilot in the Air Force.

After the War, he rejoined AWA and was appointed Manager of the company's Melbourne office where he undertook demonstrations in broadcasting technology.

He later transferred to the Head Office in Sydney as Assistant Manager, becoming Deputy General Manager in 1925.

During 1930–32, he made an extensive overseas tour on behalf of AWA investigating developments in Radio Engineering technology, particularly in the manufacturing area in USA and Europe.

In 1936, he became General Manager of AWA. He was a Councillor of the Institution of Radio Engineers (Aust) 1932–39 and was appointed to the grade of Fellow of the Institution. He was Deputy Chairman of the 1938 World Radio Convention held in Sydney and at the Convention delivered a paper 'Australian Radio Communication Services'.

When Sir Ernest Fisk left AWA in 1945, Lionel Hooke was appointed Managing Director.

He was knighted in 1957.

In May 1962, Sir Lionel became Chairman of the Board, a position he held until 1974.

Besides his role with AWA, Sir Lionel held many important positions with other organisations including Telecon Aust, Pty Ltd; Australian Technical Services and Patents Co., Ltd; Email Ltd; United Telecasters Sydney; Electronics and Tele-communications Industry Advisory Committee and many others.

John Hooke son of Sir Lionel succeeded his father in 1974. John, a University of Sydney graduate in Science and Engineering, joined AWA in 1959 becoming Assistant General Manager in 1966 and Director in 1971. From 1974 until 1988 he was Chief Executive and Chairman of AWA and also occupied positions with AWA subsidiary companies and other organisations.

In 1979, he was made a Commander of the Order of the British Empire (CBE).

In 1988, Peter Mason became Chairman and occupied that position until 1990 when he was succeeded by John Iliffe who was still Chairman in 1993 when AWA celebrated its 80th Anniversary of operation. Mr Iliffe joined AWA as Director in 1988 and became Chief Executive in 1989.

In mid 1997, Trevor Kennedy, widely experienced in the media industry, replaced John Iliffe as Chairman. Mr Kennedy was founding Editor of 'The National Times' and had been Editor of 'The Bulletin' and Managing Director of Consolidated Press Holdings.

BLAND RADIO

Bland Radio was established in Adelaide in 1927 by W J (Bill) Bland and is the only company in South Australia established in the 1920s for the manufacture of radio receivers still active in 1996 and providing a service to the broadcasting industry, although no longer manufacturing domestic broadcast receivers.

Bill Bland was one of the early South Australian Wireless experimenters and was a foundation member of the SA Division of the Wireless Institute when it had its inaugural meeting in 1919. He operated experimental station with callsign S173 and later 5AG. He was one of the first local experimenters to use the English R type valves when a quantity was acquired in 1922 by a colleague and prominent experimenter Roy Cook 5AC, who used one of the valves to broadcast a live concert performance in 1923. Bill also imported a range of double ended receiving type valves from manufacturers in USA for use during his experimental activities. Some of these valves were on display at the Adelaide Telecommunications Museum when the Museum was in Electra House.

When Wireless Supplies Ltd commenced business at 109 King William Street in the early 1920s specialising in locally assembled four valve tuned anode tuned grid receivers, Bill Bland was in charge of production and development work. The company manufactured other designs to order, and at the Radio and Electrical Exhibition in Adelaide in 1925 was awarded prizes for the Champion Four Valve Reflex set and the Champion Multivalve set, a superheterodyne circuit with the receiver being built into a cabinet which included a fold-up writing table.

In 1925, Bill Bland founded Harland Radio and Electrical Co. in Grenfell Street where he manufactured a range of Harland brand receivers including a popular five valve tuned radio frequency model. For top of the range models, cabinet work was undertaken by Mathias, a local cabinet maker. One of the first receivers manufactured was purchased by a farmer near Maitland on Yorke Peninsula who wrote to Bill and reported he received both 5DN and 5CL loud and clear using an aerial supported by two 40 ft (12 m) steel pipes. The farmer's neighbour was so impressed after hearing the set in operation that he purchased a similar set on his next visit to Adelaide. He also asked Bill to make a crystal set for his son.

In 1927, he established Bland Radio with operations being conducted from a building on the site of his residence in Glenside. He employed a small work force and produced a range of models for Adelaide Department stores and other retail outlets.

About mid 1930s, he set up facilities in Hindmarsh Buildings, Hindmarsh Square and began manufacture of receivers under the Operatic label. The brand was to become one of the most well-known labels in Adelaide for over 30 years.

The 'Operatic' label was not new. It had been employed by Colonial Radio Co., Pty Ltd, A'Beckett Street, Melbourne, in 1934 and for receivers manufactured by Gossards Pty Ltd, Elizabeth Street, Melbourne in 1935.

During 1936, there were at least 13 Operatic models in production. They were mostly console types with three employing tuned RF circuits using three valves powered from AC, battery or accumulator/vibrator sources. The others employed superheterodyne circuits with a 465 kHz intermediate frequency and included MF band and dual wave types. Model Uni 7D was a seven valve dual wave console cabinet receiver powered from a Universal power source.

Models released in 1937 included BW5, an AC powered MF band receiver in mantel cabinet; P5DA, a five valve AC powered dual wave radio-gramophone combination; and Uni 6D, a six valve receiver in console cabinet powered from a Universal power source.

One of the employees who joined the company about this time was Ted O'Neill who had previously worked with National Radio Corporation Ltd, Adelaide.

Sales Manager was Joe Vardon who came to Bland Radio after working in the commercial side of radio for many years. He spent periods with D and W Murray Ltd; A G Healing Ltd; and Duncan and Co. He was an active member of the Wireless Institute of Australia serving on Council for six years 1924–30, including four years as Treasurer. He operated Amateur station A50M from his home in Unley in 1924, and at Fullarton in the early 1930s. Joe was well-known throughout South Australia having travelled as Radio Salesman for the various employers since about 1924.

The company was one of the largest suppliers of locally manufactured receivers in the State and by late 1937 had seven models on the market including sets powered from the AC mains, vibrator 6V battery, 2V battery and HT dry cell batteries, and universal power supply. A radiogram was included in the range, together with receivers which could operate from home lighting installations of 32, 50 and 110 volts.

One of the Engineers employed at Bland Radio in the 1930s was Ben Wilson, who later became Chief Recording Engineer and Senior Technician for the Advertising Broadcasting Network in South Australia. He graduated as Electrical Draftsman from the Auckland University in 1926 and commenced his radio career as a Radio Serviceman with A G Healing Ltd, in Adelaide. After three years, he transferred to Bland Radio where he played a major role in the design and production of receivers and components for nearly three years before leaving to take up a position of Design Engineer with Duncan and Co.'s Radio Factory. He joined the Advertiser Network in 1934 and one of his major works was the design and construction of the transmitter and studio facilities for 5SE Mt Gambier in 1937.

Shortly before the outbreak of the Second World War in 1939, Bland Radio transferred operations to a three storey building in Coromandel Place where manufacturing facilities were expanded to include an assembly line area occupying an entire floor, machine area, spray paint booths, test and development area, store room, packing and dispatch area as well as administration offices.

With the outbreak of the Second World War, the company diverted its production facilities to Service requirements. Items manufactured included Fortress amplifiers, emergency transceivers for lifeboats on troop ships, radio equipment for training RAAF Wireless Operators, power supply units and components.

Manufacture of domestic radio receivers resumed after the War, with releases during 1945–46 including:

- Model 36M, an AC powered four valve MF band mantel receiver.
- Model 28T, a dual wave vibrator/battery-powered five valve receiver that had been in production since 1939.
- Model 45M, a five dual wave AC powered mantel set.

A program of development was implemented, and many new designs were added to releases during 1948. They included:

- Models 29T, 30T and 31T, dual wave vibrator/battery-powered five valve mantel receivers.
- Model 36P, a battery-powered four valve personal portable receiver.
- Model 37MA, an AC powered four valve MF band mantel receiver.
- Model 47M, a five valve AC powered dual wave mantel receiver.
- Models 49T, 50T and 51T dual wave five vibrator/battery-powered receivers for 6 volt, 12 volt and 32 volt operation respectively.
- Model 60E, a five valve dual wave AC powered console receiver.
- Model 61RG, a dual wave five valve AC powered radiogram with 4.5 watts output, Garrard gramophone unit, spring balanced lid support and cadmium plated chassis.
- Model 62RC, a seven valve AC powered dual wave radiogram with push-pull output stage, 10 watts audio output, Garrard automatic record changer and lustre finished cabinet.

The receivers were marketed with names which included Carmen, Aida, Rigoletto, Faust, Tosca, Tannhauser, Martha, Mignon RF, Minor, Maritana RF and others. Table models were available with plastic cabinets of colours walnut, cream, burgundy or grey with gold finished expanded aluminium loudspeaker grill.

Included among the large staff employed at the factory were Ian Drinkwater, Arthur Symons, Harold Pitman, Murray Lamprey, Bill Hammel and others.

When transistors became available, the company produced a portable set in 1957 but within a few years production of radio receivers ceased. However with the introduction of television to the State, television receivers employing valves were manufactured. By that time, the manufacturing facilities were located at South Road, Edwardstown.

One of the items produced during the 1960s was a mast lighting transformer for broadcast station radiators. The first unit developed in co-operation with Bill Gold of the PMG's Department, Adelaide was fitted to the 172 m 5CL/5AN dual frequency radiator at Pimpala in 1960. Units were fitted at the radiator base and at the sectionalising point. Units were subsequently supplied to other broadcasting stations in other states.

By the mid 1970s, radio and TV manufacturing operations had ceased and the company name changed to Bland Sales and Service Pty Ltd. In 1996, the company was operating from premises in Stepney and specialised in transformers for industrial application and the installation and maintenance of public address and video systems for schools and factories.

Breville Radio

Breville Radio was registered on Melbourne Cup Day, 4 November 1932, the day that Peter Pan won the Cup. The company was formed by partners C H Norville and W J O'Brien, with Mr Norville being the Chief Engineer and Mr O'Brien being the Sales Manager. The name Breville was derived from the surnames of the two partners.

Charles Henry (Harry) Norville began his Professional Engineering career with the New South Wales Railways. He later transferred to Philips Lamps (A/Asia) Ltd where he worked as a Radio Engineer during 1931–32. He left Philips to become a partner in Breville Radio but left Breville in 1937 just prior to undertaking an extended visit to the USA. During his period as Chief Engineer with the company he laid the foundation for efficient mass production of high quality receivers based on rigid quality control practices throughout the entire assembly and testing processes.

William (Bill) O'Brien began work with the Victorian Railways after leaving school but became fascinated with the new fast developing science of radio and in 1918 enrolled in a part-time course with the Marconi School of Wireless. He completed the course with distinction and on obtaining a Wireless Operators Certificate went to sea as a Ship's Wireless Operator for about six years on British and American ships. Before he had reached his 21st birthday, he had been around the world three times. Following marriage, he left the marine service and spent some years as Sales Manager for a number of Radio Houses in the USA before returning to Australia in 1929 where he took up a position as Manager of the Radio Department of Suttons Ltd and later as Sales Manager for Thom and Smith. At the time, Suttons were distributors of the popular five valve Centurion Phono-Radio using a neutrodyne circuit and fitted out to replay gramophone records, while Thom and Smith manufactured and distributed Tasma brand receivers. In 1932, he became a partner in Breville radio.

The partners started with a paid up capital of £500 and profits for the first year's production exceeded expectations and placed the company on a sound footing to compete with the other large manufacturers of domestic radio receivers.

Breville manufactured high grade AC, DC and battery-powered MF broadcast band and all wave chassis for other companies including Beale and Gulbransen as well as complete receivers marketed under the Breville label. Breville Radio was one of the first manufacturers to offer one unit midget receivers, battery-powered receivers equipped with automatic volume control and a successful high performance all wave domestic receiver.

Included among the 1934 releases were:

- Model 44, an AC powered four valve short wave converter in Bexley cabinet intended for MF band receivers so that they could receive short wave stations by a simple switch operation.
- Model 46, a six valve battery-powered superheterodyne receiver housed in a Kent cabinet, and employing valve types KF2, RF amplifier; 1C6, pentagrid converter; KF2, IF amplifier; KBC1, detector, AVC and driver. The detector was coupled to a B217 functioning as first audio, the circuit being reflexed back to the triode section of the KBC1 which then acted as driver to a Class B, B240 valve.

  Features included IF 175 kHz; employment of new series of 2 volt filament valves; AVC; three gang tuning capacitor; Efco Aero dial; high grade permag loudspeaker. Batteries included A battery 2 volt accumulator with 0.7 amperes drain; B battery consisting of three 45 volt dry cell batteries in series with drain of average 10 milliamperes, and C battery of 4.5 volt dry cell type.
- Model 39, an AC powered five valve superheterodyne receiver designed for local station reception and employing six volt dual purpose valves.
- Model 45 Economy, a four valve battery-powered superheterodyne set employing A battery 2 volt accumulator with 0.7 amperes drain, and three 45 volt dry cell batteries in series as B battery supply. Average B battery drain was 8 milliamperes.
- Model 41, a six valve AC powered superheterodyne receiver designed for long distance reception and employing IF of 175 kHz.
- Model 37, a six valve AC/DC superheterodyne set in a Beale console cabinet.
- Model 43, a five valve AC/DC mantel receiver in Derby cabinet with selected walnut veneers hand-rubbed to piano finish. It was fitted with a 6 inch (150 mm) loudspeaker.
- Model 38 DeLuxe, an AC powered five valve superheterodyne set in Oxford console cabinet, and employing IF 175 kHz, and a three gang capacitor with preselector circuit.

To meet the change in public preference in cabinet finish at the time, all cabinets were presented in high gloss piano finish. This was a departure from the flat or satin finishes of previous years.

A large number of cabinets for Breville radios were manufactured by Beale and Co., Ltd, a Sydney firm which specialised in high quality cabinets for radios, sewing machines and pianos. The mid 1930 cabinet designs included Bexley, Kent, New Sussex, Beale, Derby and Oxford.

From about 1932 until shortly after the outbreak of the Second World War, Breville supplied chassis to Beale who provided their own cabinet designs and marketed them under the Beale brand.

In late 1934, Harold Wilshire of the Testing Department left Breville to take up a position with R Chilton, Radio Laboratory, Broadway and City Road, Sydney as Manager of the Laboratory Service and Repair Section.

The company soon outgrew the small factory it occupied at Woolloomooloo and in 1935, transferred to larger premises at 486 Elizabeth Street near Cleveland Street, Sydney where it installed more modern production facilities. About 100 people were employed at the time, and a new series of models were designed to meet the rapidly expanding market for domestic receivers. New listener's licences were being issued at an expanding rate, increasing at the rate of about 100000 each year. At the beginning of 1935, there were 67 stations on air with 15 being planned for commissioning during 1935. There was also a high demand for receivers in New Zealand and the company opened a distribution outlet there during the same year.

In early 1935, the company announced that 14 different chassis were available together with six interchangeable consoles with two mantels and a short wave converter. This made a total of 87 models produced under the Breville label.

The range included:

1. MF band, dual wave and all wave superheterodynes for AC operation.
   - Model 48, a five valve 460 kHz IF mantel or console superheterodyne receiver.
   - Model 42A, a five valve 460 kHz IF, MF band superheterodyne set.
   - Model 39A, a five valve 460 kHz IF, MF band superheterodyne receiver with preselector.
   - Model 38A, a five valve 175 kHz IF, MF band superheterodyne receiver with preselector and AVC.

- Model 41A, a six valve 175 kHz IF, MF band receiver with RF stage and AVC.
- Model 55, a five valve 175 kHz IF dual wave band receiver with preselector and AVC.
- Model 56, a six valve 460 kHz IF dual wave set with RF stage and AVC.
- Model 47A, an eight valve 460 kHz IF all wave receiver with RF stage and AVC.
- Model 44, a four valve mantel type short wave converter.

2. MF band AC/DC or Universal superheterodyne models.
   - Model 49, a five valve 460 kHz IF mantel or console receiver.
   - Model 37A, a six valve 175 kHz IF console superheterodyne set with RF stage and AVC.
3. Battery-powered MF band and dual wave superheterodyne models.
   - Model 45A, a four valve 406 kHz IF, MF band set with 2 volt filament valves.
   - Model 21A, a five valve MF band with 175 kHz IF and RF stage plus AVC.
   - Model 46A, a six valve 175 kHz IF, 2 volt filament valves, MF band superheterodyne with RF stage, AVC and Class B output.
   - Model 54, a seven valve 460 kHz IF, 2 volt valves, dual wave superheterodyne receiver with RF stage, AVC and Class B output.

The seven valve dual wave battery-powered Model 54 in Beale cabinet was particularly popular with country listeners. John McKinney, the Toowoomba Airzone Distributor sold 12 sets to listeners during 1935 when new Commercial broadcasting stations 4WK Warwick, 4AK Oakey and 4IP Ipswich came on air. Station 4GR Toowoomba had already been transmitting since 1925 giving a selection of four B Class stations in the Darling Downs area. The set was powered by A battery comprising 2 volt accumulator and three 45 volt dry cell batteries in series for the B supply. High tension drain averaged 13 milliamperes.

In 1936, Breville Radio became Breville Radio Pty Ltd and following the departure of Harry Norville in 1937, William O'Brien became Managing Director of the company.

One employee who joined the company about this time was Arthur Spring who during the War years was associated with the production of Breville's mine detector and Bren Carrier multiband receiver for the armed Services. In later years, Arthur became Chief Engineer of A W Jackson Industries who produced Precedent brand TV receivers.

During the late 1930s, the many different models in production included such technical features as variable selectivity, push-pull output, edge lit 8 inch (200 mm) diameter dials, and lamp switching by the selector knob. A different dial format was provided for each State with the station lettering for a particular State being double size for easy identification. One of the best selling models of the period was the Model 81 a five valve mains powered mantel receiver with a 6 inch (150 mm) Amplion speaker.

When the 2 volt Eveready Air-Cell was released in mid 1937, Breville marketed Model 102 to take advantage of the new A battery-power source. It was a five valve dual wave receiver employing the unusual IF of 182.5 kHz. The usual cabinet style was a Leeds type but others could be used to suit customer preference.

From the start, Breville had a reputation for producing highly reliable receivers and files of letters from listeners, retailers, business houses and Radio Servicemen bear witness to this. Typical of letters from distributors is one from the Manager of Central Western Broadcasting Company Pty Ltd Longreach in which he wrote:

> 'There is no doubt as to the popularity of Breville in our district, and we can assure you that the orders which will come from here will be surprisingly numerous. We have definitely discontinued all other radio lines and will push Breville exclusively.'

The company operated Commercial station 4LG Longreach which had commenced operation on 4 May 1936 with an STC manufactured transmitter transmitting with a power of 500 watts on 1100 kHz.

A letter from a listener, Mr E Stapleton living at Augathella in Queensland where there was no local station is typical. He wrote:

> 'I am writing to you to give you an idea of the kind of wireless I have. Thirteen months ago I purchased from your Agent in this town Mr W Branington, a five valve vibrator Breville radio. I must say that the set is wonderful. It has given me no trouble at all and I am more than satisfied with my purchase. As far as tone, pick-up etc are concerned, it is excellent. I would not or could not wish for a better set. I also know two other chaps in this town who have Breville sets and are getting excellent results.'

In addition to Branch Offices in Melbourne and Brisbane, the company had Interstate Representatives in Bundaberg, Rockhampton, Adelaide, Perth, Launceston, Devonport, Hobart as well as in Wellington, New Zealand.

Just prior to the outbreak of the Second World War, the Chief Engineer was Noel Smith. A feature of many models produced was an eight station Zip automatic tuner. A range of models was also produced for 32, 50 and 110 volt home lighting system operation. From 1938, the company had produced at least 20 different models each year and maintained this schedule until 1941 when effort had to be diverted to the supply of military equipment.

During the War years, Breville produced equipment for the Services including FM transceivers, mine detectors, beacon monitors, test equipment and humidity control equipment. The Proprietor, Bill O'Brien, originated a special training scheme for the RAAF called VENTS.

The program used qualified civilian experts to train RAAF volunteers in the use of radio equipment while they awaited call-up. Two of Breville's wartime employees were Vic Humphrey and Alan McKeown, both Final Testers. Production of domestic receivers resumed in 1946 and soon reached an output of 200 units a week. This fell far short of order requirements and larger premises were acquired and fitted out at 67 Missenden Road, Camperdown.

Domestic receivers produced during 1946 included:

- Model 657, a five valve portable receiver covering the MF broadcast band. It was battery-operated and was fitted with a 5 inch (125 mm) loudspeaker. The receiver was fitted with loop aerial, terminals for earth and external aerial, snap action leather handle with the case being covered with leatherette fabric.

In 1947, Models 621M, 621W, 622M, 622W, 675W and 675M were released. Model 621M was a four valve AC powered broadcast mantel receiver employing a reflexed circuit. Features included 5 inch (125 mm) permag loudspeaker; perspex edgelit dial; and a metal cream coloured cabinet.

Model 621W was similar to 621M but was housed in an Ace polished veneer wooden cabinet with chrome trimming. The 622M was a five valve AC powered MF band receiver housed in a 'Pick-me-up' cabinet with retractable handle. The 622W was similar to 622M but housed in an Ace cabinet. The 675W model was an MF band table four valve receiver powered by a vibrator/battery system. Features included 6 inch (150 mm) loudspeaker; inverse feedback; and AVC. It was housed in a Leslie cabinet. The 675M was similar to 675W but housed in a moulded Keith cabinet.

Valves employed in all models were post War types.

By 1948, Breville had at least five models available in Radio Shops in Apex console and Acme table cabinets. They included five valve dual wave AC powered receiver; five valve dual wave set powered by vibrator/battery system; five valve dual wave, powered by dry cell batteries, and fitted with 1.4 volt filament valves; six valve dual wave AC/DC receiver; and five valve dual wave set designed for operation from home lighting plants of 12, 32 or 50 volts. The Apex console models were provided with 12 inch (30 cm) loudspeakers, while the Acme table sets had 8 inch (200 mm) loudspeakers.

One of the last Breville radiograms manufactured was a five valve dual wave receiver with 3 speed fully automatic record changer in roll top cabinet with highly polished veneer wood.

In 1951, the company sold Breville Radio Manufacturing Division and concentrated on the agency side of business which they had started even before the War, representing Schick Shavers and Beach Refrigerators in Australia. However, the company still retained some interest in local manufacturing, producing the Breville 5 Minute Washing Machine which enjoyed spectacular success before and after the War.

By 1956, the company move to Harris Street, Pyrmont and in 1960 a further move became necessary to larger premises at 67 Murray Street, Pyrmont.

In 1968, Bill O'Brien decided to step down, and son, John took over as Managing Director.

Long time General Manager, Ron Preston became Managing Director in 1984 and John O'Brien became Chairman of the company.

In 1986, Breville headquarters were located at 149 Pyrmont Street, Pyrmont and all manufacturing was located off shore, principally in Hong Kong. However, many of the successful products were conceived and developed in the Australian based R & D Section.

The Breville Radio Manufacturing Division which had been sold in 1951, changed hands again in late 1955 when it was acquired by A W Jackson Industries. Under the new management receiver production continued with both Breville and badge engineered models being manufactured.

With the introduction of television the company manufactured Precedent TV receivers with Arthur Spring being Chief Engineer. Operations were later relocated to Annandale where Factory Manager was Alan McKeown.

In 1968, the business was sold to Radio Corporation but operations ceased in 1970 and the factory sold in 1972.

In 1998, the company businesses included Breville R & D Pty Ltd, Breville Pty Ltd and Breville International based in Hong Kong. The company specialises in research and development of innovative electrical appliances. Mr W John O'Brien was Chairman with headquarters at Hale Street, Botany.

BRITON ELECTRICAL AND RADIO PTY LTD

Briton Electrical and Radio Pty Ltd Sydney was founded by John Noel Briton in 1935. He was a First Class Honours graduate in Electrical Engineering and also held a Science Degree. Following graduation, he worked with Philips in their newly established receiver manufacturing factory in Sydney undertaking receiver design projects under Ir Groeneveld, Chief Engineer and formally from Philips Holland. In 1934, he left Philips to work as Assistant Engineer with Breville Radio Company. In the same year, at the Annual General Meeting of The Institution of Radio Engineers (Australia), he was elected to the Council of the Institution. He was an active participant in Institution activities, delivering papers at the meetings of the Sydney Division. During 1951–52, he served as President of the Institution.

The business, registered as Briton Electrical and Radio Company was initially located at Mountain Street, Broadway and manufactured receivers under the Briton brand name. On 1 July 1936, the business became Briton Electrical and Radio Pty Ltd and was located at Parramatta Road, Petersham.

Briton was a partner and Chief Engineer in the business. In 1936, George Hunt joined the organisation as General Manager. Prior to joining the company, he had been General Manager with Electrical Speciality Manufacturing Co., manufacturers of Aristocrat brand receivers. He was with that company from 1932 until 1936 having moved over from Darelle Products.

Briton prepared a number of designs for the production of high quality receivers and in the first year of operation 10 models came off the production line. A feature of Briton designs was the high level of detail applied to ensuring a high quality product. He undertook a lot of the development work personally. One of the early models was the Model 4E, a six valve AC receiver designed for operation in country areas of low signal strength. A listener at Minlaton in South Australia purchased one of these models and it was still in operation in 1960 when the owner was visited by the Radio Inspector in response to a complaint concerning interference from a nearby power mains transformer. The owner told the Inspector that, except for new valves, the only parts replaced had been electrolytic capacitors in the power unit, a dial lamp and a power cord.

Other models produced in the 1935 range included:

- Model 4C, a high quality AC powered five valve receiver. A similar design but with AVC, was designated Model 4CC.
- Model 6B, a six valve battery-powered set with AVC and B Class audio output stage.
- Model 12, a five valve AC/DC powered receiver with AVC. Valve types were Philips Golden series and all circuits were of the superheterodyne design.
- Briton Portable with valve types KF2, RF amplifier; 15, autodyne; KF2, IF amplifier; KBC1, diode detector, driver; B217, AF amplifier; B240, output. Intermediate frequency was 175 kHz and loudspeaker employed was an Amplion permag type. A battery was 2 volts with 0.7 ampere drain while B batteries were three 45 volt units in series with drain of 9 milliamperes.
- Models 4CD and 6CD. The 4CD was equipped with 4 volt filament valves types AK1, AF2, E454, E463 and 1867 while the 6CD was fitted with 6 volt filament valve types EK1, 6D6, 75, 42 and 80. The dual wave console receiver was referred to as a 175 kHz superheterodyne but the actual IF was 181.5 kHz. Sensitivity was 5 microvolts, with maximum power output being 3 watts.
- Model 6MD, a dual wave mantel set with IF of 450 kHz, employed valve types EK1, 6D6, 75, 42 and 80.

In 1936, the company released the Briton Loughboy Model 94CH combination with radio and record playing facilities, and also a new six valve dual wave design featuring octode frequency converter, providing high sensitivity and low noise level; band pass tuning with 450 kHz IF channel; new duo-diode triode detector-amplifier feeding a 3 watt pentode; 10 inch (250 mm) loudspeaker of the Amplion wide range type; short wave coverage 18 to 55 metres; Whitford short wave switch; 7 inch (175 mm) Efco dial; cabinet available as standard piano finish or deluxe velvet two tone finish and incorporated special acoustic properties.

The Model 94CH was a nine valve high fidelity combination with automatic record changer for 10 inch and 12 inch records and provided with a 12 inch (30 cm) wide range loudspeaker. All valves were Philips P base types with the circuit including RF stage, two IF stages, and push-pull E406N output triodes fed by Ferranti transformer. The loudspeaker field coil was energised by an independent power supply. The combination was also available as Model 94CS employing a similar cabinet and receiver chassis but with a normal turntable and pick-up assembly and fitted with a standard 12 inch (30 cm) loudspeaker.

Included in the range of console cabinet designs were Alison, Park and the Briton 'V' front with an inclined loudspeaker baffle.

In late 1936, the company released a range of six models with an advertising theme, 'Rational Radio — a comprehensive range of receivers that are rational in construction, in appearance and in price'.

- Model 1, The Buccaneer, a 4/5 valve AC powered dual wave mantel set with edgelit glass dial, AVC, tone control and covering short wave band 16–50 metres.
- Model 2, 4/5 valve MF band console receiver with AVC, bandpass preselection, tone control, 8 inch (200 mm) loudspeaker.
- Model 3, 5/6 valve dual wave AC powered receiver with AVC, bandpass preselection, Magic Star visual tuning, 10 inch (250 mm) loudspeaker and covering short wave band 18–55 metres.

- Model 4, 6/7 valve AC powered dual wave set covering short wave band 18–55 metres.
- Model 5, a five valve battery-powered MF band receiver with RF stage and AVC.
- Model 6, a five valve battery-powered dual wave model with 8 inch (200 mm) loudspeaker, low battery consumption and covering short wave band 18.5–51 metres.
- Model 7, a six valve battery-powered dual wave console set with 10 inch (30 cm) permag loudspeaker and covering short wave band 18.5–51 metres.

Models 5, 6 and 7 were designed to operate from the 2 volt Eveready Air-Cell power source.

In 1938, Briton produced a range of three models of Theatrette receivers. French and British versions had been available since about 1936. The Briton made sets were marketed by Briton and Philips. The first design, Model 30 was a dual wave chassisless set with octal valve types EK2G, frequency converter; 6U7G, IF amplifier; 6B6G, detector, AVC rectifier, AF amplifier; EL3G, high mu output pentode and 5Y3G, rectifier. The receiver was fitted with an 8 inch (200 mm) Magnavox loudspeaker. The cabinet design was uniquely fashioned after the proscenium of a theatre enhanced by a finely moulded cabinet with narrow vertical pillars. Model 31 had MF band capability only, while Model 32, also MF band type was a battery-powered version.

John Briton had undertaken considerable development work with components for his receivers and in particular, inductors. At the World Radio Convention held in Sydney in 1938, he delivered a paper 'The Application of Iron in High Frequency Circuits' in which he outlined the application of iron core materials in aerial, RF, IF, oscillator and filter inductors. In his address he included a description of a frequency converter stage he had designed for a receiver arranged to provide eight pre-tuned station settings using individual iron cores for each coil assembly.

John Briton left the company he founded about that time to take up a position as Factory Manager of Radio Productions (HMV) with The Gramophone Co., Ltd. David Wyles who had previously worked with AWA and Philips became Manager of Briton Electrical and Radio Pty Ltd.

Just before Christmas 1940, the company released four new models for the Christmas and New Year sales market, housed in cabinet designs designated Cumberland 49, Norfolk 40, York 40 and York 52. The Cumberland 49 housed a four valve battery-powered MF band set with valve types KK2, KF3, 1K7G and KL4 with a superheterodyne circuit using prematched and sealed aerial and oscillator coils. The Norfolk 40 housed a four valve battery-powered dual wave receiver covering short wave band 13.5–37 metres. The York 40 housed a four valve dual wave receiver with 8 inch (200 m) Rola loudspeaker and used Philips 2 volt filament valves powered by a 2 volt battery, Air-Cell battery or vibrator/battery system. The York 52 housed a five valve AC powered dual wave set with valve types EK2G, octode frequency converter; 6U7G, IF amplifier; 6B6G, detector, AVC, AF amplifier; EL3G, high gain output pentode and 5Y3G rectifier. Features included a surge limiting electrolytic filter system, and bandpass filter between MF band aerial input and mixer grid.

Briton receivers were still being sold in Radio Shops during mid 1940, but the company appears to have ceased business later that year.

COLVILLE WIRELESS EQUIPMENT CO., PTY LTD

The Company commenced operation as Colville-Moore Wireless Supplies Ltd, 10 Rowe Street, Sydney, near Hotel Australia, in 1921. The founding partners were Messrs Colville and Moore.

Sydney Victor Colville, who later conducted the Company on his own, began his career in radio as an experimenter in 1911. He operated a spark wireless telegraphy station with callsign XQF in South Brisbane, Queensland. In 1919, he constructed a high frequency alternator phone transmitter making him one of the first experimenters in Queensland to broadcast sound on long wavelength. He played a major role in establishing the Queensland Wireless Institute in 1919 and constructed its first transmitter employing two V24 valves.

Mr Colville later moved to Sydney where he became involved in the commercial application of radio with Mr Moore.

Syd Colville also had an interest in the use of radio in Aircraft and took up flying in 1927. He undertook development and studies for a number of Governments in the Pacific area in the establishment of radio navigation aids for aircraft landing fields. He was Radio Instructor for the NSW Aero Club and designed and built their radio stations 2FA and 2FB and for a period was Radio Navigator for the Second NZ Fliers. During 1934–35, Syd was Councillor of the Institution of Radio Engineers (Australia) having become a Member in 1932. At the time of the World Radio Convention in 1938, he was a member of the Institution's Editorial Board together with Charles Tyrrel, Ray Allsop, Tom Court, Fred Canning and Richard Kennell.

Mr A L Moore had been involved in experimental radio work for many years before joining with Syd Colville to form the company. He was a qualified operator possessing a Commercial Wireless Certificate.

In his early work, he did a great deal of development work with receivers particularly loose couplers. One of his improvements with loose couplers was the provision of a vernier adjustment device on the secondary coil in the form of a cotton cord and small pulley device. He also developed an improved crystal detector by grinding up several galena crystals to almost powder form and pasting the material on a copper tube using Wood's metal. The cat's whisker was attached to a rotating arm so designed that the cat's whisker could contact any part of the tube on which the crystals had been deposited.

When valves became available after the War he obtained a box of unused R types and constructed a five valve receiver with a regenerative first stage, crystal detector followed by audio stages and feeding a loudspeaker which used a Baldwin earpiece mounted in the base of phonograph horn. Six plug-in type coils were used to cover the various bands.

With the imminent establishment of broadcasting stations in Australia, the company prepared plans for the manufacture of a range of domestic receivers to meet the anticipated demand. They were in a good position of readiness when 2SB (2BL) and 2FC began transmissions just before Christmas 1923.

Within a short time, the company had one of the largest range of locally designed and manufactured receivers in Australia.

At the Royal Agricultural Society Easter Show in 1925, some of the receivers were exhibited, and resulted in a great deal of interest by the public with many orders being placed, particularly by country visitors to the Show. The receivers were produced under the brand name Colmovox and models on display included:

- Model J20 — a single valve regenerative receiver designed for reception of stations up to 80 km.
- Model J21 — a two valve set with the same circuit as the J20 followed by an AF stage.
- Model J22 — a three valve regenerative receiver with detector and two AF stages. The apparatus was housed in a polished maple case with an engraved bakelite panel and had capability of reception up to 150 km.
- Model SE20 — a single valve three coil regenerative receiver of high selectivity supplied complete with polished cabinet, batteries, coils, headphones, and aerial wire.
- Model SE22 — a three valve model designed for loudspeaker operation with stations up to 150 km.
- Model SE23 — similar to the SE22 but with the addition of an RF stage.
- Model S20 — a moderately priced three valve regenerative receiver employing two dials.

- Model S21 — a four valve RF regenerative receiver designed for country listeners to provide loudspeaker reception up to 450 km from the transmitter.
- Model SU21 — a six valve non-regenerative receiver guaranteed by the Company to provide loudspeaker reception anywhere in Australia from A Class stations. It was marketed as the Super Colmovox receiver.
- Model SUP — a seven valve receiver also designed for the country listener. It employed a circuit similar to the six valve model but had a power amplifier stage added.
- Model SU20 — a five non-regenerative receiver of high quality performance up to 800 km from A Class stations.

Any of the multivalve receivers could be supplied in cabinet styles, upright or horizontal and in colours to suit the buyer. Many customers preferred that the finish of the cabinet be such that it harmonised with the other furniture in the room in which it was to be placed. Flat and satin finished mahogany, walnut and teak were popular with many buyers. One grazier from Bathurst ordered a specially manufactured cabinet for his Super Colmovox six valve receiver to match the finish of a piano he had bought with him when he migrated from Germany about 1920.

All receivers on show were set up in operational condition. Advance orders were received for 14 receivers including six of the Super Colomovox model. They went to customers residing at Newcastle, Bega, Dubbo, Broken Hill, Grafton and Taree.

In 1925, the company was the manufacturer and sole distributor of the 'Maclurcan' receiver designed by Charles D Maclurcan, a Consulting Radio Engineer and an accomplished radio experimenter and operator of Amateur station A2CM which provided regular broadcast of high quality programs before the establishment of A and B Class stations in Sydney.

A feature of the Maclurcan receiver was a facility to provide three different tones. These were:

- Ordinary radio.
- Rich, full mellow tone of the human voice.
- A subdued version of position 2.

The tone facility was developed by Maclurcan and could be purchased from the company retail store and some other outlets. It was known as the Maclurcan Tone Purifier.

The company had a retail sales outlet at its premises at 4 and 10 Rowe Street, next to Hotel Australia and stocked a wide range of components made locally in their factory, and imported overseas components from USA, France, Holland and England. In addition to Colmovox label valve receivers and crystal sets, the stock included Colmo parts; Solodyne, Three Valve Low Loss, Two Valve Reflex and Grodan Neutrodyne kit sets; Maclurcan Tone Purifier; Advance products; Radiokes products; Emmco components; Radio and Dilecto panel materials; Philips, Radiotron, Osram and de Forest valves; Hellenson B batteries; Benjamin anti-microphonic valve sockets; Pilot radio products; Wetless capacitors; Harlie detectors; Cutler-Hammer radio products; Gilfillan radio products; Giblin Remler coils; Frost headphones; Clydon, Ormond, Igranic, AWA, variable capacitors; Amplion, Sterling and BTH loudspeakers; National products including the National Regenaformer, a new development in RF transformers which became popular with locally constructed receivers employing the Browning-Drake circuit and Jefferson AF and RF transformers.

They had on display one of the largest ranges of Gilfillan products manufactured by Gilfillan Bros., Incorporated, a major USA manufacturer of radio parts and receivers. Components in the showcase comprised detector units, valve sockets, knobs and dials, potentiometers, transformers, binding posts, rheostats, variometers, variocouplers, adapter, contact studs, stops, capacitors, jacks, phone plugs, switch arms, contacts and inductance switch. An assortment of photographs showing the range of Gilfillan receivers was also shown but only one receiver was on display. It was a five valve console receiver in a brown mahogany cabinet and featured a voltmeter to check battery condition and a reflex type loudspeaker. It was later sold to a business lady who had a dressmaking business in George Street, Sydney.

Receivers produced during 1930 included the three valve 103 and four valve 104 all-electric receivers with the model 104 being the first model manufactured by the company with a screen grid valve. The design incorporated screen grid high frequency amplifier, power detector, super power 245 audio amplifier and rectifier.

Both models had single dial tuning facility with a tuning chart being provided showing at a glance, the dial settings for any desired station.

A standard table type cabinet was provided for both 103 and 104 models but the 104 was also available with console cabinet and designated as 104C. The loudspeaker was built into the cabinet of the console.

The 103 and 104 table models required an external loudspeaker. A polished maple table and baffle combination was available on which to stand the receiver and mount the loudspeaker unit. A Magnavox or loudspeaker of similar design could be fitted into the baffle.

Many experimenters had the company construct transmitters and receivers for their stations. The transmitter built for a well-known Newcastle experimenter in the early 1930s was crystal controlled, it had capability for telegraphy or telephony mode operation with three switchable different methods of modulation for telephony, and produced an output of 25 watts in the 20, 40 and 80 metre bands. The unit was mounted in a cabinet about 1.5 metre high and 450 mm wide and was constructed to the same high standard as a Commercial broadcasting station transmitter.

Another project undertaken in the same period, was an aircraft transmitter and receiver designed for Sir Charles Kingsford-Smith for use in the Australian built monoplane 'Codock'. It was self-contained and produced an output of 25 watts when powered from an 8 volt accumulator.

One unusual custom built receiver at the time was one constructed for the owner of a launch. It was a Super Six battery-operated set with all components being thoroughly waterproofed, all wiring dipped in lacquer before assembly and transformers being hermetically sealed in metal cases.

One popular receiver on sale during the 1931 Christmas period was designed for country listeners located some distance from a broadcasting transmitter. The company guaranteed daylight reception from local stations and good reception at loudspeaker strength during night-time from all Australian and New Zealand stations. It employed two stages of RF, a detector and push-pull audio stage. It had facilities for playing gramophone records. The receiver was housed in a Cathedral Series of cabinets designed and made by Dickin.

With the rapid expansion of the number of broadcasting stations licensed in the 1930s, the company expanded its activities to include a range of equipment to suit transmission and studio requirements. Equipment included transmitters manufactured under licence by Philips. Stations installed with the equipment included 4AY, Ayr, October 1934 (500 W); 4IP Ipswich, September 1935 (100 W); 4BU Bundaberg, December 1935 (500 W) and 2TM Tamworth, 1937 (2000 W).

William McGuire, the company Design and Construction Engineer played a major role in providing and installing Commercial station transmitters and studio equipment over many years. He joined the organisation in 1927 after having been trained at the Marconi School of Wireless in Sydney. Bill later moved to AWA where he was engaged on design and development of equipment for the Services during the War period.

Another Engineer who worked with the company was John Fletcher. He was a member of the group working on transmitters during 1937–38 and had previously been Transmission Engineer with Philips. After leaving Colville Wireless in 1938, he returned to Philips. Other company staff during that period included Vic Humphreys and Ron Mitchell.

By 1937, the business was being operated at 8 Smail Street, Broadway, Sydney. Major products included broadcast transmitters; radiocommunications transmitters and receivers; custom built broadcast receivers; Colvillco variable and fixed transmitting capacitors; HF inductors; audio, radio frequency and power transformers; audio, radio frequency and power chokes; frequency control units; program input equipment; studio control desks; Philips transmitting valves; aircraft radio equipment etc.

At that time, the company traded as Colville Wireless Equipment Company Pty Ltd.

One of the major contributions to broadcast technology by the company in the late 1930s was the design, construction and commissioning of a 2000 watt transmitter for 2TM Tamworth operated by Tamworth Radio Development Co., Ltd. The transmitter was unusual at the time in that it employed Philips pentode valves throughout the transmission stages. The transmitter was manufactured under licence from Philips and only seven valves were employed to produce the 2000 watt output. With the exception of the pump for the water cooling system for the final stage valve, no rotating machinery was employed in the unit. All filament, grid and anode voltages were provided by rectifier systems.

Modulation was effected by a pair of triode connected Philips type PE02/5 pentodes connected in push-pull and fed directly from the studio program line via a transformer. This stage was linked to the suppressor grids of two PC1.5/100 directly heated valves in parallel which performed the function of the modulated amplifier. A Philips water cooled pentode type PA12/15 was used as a linear amplifier delivering 2000 watts to the transmission line.

During commissioning, the transmitter provided an efficiency of 22.5% when delivering 3.5 kW to line. However, in order to meet the licence conditions, the excitation was reduced to provide 2 kW to line, and at this level, the efficiency was measured at 18.5%.

During the War years, although operating at restricted staff levels, the company produced a range of equipment for the Services including transmitters, receivers, RF amplifiers and accessories.

By early 1941, the company had transferred activities to 52 Carrington Street in the city and became heavily involved in commitments for the Defence Forces. It appears to have ceased trading about 1958.

COMMONWEALTH ELECTRONICS PTY LTD

The company is typical of several set up by entrepreneurs with a technical background to manufacture equipment to meet a market need in the 1950s and then disappear from the industry after about 20 years operation.

Commonwealth Electronics Pty Ltd was formed in Sydney in 1950 by Ron Hope, former Chief Engineer 7HO, Alan McKenzie and Bob Zucker with a factory of modest proportions located at Baulkham Hills, Sydney.

After getting facilities operational, a branch was established at Derwent Park Munitions Annexe near Hobart about 1957, with Bill Nicholas former Chief Engineer 7HT, and John Dodds as additional Directors. They were later joined by Dave Hildyard. Messrs Hope, Nicholas, Dodds and Hildyard had all been previously associated with Commercial broadcasting stations in Tasmania.

The company produced a range of products including Minifon and Ultra Minifon hand-held transceivers, single channel radio telephone systems, airport radio equipment including beacon transmitters, MF broadcast transmitters, tape recorders, turntables and others.

The Hobart factory produced the CE turntables including the die-casting operations. They were produced in large numbers and sold well with units being employed in professional recording studios, Commercial station studios, ABC studios and overseas broadcasting station studios. They were also fitted to emergency studios at some staffed NBS transmitting stations.

The turntables were recognised at the time as amongst the best available for broadcasting purposes, even when compared with imported overseas products. The high level of quality control, the skilled staff and the high class machinery installed in the factory ensured a top quality product. Main features of the turntable included four pole synchronous motor with heavy duty rating; motor suspended in shock absorbent mounting; speeds selected by shift mechanism on idler wheel; neoprene idler wheel employed to transfer drive to the cast aluminium turntable; turntable shaft mounted at bottom on thrust ball and high speed acceleration of turntable providing full speed within half a revolution from start position. The wow and flutter factor was better than 0.1% at 33½ RPM which exceeded the USA NAB Standard at the time of 0.2% of the mean speed. The low frequency noise output of the turntable (rumble) also exceeded the USA Standard.

A point of interest with the machine was the great care taken to ensure the turntable ran at constant speed without vibration or waver. This was achieved by employment of a heavy duty synchronous motor, a heavy rimmed table, a point pressure bearing and a neoprene idler wheel. The steel turntable shaft was of liberal length to obtain a long bearing effect. The bottom of the shaft sat on a steel ball which rested in a conical cup at the bottom of the white metal lined bearing. Resultant friction was reduced to an absolute minimum and the bearing ensured no side play.

About 2000 CE turntables were produced in the Hobart factory up to the time of closure in 1972.

The portable CE tape recorder, well-known to Technicians at the ABC studios, was designed in response to the Postmaster General's Department specification for the use by ABC staff at the 1956 Olympic Games in Melbourne. They were a popular recorder being in service at most major ABS studios. The tape transport mechanism of the recorder was powered by a spring-driven motor fitted with a speed governor. The mechanism moved the ¼ inch tape at a speed of 7½ inches per second. The valve amplifiers were powered by dry cell batteries. Performance met CCIR specifications in the range 50 to 7500 Hz. Electronics for the recorder was undertaken by the Sydney factory staff while Hobart staff were responsible for mechanical design, manufacture of the complete unit and the acceptance testing.

Other equipment produced in the Hobart factory included VHF cavity filters, UHF amplifiers, coaxial relays and many mechanical 'one-off' items and repetitive turning for the Sydney factory requirements.

The local factory also employed two Technicians full-time on specialised service, X-ray equipment in Tasmanian hospitals, survey equipment, microwave ovens, 2-way radios, small ship's radios and audio equipment installations.

The Sydney factory produced a range of transmitters for MF broadcasting stations including twin 50 watt units for NBS stations at Tennant Creek and Katherine in Northern Territory which went to air during 1960, and twin 200 watt units for 6CA Carnarvon which was commissioned during 1964. Higher power units including the type MFT8/2500 were supplied to other stations in 1965.

For a period, the company had an arrangement with Westrex Australia Pty Ltd to take advantage of Westrex electronic expertise.

In 1969, Commonwealth Electronics Pty Ltd became part of the Philips organisation and the name changed to CE Electronics Pty Ltd. The Hobart factory closed in 1972, and the Sydney operations transferred to a Philips complex at Brookville where it operated for a while before closing down.

CRAMMOND RADIO MANUFACTURING CO.

Crammond Radio Manufacturing Company established in the mid 1920s, was a subsidiary of Melton and Co. Melton and Co. located at 8 Queen Street, Brisbane near the Victoria Bridge, was one of the oldest radio and photographic businesses in Queensland, trading in both wholesale and retail fields.

In addition to manufacturing receivers and some components on the premises, Crammond provided a rebuilding service to modernise old receivers, with conversion from battery to AC mains operation being a profitable activity. The Radio Department Manager was A Crammond with Keith Elliot being a member of the Technical staff. Another staff member was Eric Cantelin who was also Technical Editor of The Queensland Radio News.

Locally designed and manufactured receivers were marketed under the brand name 'Crammond'. In 1929, models included Crammond Three, a three valve receiver fitted into a polished wooden cabinet; Crammond All Metal Super Three finished with a nickel or bronze cabinet, and the Crammond All Metal Screen Grid Four Solodyne in a cabinet of sheet brass finished in nickel, bronze or Duco.

In 1930, the company produced the Crammond Screen Grid Four manufactured in both table and console models for battery or AC mains operation. Facilities were built-in to enable use of an electric gramophone pick-up. The circuit comprised two screen grid RF stages, high gain detector with reaction and a pentode output stage. The three tuning capacitors were ganged and provided with small balancers for accurate alignment. The coils were totally screened and components mounted on an aluminium chassis. The power pack was a separate unit fitted into the cabinet adjacent to the receiver chassis. Tuning capacitors were AWA types while components employed in the power pack were of Philips manufacture. It was claimed to be the first commercially built screen grid all electric four valve receiver in Queensland. With the console model the loudspeaker was built into the cabinet but for table model a separate loudspeaker was located externally. The models were also available as battery-operated versions.

Melton and Co., also stocked other brands including Rotor Five, Atwater Kent, Philips Radioplayer and Radiola models. Major component lines comprised Magnavox, Philips Peter Pan, Philips Sevenette, Philips Baby Grand, Manhattan, AWA and Amplion loudspeakers; Advance, Ediswan, Effesca, Philips, AWA AF transformers; Igranic variable capacitors; Radiokes Solodyne coil kits and others.

Between 1938 and 1947 the company produced well over 100 models with brand names including Hawk, Senior, Eagle and Falcon. The range included designs powered by AC, battery, vibrator/accumulator, Eveready Air-Cell and Universal power sources with mantel, table and console cabinets as well as portables.

The largest receiver produced was a 10 valve Model 1005C Eagle released in 1938. It was an AC powered dual wave superheterodyne receiver with IF of 453 kHz and housed in a console cabinet.

It is of interest that the company employed an IF of 200 kHz for some of its designs. They included three Models 505C produced in 1938–40 as AC powered dual wave five valve consoles; Models 624C produced in 1938–40 as Universal powered MF band six valve consoles; and Models 625C produced 1938–40 as Universal powered dual wave band six valve consoles.

Other IF's employed were 453 and 455 kHz.

During the War years, Crammond supplied radio teletype units and Fortress signals equipment for the Services.

After the War, Crammond began production of other equipment lines besides domestic radio receivers. They included noise and fault locators for PMG's Department and Councils, and also pH equipment for sugar mills throughout the world.

DUCON CONDENSER PTY LTD

In the 1920s, receiver manufacturers and hobbyists were well-served by Radio Shops and distributors with fixed capacitors. There were at least 25 brands available from overseas sources, and several Australian manufacturers including Wetless, Advance, EMMCO, AWA and others.

At the start of the 1930s, other Australian manufacturers entered the scene to provide for an expanding market. One of these organisations which is still a major components business was Ducon Condenser Pty Ltd, formed on 1 June 1932 when it acquired the manufacturing activities of H Hecht and Co., which had began producing electrolytic and paper capacitors, in November 1931 in Regent Street, Sydney. Hecht and Co., products were sold under the Chanex 'condenser' and Chancery potentiometer labels. Andrew Persson became Manager of Ducon Condenser Pty Ltd and H Hecht and Co.

It is of interest that the word 'Ducon' was the trade name of a device comprising two capacitors which could be fitted to an electric light socket and made to serve in place of an outdoor aerial. It was a product of the USA company, Dubilier Condenser and Radio Corporation established in 1917. The device was available from many Australian Radio Shops in the mid 1920s.

Within 12 months, the Regent Street premises had become too small and larger premises were purchased in Kippax Street, Sydney where the product range was expanded to include paper dielectric capacitors for power factor correction purposes.

In late 1933, Ducon began manufacture of the Jubilee loudspeaker with distribution being handled by H Hecht and Co.

The loudspeaker had a number of interesting features including a new concentric disc design which ensured permanent alignment of the speech coil; high sensitivity; expanded frequency range response; enclosed air gap ensuring freedom from dust; low distortion at the rated power; a protected terminal strip on the transformer; available in single or twin types; and finished in nickel or chromium.

On Monday 17 December 1934, the whole of the manufacturing activities were transferred to newly built factory and office premises at 73–83 Bourke Street, Waterloo where floor space was double that available at Kippax Street. The executive and office staff of Ducon and H Hecht and Co., were also located at the new premises.

A number of other products including mica dielectric capacitors and wire wound resistors were added to the range.

At the time, Keith Blackwell who had previously been with the AGE company and Philips Lamps (A/Asia) Ltd was company Chief Technical Engineer, Clarry Healy was Chief Research Engineer and George Davidson was Sales Manager.

About this time, Mr J Katzman an American Consulting Engineer and expert in the design and manufacture of electrolytic capacitors, came to the Sydney factory for a period, and following his recommendations, a new range of electrolytic capacitors was introduced. They included type 80 and type 81 both aluminium can models, types 20, 21, 22, 26 and 27 all flat packs and types 60, 61 and 61 cylindrical jelly types. The type 81 was a new development capable of handling peak or surge loads up to 800 volts and continuous working at 600 volts DC.

In 1938, Ducon purchased another capacitor manufacturer, Continental Carbon Co., Melbourne and in doing so, acquired some valuable patents and processes controlled by an American company.

In order to improve its ceramic materials, especially for high voltage transmitting capacitors, Cliff Gittoes, Technical Director, visited the USA shortly after the outbreak of the Second World War to negotiate for supply of steatite materials. Cliff, a former student of the Marconi School of Wireless, had joined Ducon in 1933 as Chanex Production Manager, becoming Assistant Manager of Ducon in 1938. By 1942, with production increased to meet Defence needs, a nearby property was purchased making Ducon the largest manufacturer of capacitors in Australia, with employee numbers exceeding 700.

Simplex Products Pty Ltd, manufacturers of mica dielectric capacitors became a subsidiary of Ducon in 1948. Simplex had been founded by Horace Hankin, and Gordon Rich was Proprietor when the firm was linked with Ducon. Gordon Rich had joined Simplex as Sales Manager in 1931. Simplex specialised in mica dielectric capacitors and in order to ensure a reliable supply of mica, Ducon purchased Mica Products Pty Ltd.

In 1952, Ducon began production of ceramic capacitors following an agreement with a French organisation who specialised in this field.

To meet expanded production requirements, the company purchased a site at Villawood and erected a large complex with the most up-to-date facilities. Production at the site began in 1955 with new products including polystyrene capacitors. In 1960, the Villawood plant was extended to cater for production of power network capacitors and for the establishment of a high voltage testing laboratory. In 1963, Ducon Condenser Pty Ltd was acquired by the giant British company Plessey. The holding company, Ducon Industries Ltd controlled six subsidiary companies, Ducon Condenser Pty Ltd, Ducon General Ceramics Pty Ltd, Mica Products Pty Ltd, Resistor Engineering Co., Pty Ltd, Simplex Products Pty Ltd and Ducon (NZ) Ltd. It had 1600 people on the payroll.

Today, the company trades as Plessey-Ducon.

Many technical and scientific people have been associated with development, design and production of the company products over the years. Some of these people include Keith Blackwell, Mervyn Burt, Jack Catto, Ray Darnell, Chris Dvornik, Tom Evans, Charles Farley, Laurie Fennell, John Ferguson, Noel Fetherston, Bruce Gittoes, Cliff Gittoes, Graham Hall, Don Hille, Jack House, Ron Kirton, Ray Kirkwood, Alex McMurray, John Nichol, Andrew Persson, Conrad Persson, Warner Pilmore, Hans Rucket, Jim Starling, Ron Tillman, E Tischler, Mick Turyman, R Whitehead, R S Worth, and others.

Noel Fetherston, an analytical and research Chemist by profession was Chief Research Engineer of the company at the outbreak of the Second World War in 1939. He had previously worked with Continental Carbon Resistor Co., Ltd where he had been engaged in research with a wide range of products including bakelite moulded insulated resistors and coils, IF transformers, switch units and other components. In 1935, he joined Ducon and became Chief Research Engineer in February 1938.

ECLIPSE RADIO PTY LTD

Eclipse Radio Pty Ltd was registered in 1925 by two brothers, Saul and Albert Aarons at 349 Flinders Lane, Melbourne. Saul Aarons had been involved in the sales side of radio for some time. In 1924, he commenced with Corbett, Dernham Pty Ltd as Sales Manager marketing the company's Tunafone brand models with the Tunafone Three produced in 1925 being one of the most popular models. It was a battery-powered model and provided with a set of seven plug-in coils and a Tunatalker loudspeaker. When Corbett, Dernham Pty Ltd established a branch at City Chambers, Pirie Street, Adelaide Saul helped to set up the sales and promotional side of the business.

One of the first major contributions to the broadcasting industry by the company was the release of the Pierce-Airo six valve battery-powered receiver in 1927. It featured a handsome table model cabinet, one dial tuning control and resistance-capacity coupled stages, a technique not widely employed at the time. The tuning capacitors comprised an in-line three gang model with vernier control and with all three capacitors mounted on a single shaft. Distributors handling the receiver included Langford, Pickles and Co., Little Collins Street, Melbourne; D and W Chandler, Flinders Street, Melbourne; Radio Sales and Exchange, Russell Street, Melbourne; Tremon Wireless Co., Lonsdale Street, Melbourne; and W H Knight and Peters Bros., Launceston. In an advertisement in the local technical press, the company claimed the receiver had received at good strength the local stations 3LO, 3AR, 3UZ and 3DB and interstate stations 2BL, 2FC, 2KY, 2BE, 2GB, 4QG, 5DN and 5CL.

By 1928, the company had in stock one of the largest range of components available in Melbourne. Components included Stewart-Warner, Kellogg Symphony and Brandes H type horn loudspeakers; Racon exponential horn loudspeakers; Kelford audio frequency transformers and valve sockets; Compact Scientific logarithmic tuning capacitors; Kenyon audio frequency transformers; Little Spitfire Tower horn loudspeaker; and many others.

Included in the range of receivers were Grand Opera All-Electric Three, an AC powered receiver with single dial control and housed in a highly polished wooden table type cabinet, and the Kelford All-Electric Three, assembled employing Kelford parts.

During the 1929 Christmas period, the Simplicity Three kit set was a popular sales item. Two of the kit sets were purchased by the Sacred Heart College Radio Club in Adelaide and donated as Prizes to Club members. The set was an AC powered model and employed valve types Vox 226, 227 171A and 280. Components were manufactured by many well-known businesses and included Lewbury, Kelford, National, TCC, Dresner, Amaco and Essanay brands.

In 1931, Charles Welsh joined the company and the trio ran Eclipse for many years. In August 1938, Albert Aarons retired, and Saul Aarons became Managing Director.

When the Commonwealth Government imposed tariff on imported receivers and radio components, production of receivers using Australian made components increased. In 1932, Eclipse released the Univox, a seven valve superheterodyne receiver in a beautiful cabinet with piano finish. Shortly after release, it was upgraded with a patented 'Tune-by-light' system. A red light dimmed to indicate that the station had been correctly tuned in.

The 1933 models included a five valve midget or mantel superheterodyne set employing valve types 2A7, pentagrid converter; 58, 465 kHz IF amplifier; 57, second detector and 2A5 output pentode providing three watts to a Saxon midget electrodynamic loudspeaker with a four inch cone, and full wave rectifier. The Alpha Superhet kit set was also manufactured during the same year. It comprised aerial, selector, RF and oscillator coils; two intermediate transformers; a four gang variable capacitor; dial; full set of shielding cans; padder capacitor; knobs; escutcheon plate and full size circuit diagram together with instruction sheet, all contained in a box.

By 1934, Eclipse had expanded its manufacturing facilities to include the manufacture of all components and parts required for its operations. These included such items as grid leaks, power and audio transformers, loudspeaker, fixed and variable capacitors, fixed and variable resistors and all mechanical parts. The only items not manufactured on site were valves and electrolytic capacitors. The involvement also included the complete production of all technical leaflets, brochures, booklets and advertising copy using its own printing presses. It also manufactured and labelled its own cartons and boxes to house components and units. At that stage, the company was producing Saxon components, Croyden car receivers and was in the process of manufacturing the Eclipse Endeavour receiver intended for release during the Melbourne Centenary Celebrations. Saul (Sol) Aarons was in charge of the technical side of the business.

The Endeavour series included a beautiful console cabinet and a table type cabinet. The console set employed Tungsol valves in a superheterodyne circuit, an 11 inch (275 mm) Saxon electrodynamic loudspeaker, Efco Aero dial and an escutcheon plate specially designed by a leading sculptor.

The mantel or midget version was a five valve superheterodyne receiver with IF 465 kHz and employing valve types 77 (two), 6D6, 89 and 280 rectifier. A six inch (150 mm) Saxon loudspeaker was employed. Twin oxidised escutcheons provided a neat finish to a highly polished mahogany cabinet.

About the same time, the five valve Croyden mantel set with valve types 57 (two), 58, 2A5 and 280 rectifier was available.

Eclipse receivers were in such demand that in mid 1934, about 1000 units were being despatched from the factory each week. A range of 25 cabinet types was available. Staff employed exceeded 850.

In addition to AC powered models there was a range of battery-powered sets. These included:

- Model 306, a superheterodyne console receiver with 175 kHz IF and employing valve types 32, RF amplifier; 32, mixer; 34, IF amplifier; 32, detector; 30, driver and 19 Class B output. A battery was a 2 volt 80 Ahr accumulator with 0.5 ampere drain while B battery used four 45 volt Eveready dry batteries with drain (quiescent) 10 to 12 milliamperes. Loudspeaker was Saxon permag type.
- Model 510, a five valve superheterodyne set with 175 kHz IF and valve types 34, RF amplifier; 6A7, mixer; 34, IF amplifier; 6B7 detector and 38, output. A battery was a 6 volt accumulator while B battery was four Eveready 45 volt batteries in series.
- Model 508, a five valve TRF receiver employing valve types 34 (three), RF amplifiers; 32, detector and 33, output. A battery was 2 volt accumulator. B battery comprised three 45 volt dry cell types in series. The set was enclosed in a console cabinet.
- Six valve receiver employing valve types 1A6; 32; 34 (two); 30 and 19 in line with Class B output. IF was 465 kHz. A battery was a 2 volt accumulator, B battery consisted of four 45 volt dry cell batteries in series and C battery was a tapped 12 volt dry cell type. B battery drain at average listening volume was 9-15 milliamperes.

In 1935, Eclipse produced one of its most popular components. It was a newly designed Saxon three gang variable tuning capacitor. Features included phosphor bronze contact spring, oversize trimmers, special ball bearings at both ends of the shaft, high quality stator insulation, best quality aluminium plates, three point floating suspension, bracket provided for pilot lamp assembly, smooth vernier action, spring for adjustment of dial cord, specially designed dial with mounting slots to facilitate zero adjustment.

One of the most popular car radios on the market in 1935, was the Eclipse Endeavour. Model 519 was a 12 volt powered receiver with a relatively low current drain, being only 2.25 amperes. Valve types were 78, RF amplifier; 1A7, pentagrid converter; 78, 175 kHz IF amplifier; 6B7, detector and audio amplifier; and 89 pentode output. The AVC operated on both amplifiers and also the pentagrid converter, to give very effective control. Loudspeaker was a 6 inch (150 mm) Saxon type.

The company established a Branch at Clarence Street, Sydney shortly after starting operations in Melbourne. In 1930, the Sydney office had a staff of only about half a dozen but by the mid 1930s, staff had increased to over 30 employees. Chief Engineer in charge of the technical arm of the Branch was N H Buchanan. He had previously been Chief Engineer of Zenith Radio Co., Ltd. He left Eclipse about the mid 1930s to take up a position of Director and Chief Engineer, Sterling Radio Pty Ltd.

In mid 1935, newly released Croyden label receivers included:

- Model 534, a five valve superheterodyne AC powered receiver housed in a mantel cabinet which was a replica of a large console and labelled a 'consolette'. Valve types were 77 (two), 6D6, 89 and 80 rectifier. Loudspeaker was a 6 inch (150 mm) Saxon electrodynamic type. The set was fitted with a full vision dial with a unique bakelite escutcheon.
- Model 608, a dual wave six valve superheterodyne set housed in a console cabinet and fitted with the latest American type super vernier dial assembly with 80:1 and 10:1 ratios. A new trimmer design provided sharp tuning on short wave reception. Loudspeaker was a 12 inch (30 cm) Croyden model.
- Model 539 was a five valve version of Model 608.

Among the new releases of 1937 were:

- Series 571, a five valve automatically tuned dual wave receiver in a bakelite mantel cabinet.
- Series 573, a five valve dual wave receiver without the automatic tuning facility.
- Series 572, a five valve MF band superheterodyne receiver.
- Series 413, a four valve MF band superheterodyne set.

In 1938, the automatic tuning facility was revamped and designated 'Touch Tuning'. Model 583/22 was one which featured the new permeability push-button tuning unit.

With the availability of the 2 volt Eveready Air-Cell A battery source in mid 1937, Eclipse produced three models designed for operation with the Air-Cell. They were:

- Model S409, a four valve MF band console cabinet receiver.
- Model S548, a five valve MF band console cabinet receiver.
- Model S604, a six valve dual wave band console cabinet receiver.

All were marketed under the Croyden label.

Over a five year period from 1933, some 40 different models were produced under the Croyden label. Twenty-two models were produced 1939–40.

During the late 1930s, the output of domestic receivers was considerable and included many models. Well-kown labels produced by Eclipse included Croyden, Monarch, Endeavour, Univox, Peter Pan, Genwin Show Box, Saxon, Chorister, Saxonette, Meteor, Kelford, Pierce-Arco and others. The company was also involved in Badge Engineering, producing unbranded chassis for sale by Department stores, small receiver assembly businesses and Radio Shops with their own logos.

By 1939, Eclipse Radio Pty Ltd had become part of the Electronic Industries Ltd group. EIL was subsequently acquired by Philips Industries Holdings Ltd.

Receivers under the Monarch label were produced with about 16 models being available during 1939, and 40 during 1940–41. Included in the designs were two valve AC powered receivers employing a TRF circuit. They were Models, Baby released in 1939, AR released in 1940 and ARK released in 1940–41.

Production of Monarch receivers resumed after the War with about 14 models being available between 1946 and 1948.

Peter Pan was another popular Eclipse manufactured receiver marketed 1938 to 1948 with a three-year break during the War years. The Model GMP produced in 1948 was an AC powered 12 valve dual wave radiogram unit.

The Works Manager was William (Bill) Kerr who had founded Kerr and Muir Wireless Pty Ltd in 1922. It was later absorbed by Eclipse. In 1939, technical staff included Robert Sykes, Chief Engineer and George Williams. George was a graduate of Leipzig University and joined Eclipse in 1928, later becoming Chief Laboratory Engineer.

During the War years, the company undertook many major changes to its production line facilities in Sturt Street, South Melbourne in order to handle the large Defence orders. One of its important contributions was the manufacture of the 500 watt HF transmitter type AT20 as a mobile unit for the RAAF. It was no simple matter to change operation to manufacture of these units under pressure. Other items included production of radar equipment for anti-aircraft guns, shore defences and aircraft ASV, fortress telephone amplifiers and an 18 valve communications receiver AMR200, covering the range 1250 kHz to 30 MHz for the USA Signal Corps.

After the War, Eclipse returned to the manufacture of domestic radio receivers with Monarch and Peter Pan being among the early models to come off the production line. However, the introduction of new technology, such as the transistor, in receiver design and intense competition from low priced imported receivers, the production line facilities were closed down in 1970 when Philips Industries rationalised its operations.

One of the early 1930s employees who commenced work at Eclipse was Harry Mauger. Harry commenced work as a Junior Wirer following education at Swinburne College. By 1940, he had graduated to a position in the company Research Laboratory and soon after, joined the Army for War service with Army Divisional Signals. After the War, he resumed work as Project Engineer with Eclipse which by that time had been taken over by the Astor organisation. While employed in the Astor Research Laboratory developing high quality radiogram equipment, the company became involved in the production of Mercury hi-fi records and Harry became involved in their production with other employees including Colin Swan, Charlie Gendle, Bob Morrison and Frank Hulbert. A factory was set up in Richmond, Melbourne in the early 1950s to set up Mercury (Australia). By the time the production of 45 and 33⅓ RPM began, Harry had been appointed Production Foreman. In 1956, a new factory was established at Huntingdale to replace the original factory.

EFCO MANUFACTURING CO., PTY LTD

The Efco organisation was founded in June 1920 by the Facer family, headed by Richard Facer. The business with a work force of seven, manufactured builders hardware in a galvanised iron shed at Princes Highway, Arncliffe.

In 1929, the business was registered as Efco Manufacturing Company Ltd. The name EFCO was derived from the family name initial plus CO.

In 1932, the company began the manufacture of dials for radio receivers. Following the success of this venture, they began the manufacture of other radio products involving Mechanical Engineering practices. Management of the works was undertaken by Thomas and Reg Facer, sons of Richard Facer. Reg was Superintendent of the radio side of the business. Chief Engineer was L Poole who joined Efco in 1924. He had previously worked with Enfield Small Arms Co., in England, and served in France during the First World War. Prior to joining Enfield Small Arms Co., he had conducted an Engineering business on his own behalf.

In 1933, the company produced the Efco Visual Tuner. It was followed by the type K tuner, a three gang tuner constructed from heavy gauge nickel plated steel, fitted with front and rear end ball bearings and plates formed from double rolled aluminium sheet.

Efco dials were available with all sizes of spindles being catered for. Clockwise and anticlockwise scales could be substituted. Escutcheons were finished in Florentine bronze. Models included The Beam, cord drive dial; Senior Ship, wedge drive with travelling light; Gondola, with similar movement to Senior ship; Moderne, fixed light with full vision; Aero, broadcast band with high ratio movement; Aero, dual purpose, all wave and MF band calibration; Avon, full vision, fixed light and wedge drive; Gothic, full vision, travelling light and wedge drive; Lion, full vision, travelling light and wedge drive; Junior Organ, full vision, travelling light and wedge drive; Midget Cameo, supplied with two small escutcheons marked 'selector' and 'volume'; AW, all wave dial with vernier action and three colour scale; Lyric, drum dial with cord drive; Efco, remote control in bakelite case; Bedford, with MF band scale, travelling light and wedge drive; Stratford, with special winch non-slip action; Bedford Mark 2, with inclined dual purpose scale and provided with 10:1 gear ratio; Cameo, for small receiver models or where two dials were required. Other designs were subsequently produced.

In 1934, the company produced the Radio Master Aero Junior dial which was popular with home constructors for many years. It was available in bakelite, chromium plated or oxidised metal, and employed the well-proven wedge type drive providing smooth and positive action. It had a gear ratio of 9:1. It was sometimes called the Aeroplane dial.

Typical of Efco products incorporated in receivers produced by manufacturers during 1935 included midget gang capacitors covering the range 19–385 MFD, with nickel silver trimmer capacitors; Radiomaster dial with pyralin drive, available as single speed (5:1 ratio) or two speed (5:1 and 33:1 ratios) models, and type B switch available in sizes up to 5 gangs and fitted with silver contacts.

At the outbreak of the Second World War, the company was a large supplier to the radio industry of dials, tuning units, dial escutcheons and band switches as well as suppliers of anodised aluminium, die castings in brass and zinc, and metal stampings.

During the War years, Efco diverted its resources to producing materials and services for the War effort producing die castings and anti corrosion treatments.

ELECTRICAL SPECIALTY MANUFACTURING CO., LTD

The Electrical Specialty Manufacturing Co., Ltd was formed by Oliver Turner and George Schliesman in 1933 with manufacturing facilities at 17–19 Glebe Street, Glebe.

Oliver Turner, a Member of the Institution of Radio Engineers (Australia) was, in addition to being Director of the company, Chief Electrical Engineer responsible for design of company receivers. He had trained as an Electrical Engineer and in 1926, took up a position as Foreman in the Electricity Meter Manufacturing Co. (EMMCO). He later became Chief Engineer of EMMCO and left in 1933 to become a partner in ESM.

George Schliesman began a career in radio dating back to the period before the First World War, and joined the staff of EMMCO shortly after the company began operations. He later became Assistant Chief Engineer to Oliver Turner at EMMCO. He left in 1933 with Turner to set up a partnership business.

The company manufactured a range of receivers under the brand names ESM and Aristocrat.

General Manager of the company was George Hunt who had previously worked with Darelle Products. Hunt remained with the company from 1932 until 1936 when he transferred to Briton Electrical and Radio Pty Ltd.

In 1937, John Dunn became General Manager. He had previously been with Bennett and Wood Ltd, radio wholesalers as Radio Salesman.

Among the early receivers designed by Oliver Turner and produced by ESM were a series of four models in deluxe consoles distributed by P and R Williams Ltd, Wentworth Avenue, Sydney:

- Model 56, a six valve superheterodyne receiver with AVC.
- Model 46, a five valve superheterodyne set.
- Model 22, an AC/DC universal six valve superheterodyne receiver with AVC.
- Model 60, a battery-powered six valve autodyne superheterodyne set using type 19 twin B Class power output and employing an IF of 175 kHz.

Just before Christmas 1934, Models 80 and 90 were released. The Model 80 was an 8 valve AC powered all-wave autodyne superheterodyne set with AVC, visual tuning and an IF of 175 kHz. Model 90 was a nine valve all-wave autodyne superheterodyne battery-powered receiver with AVC. Both models were housed in deluxe highly polished console cabinets. The short wave bands covered 20 to 40 and 40 to 80 metres with the short wave dial section having two scales of distinguishing colours and calibrated in metres. The specially designed change-over switch enabled bands to be changed in silence, so eliminating annoying loud clicks. Valve types employed in the Model 90 were 32, short wave detector; 30, short wave oscillator; 34, RF amplifier; 25, MF band detector; 34, IF amplifier; 30, second MF detector; 32, first AF amplifier; 30, driver; 19, twin B Class power output. Valves were powered by 2 volt A battery with drain 0.8 amperes and B batteries with a drain of 10 to 15 milliamperes.

In early 1935, a range of Aristocrat series was released. They included:

- Model 450, a four valve superheterodyne battery-powered receiver in console cabinet, designed for MF band reception, and provided with preselector short wave adaptor socket.
- Model 750, a seven valve superheterodyne battery-powered receiver in deluxe cabinet, with preselector and short wave adaptor socket.
- Model 950, a nine valve superheterodyne battery-powered all wave receiver in deluxe console cabinet with AVC and visual tuning. Wave band capabilities comprised 200–550, 19–40 and 40–80 metres.

All these models employed an IF of 210 kHz.

- Model 250 a battery-powered short wave converter.

The ESM Aristocrat range was extensive and incorporated console, mantel and all purpose combination models covering MF and short wave bands, and powered from AC, AC/DC or battery sources. Distributors outside Sydney included Electrical Service Co., Newcastle; Trackson Bros., Pty Ltd, Brisbane; Carlyle and Co., Perth; and McCann Bros., Hobart.

Aristocrat receivers on sale in Radio Shops at Christmas 1936 included Models 508 and 510. They were both 5 valve superheterodyne receivers employing an attractive console cabinet design. It was 40 inches (1.2 m) high with figured highly polished walnut veneers with deeply recessed panel of burr walnut. The 508 employed an IF of 452 kHz while the 510 was designed with an IF of 210 kHz.

During 1937, there were 15 Aristocrat radio models in production. Five were AC powered while the remainder were battery-powered. The AC models included Model 801, an eight valve dual wave set with electric eye and straight line tuning. In the battery-powered range, Models 552A, 553A and 651A were designed for Air-Cell operation while Models 552V, 553V and 651V were intended for vibrator/battery operation.

In early 1938, the organisation became Syme, ESM Pty Ltd. Managing Director was W A Syme who had previously owned W A Syme and Co., manufacturers of Symefona receivers, amplifiers and chassis since 1930.

The new organisation released five new portable models with features including driftless permeability tuning; no requirement for external aerial; large 6.5 inch (162.5 mm) loudspeaker; AVC: Aristocrat Magic Tuner; available as AC, battery or vibrator/battery-powered operation; cabinets provided in a range of colour combinations.

On 10 February 1939, Ron Syme the company Sales Manager announced plans for the production of an entirely new range of models incorporating distinctive cabinet designs, attractive dials, outstanding performance, high reliability, flexibility in chassis-cabinet combinations; cabinet designs to be designated as standard, deluxe console, console Grande and mantel; all large consoles to employ 12 inch (30 cm) loudspeakers; baseboard to be fitted in all consoles to enhance loudspeaker performance; Visographic tuning to be employed; cabinet finishes to include polished light veneers and black relief mouldings.

Among the 30 models originally planned, were models 950 and 951. Model 950 was a five valve AC powered MF band receiver incorporating Visographic tuning; automatic bass compensation; volume control; extended frequency range to 1600 kHz; beam output valve; inverse feedback network; available in cabinet designs of standard, console Grande or mantel.

Model 951, was a dual wave five valve mantel receiver employing octal based glass valve types 6A8G, frequency converter; 6U7G, 452 kHz IF amplifier; 6B6G, detector, AVC rectifier, AF amplifier; 6V6G beam output tetrode and 5Z4G indirectly heated full wave rectifier. Features included use of band-pass filter between aerial input and frequency converter grid; permeability tuned IF transformers; carefully selected components to minimise effect of humidity and temperature changes; and veneer wooden cabinet with piano finish.

At the outbreak of the Second World War, the Production Manager was P R Hall. He had been involved in radio since 1926 and prior to joining W A Syme and Co., had held positions with STC, Nock and Kirby, Heiron and Smith and others.

During 1940–41, a large range of Aristocrat receivers was produced. More than 40 models were released during the period. The 1940 models included Models 1050, 1050M, 1051, 1051M and 1052. They were all five valve AC powered types with 1051, 1051M and 1052 having dual wave band capability. Models 1050M, 1051, 1051M and 1052 were also available as Radiogram units. Seven of the models were designed for operation with 1.4 volt filament valves and were available in mantel or portable formats. Two eight valves sets were included in the range. The company also produced separate vibrator and AC power pack units.

Of the 18 models released during 1941, 13 had dual wave band capability.

Intermediate frequencies employed were either 212.5 or 455 kHz.

During the War years, the factory activities were scaled down and the company concentrated on the production of high quality headphones for the Services.

After the War, Syme ESM Pty Ltd became Technico Electronics Pty Ltd, Carrington Road, Marrickville and produced Technico and Aristocrat brand receivers. In 1946, three table models with plastic cabinets were released. They were Models 651 and 651W with 6V6G beam output valve, 8 inch (200 mm) loudspeaker, compensated inverse feedback, delayed AVC, and Model 640 a four valve set with in-built loop aerial and using an EL3NG output pentode. The following year, Model 640 was upgraded and released as Model 740.

In 1948, Chairside five valve AC powered radiograms with 12 inch (30 cm) loudspeakers were manufactured. They included an MF band set and a dual wave receiver. Both models were fitted with USA manufactured Admiral auto record changers and crystal pick-ups. Three five valve models in table type cabinets were also produced during 1948. Two were dual wave band designs.

The company were also distributors of Technico electrolytic and wax moulded paper capacitors, Technico type 55 wave change switches and Kenrad valves.

ELECTRICITY METER MANUFACTURING CO., LTD

The Electricity Meter Manufacturing Co., Ltd (EMMCO), Sydney was one of the largest manufacturers of electricity meters and radio components during the 1920s, and a major radio receiver manufacturer during the 1930s. During the mid 1920s, the company was producing 130000 electricity meters annually.

The company was founded by three Engineers from Europe. Fred Layer, Archie Schultz and Joseph Schartl set up a well-equipped workshop for manufacturing radio components in late 1924. The company had been manufacturing electricity meters since 1918.

Joseph Schartl, Managing Director of the company was educated in Vienna and spent 12 years working in the largest Engineering organisations in Europe including Siemens, Halske in Vienna; Siemens Bros., in Berlin; Siemens, Schuckert, Berlin; and AEG Berlin. He came to Australia in 1911 obtaining employment with the Postmaster General's Department where he was employed in the Telegraph Operating Room. Two years later, he left the Department and established a General Engineering business before joining up with Archie Schultz and Fred Layer to form EMMCO.

The original premises soon became too small, so operations were transferred to premises in Wentworth Avenue and two years later to even bigger accommodation at Darlinghurst.

Because all watt-hour meters were being imported into Australia, the company decided to specialise in this product and soon became the major supplier in the country. With the establishment of broadcasting being undertaken in Australia, the company also decided to enter the radio component field.

They appointed G Harry Brown as Manager of the Wireless Department to control this side of the business. Harry Brown was educated in England at Worksop College and later came to Australia where he joined the Commonwealth Wireless Service then under the control of Graeme Balsille and worked as Assistant Engineer at Pennant Hills Coast Radio Station in 1912 under Chief Engineer Charles Marr who later became Secretary to the Federal Cabinet.

After eight months at Pennant Hills he transferred to the Coast Radio Station at Thursday Island and then Townsville before returning to Sydney. In 1924, he left the Coast Radio Service to join EMMCO.

Amongst the first radio components produced by Emmco were a range of high quality audio and radio frequency transformers which soon became popular with receiver 'do-it-yourself' constructors. The AF transformers were made with ratio ranges of 2–1, 3½–1, 5–1 and 7½–1. The AF and RF transformers were made under the brand names Signal and Emmco. The Signal label was marketed by United Distributors Ltd through their offices in all States and New Zealand. The transformers sold well, with sales increasing from 100 in September 1924 to 21000 in September 1925. By mid 1926, over 40000 units under both brand names had been sold. The AF transformers which also included a push-pull model were encased in magnetically shielded cases while the RF transformers were housed in nickelled brass cases to reduce stray coupling.

The transformers were followed by a large range of other components including variable capacitors; variable capacitors with vernier drive; lightning arresters; wire wound rheostats of 6, 10, 20 and 30 ohms resistance; radio jack switch; valve sockets; dials; escutcheon plates; headphones; power transformers; power chokes; RF chokes; coils; coil formers and others. By mid 1926, there were 500 workers employed in the factory producing components.

The company produced one of the few Australian designed and made folded horn loudspeakers. It used a magnetic earpiece with a large diaphragm and a papier maché cone. It was sold under the brand name Kurlytone.

In late 1926, the company produced one of the first superheterodyne coil kits manufactured in Australia for the home constructor. The kit marketed as Emmco Super Kit comprised aerial coupling coil, plugs, three intermediate frequency transformers, filter and oscillator coil, all factory matched and balanced before packing. The kit was packed in a box complete with full size blueprint, wiring diagram and full details for constructing and testing a complete superheterodyne receiver.

In the same year, Emmco began manufacture of headphones undertaking all the work in the factory including aluminium ear-caps, magnets, coils, grinding pole pieces, stamping out diaphragms, moulding bakelite earpieces and fitting leather headbands. The only items brought in were tungsten steel for magnets and enamelled copper wire for the coils.

On 1 December 1927, the organisation became Electricity Meter Manufacturing Company Pty Ltd.

In 1927, they designed a range of B battery Eliminators and combined A, B and C Eliminators. The EMMCO A, B and C Eliminators were built for 0.25 ampere valve types and for 0.06 ampere types. High tension could be regulated up to 350 Ma. The units operated over a wide input voltage range.

Adjustment controls enabled correct anode, grid bias and filament voltages to be obtained for the receiver. The EMMCO Super Power Eliminator was designed for use with multivalve receivers. High tension could be regulated up to 85 Ma. The EMMCO B Battery Eliminator was manufactured for use with receivers with up to five valves.

Other lines manufactured in the factory at the time included Pep Punch, Midget, Cavalier, Golden Voice and Puratone AF transformers; a high rate battery charger; a battery trickle charger; lightning arrester; vernier dials; headphones; Maclurcan tone purifier; Emmostad and many others.

One of the most successful components manufactured in 1928 was the Single and Dual Control Units for receiver tuning operation. It was used in large numbers by receiver manufacturers who did not make their own components. It was the result of a lot of development work in the company laboratory. The embossed moulded bakelite face plate contained logging windows and openings through which the drum controls projected. Each drum contained an indicating strip for calibration purposes. The tuning was a friction vernier drive and included a separate capacitor plate for balancing purposes. Each capacitor was mounted on a moulded bakelite base. The capacitors were the Emmco Super Stratelyne units which provided a straight line frequency tuning characteristic.

Factory Foreman at the time was Oliver Turner who joined the company in 1926. He later became Chief Engineer. Assistant to the Chief Engineer was George Schliesman. Both men left the company in 1933 to set up a partnership business known as Electricity Specialty Manufacturing Co., Ltd to produce receivers under the Aristrocrat brand.

In mid 1930, the company produced the Emmco Universal Resistance which was an Australian version of the popular imported Pilot Resistograd. It was used as a volume control, or as an oscillator or regeneration control. It was variable over the range 0 to 40 megohms and had a rating of 7.5 watts. Housing was in bakelite similar to the Emmcostad resistance and the knob on the unit was a newly introduced Velmo knob in Mahogany.

About the same time, three power amplifiers were designed and manufactured. The lowest priced unit was the 'Home' amplifier designed for electric phonograph or gramophone combinations. The 'Concert' amplifier was designed to provide ample volume for small halls, restaurants or small business call systems. The top of the range model was the 'Emmco PA 500 Super Power' amplifier for outdoor use, or for large halls, theatres or factories where large audio output was required.

Emmco radio components available in Radio Shops in 1934 included:

- Balanced bakelite valve socket designed to eliminate valve microphonic noise. The sockets were fitted with both terminals and solder lugs.
- Sub-panel valve socket widely employed by receiver manufacturers. The valve pins had side extensions attached to permit easy soldering of busbars or flexible leads.
- Tuner drum control in either single or double style. Each drum contained an indicating strip for calibration purposes. The tuning was a vernier drive with a separate adjustment for each capacitor. Individual capacitors were matched, thus providing for balanced tuning control.

Face plates were embossed bakelite.

- Super stratelyne variable capacitor with cast bakelite base and brass frame, and cutaway brass plates in both stator and rotor.
- SQL type 535 capacitor of rigid construction without backlash, and employing aluminium plates.
- Deluxe straight line frequency capacitor with moulded bakelite frame, ball bearing adjustment brass plated metalwork.
- SLF capacitor type 530, a rugged tuning capacitor with aluminium plates.
- ABC Eliminator with Raytheon valve.
- B Eliminator.
- Super Power B Eliminator with higher output than the standard B Eliminator.
- Battery charger for charging 4 volt and 6 volt accumulators.
- Emmcostad available in seven resistance values.
- Deluxe vernier dial in black or mahogany finish providing non-slip tuning control over the whole scale.

Distributors to the trade of EMMCO products were Manufacturers Products Pty Ltd located at 139 Clarence Street, Sydney and at Sugden Place, Melbourne.

In 1930, the production line was rearranged to produce radio receivers and the manufacture of components was scaled down.

Keith James who came to EMMCO from New System Telephones Pty Ltd, played a major role in setting up the production line to manufacture the receivers, oversighting new designs and laboratory activities, and the testing of the receivers before dispatch from the factory.

About the end of June 1930, Sydney distributors, W G Watson and Co., Ltd and Bennett and Wood Ltd, received two Troubadour brands from EMMCO. They were Models AC Screen Grid 5 and Penthode AC3 housed in two tone walnut veneer wooden cabinets produced by Beard Watson and Co., Ltd. The Model AC Screen Grid featured a bandpass filter; three screen grid RF amplifiers; power detector and 245 output; and electrodynamic loudspeaker.

These two Troubadours were followed by a 7/8 valve design, the Troubadour 7. It was designed for long distance reception, being fitted with three stages of RF amplification; detector; AF stage and push-pull output stage using 245 type valves. Valve types included Cossor, Philips and Radiotron. The power pack unit with rectifier was constructed as a separate unit and housed in the lower section of the cabinet, well away from the main chassis. Loudspeaker was a Magnavox electrodynamic model.

About 1932, the range of EMMCO models included:

- Model AC2, using valve types 235, detector; 247 power penthode and 280 rectifier. Features included selection of six selectivity switch positions; cadmium plated chassis; moulded bakelite sockets, coil formers, knobs and plugs; pick-up facility.
- Model AC3, employing non-regenerative circuit with valve types 235, RF amplifier; 224, detector; 247, power penthode; and 280 rectifier. Features included stamped aluminium valve shields and coil cans; pick-up facility; low loss variable gang capacitor.
- Model AC4, employing non-regenerative circuit with valve types 235, RF amplifier (two); 224, detector; 247, power penthode; and 280 rectifier. Features included among other things a full vision dial.
- Model AC5, with valve types 235, RF amplifier (three); 224, detector; 247, power penthode; and 280 rectifier.
- Model Super Heterodyne with valve types 224, first detector; 227, oscillator; 235, IF amplifiers (two); 224, 2nd detector; 247, power penthode; 280, rectifier. Features included preselection; sensitivity control; single dial control; gramophone pick-up facility; completely shielded chassis; dry electrolytic capacitors.
- Model DC5, comprising indirectly heated valve types 236, RF amplifier (three); 236, detector; 238, power penthode. Features included dynamic loudspeaker; dry electrolytic capacitors; low current consumption; special system of AF stage coupling; full vision dial; extreme sensitivity and excellent selectivity characteristics.
- Battery Five Model with valve types 232, RF amplifier (three); 232, detector; 233, penthode audio stage. Features included automatic voltage and bias regulation; A battery consumption 0.4 amperes; special circuit permitted 50% drop in B battery voltage without affecting set sensitivity.

At the time, Philips five element valves were called penthodes.

Two Troubadour models which produced good sales figures with country listeners during Christmas 1934 were Model V64B and Model V94. The six valve battery-powered Model V64B and with an IF of 175 kHz employed valve types 34 (two), 32 (two), and 19 (two). Controls included tuning, volume and combined local/distant 'on/off' switch. Loudspeaker was Amplion 01 permag type. A battery was 2 volt accumulator and B battery three 60 volt batteries in series. Bias supply was taken from a tap on the B battery system.

The nine valve battery-powered triple wave Model V94 employed valve types 15 (two), 34 (three), 30 (two), 32 and 19. Short wave bands covered were 16–40 metres and 40–80 metres. Loudspeaker was Amplion L1 permag type. The set was provided with a unique circular dial with anti-cyclic drive with 60:1 ratio for short wave tuning and 10:1 ratio for the MF band.

A popular kit set with set constructors in 1934 was one produced by EMMCO for a seven valve battery-powered superheterodyne receiver. Parts for construction of the receiver comprised the Emmco Super Heterodyne Kit plus components, full size diagram, blueprints and a book of instructions describing how to construct the receiver. The Super Heterodyne Kit consisted of aerial coupling coil and plugs; three IF transformers; tuned radio frequency transformer (filter) all matched and balanced. The other components included bakelite panel; baseboard; variable tuning capacitor; Maclurcan tone purifier; rheostats; potentiometer; midget variable capacitor; jacks; vernier dials; valve sockets; valves; fixed resistors; fixed capacitors; grid-leak; battery terminals; AF transformer; busbar material; A, B and C batteries and an assortment of wood and metal screws.

In mid 1936, EMMCO announced the release of a range of 12 models including a five valve car radio, and AC, AC/DC and battery-powered types. By the mid 1930s, company activities were mainly concerned with the manufacture of radio receivers and refrigerators. Works Manager was Fred Layer with Keith James as Radio Engineer. Distribution of radio receivers was handled by a subsidiary company Radio Industries Ltd, also located at the Joynton Avenue, Waterloo address. Radio Industries Ltd handled distribution throughout New South Wales and supported agencies in other States including William Begg and Sons, Melbourne; J G Pritchard Ltd, Perth; Wm L Buckland Pty Ltd, Hobart and Launceston; and Howards, Brisbane.

In addition to manufacture of receivers under the EMMCO label, models were produced for Westinghouse, Gulbransen and Philco labels. EMMCO scaled down production and sales of receivers under its own label in late 1930s but continued with production of receivers for others.

In November 1934, EMMCO and New System Telephones Pty Ltd (NST) were incorporated to form the holding company Electricity Meter and Allied Industries Ltd with an authorised capital of £1 million. Technical Director and Chief Engineer was Joseph (Joe) Schartl. General Manager — later Managing Director — was Joe Carroll who had been General Manager of New System Telephone Pty Ltd which had been a registered company since 10 November 1920 and had produced a range of radio receivers under the brand name Hollingsworth which incorporated a number of innovations including floating power systems and inclined loudspeaker sound boards. From about 1936, the company manufactured only private brand models.

Joe Carroll was Managing Director until 1956 and under his leadership, Electricity Meter and Allied Industries Ltd expanded rapidly having 35 subsidiaries and about 7000 employees. During the Second World War years, the company was involved in the manufacture of equipment for the Armed Forces. Major items produced included power supply units, HT rectifier, vibrators, headsets, dynamotors and measuring instruments.

Staff members who left the company to join the Services included M Vernon, A J Ward, A Wenben, R Willmott, D A Wilson and many others.

In 1945, the company established manufacturing facilities at Orange in Central West of New South Wales with over 700 workers on the payroll. At the time of the 50th Anniversary, the number of employees had risen to 1500, producing a range of refrigerators, freezers, air conditioners, dryers and electric and gas ranges.

Initially, the company traded as EMMCO-Elcon Pty Ltd, but in July 1962 became known as EMAIL Ltd using the letters of the name Electricity Meter and Allied Industries Ltd.

By the 1970s, activities were related to the manufacture of home appliances; electronic equipment; switchgear; air conditioning equipment; electricity, gas, water and telephone meters; and a variety of industrial products. Brand names included Westinghouse, Electrice, Carmichael, Elcon, Fyrside, Email, Corox, Hussman, Marley, Metters, Weatherall and others.

In 1998, Sydney headquarters were still located at the original Joynton Avenue, Waterloo address.

EMBELTON G P & CO.

The company was founded in 1925 by George P Embelton, a University graduate and former member of the Commonwealth Civil Service, and Executive Member of the War Stores Disposal Board.

The business located at 579 Bourke Street, Melbourne, in the early 1930s, had a branch in Brisbane managed by James Bostock, also a former member of the Commonwealth Civil Service. The company was distributor of a range of radio products including Radiokes and Marquis.

In 1933, the company was manufacturing a wide range of products under the Aegis label which had been registered in March 1933, with a well-equipped workshop. Products advertised as being available in 1934 included complete receiver kits, and a wide range of quality components such as RF, IF, AF and power transformers; short wave coil kits; AF and power chokes; power packs; chassis; variable resistors; variable capacitors; shielding cans; aerial and earth accessories and others.

In 1936, James H Magrath was appointed Manager of the Radio Department, at that time, located at 208 Lonsdale Place. He had previously been with Myer Emporium Radio Department and G M Radio and later proprietor of Regent Radio Company, before joining Embeltons.

By 1937, the company had increased its range of products and also had set up an expanded workshop's facility to manufacture Aegis components. A well-equipped laboratory formed part of the facilities to ensure continued development in coil technology.

Subsequently, Mr Magrath established the well-known Melbourne wholesale business J H Magrath and Co., Pty Ltd, at the premises previously occupied by Embeltons and formed Aegis Manufacturing Co., Pty Ltd as a manufacturing subsidiary mainly to supply parts and components for Macgraths.

During the War years, Aegis contributed much in the way of specialised items of radio components which were of quantities too small for the larger organisations to handle efficiently. One notable contribution was the development of a method of tropic proofing dry batteries for use with radio equipment in the tropics.

After the War, Aegis resumed manufacture of a range of components, kit sets and other product lines. Popular kit sets produced during 1946–48 included Little Companion, a five valve two band AC powered receiver in polished wooden mantel cabinet. It featured permeability tuning with iron dust cores in MF band, short wave and IF coils. Other AC powered kit sets included Connoisseur, a five valve set and Metropolis, a four valve receiver. Both were supplied with mantel type cabinets. Battery-powered receivers included Voyager, a four valve mantel cabinet set and The Baby, a miniature four valve personal portable in lightweight leatherette covered wooden case measuring 100 mm by 112 mm by 225 mm.

In 1951, Aegis produced the KC4, a Four Band Tuning Unit aimed at Amateurs for construction of a communications receiver, covering the 10, 15, 20, 40 and 80 metre bands.

One activity of the company was subcontractor for manufacture of components required for Byer tape recorders being manufactured by Byer Industries Pty Ltd. At the time, about 20 people were employed in the factory in St Kilda Road with 'Chuck' van Scoy being Production Engineer. Some of the workshop equipment had previously been used by Kingsley Radio Pty Ltd before it ceased operation.

With the advent of cheaper imported products, the demand for Aegis products declined until the 1950s when, although still trading, the company's manufacturing activities virtually ceased.

During the 1960s, articles being marketed included ultra-linear integrated stereo six-88 amplifier, ultra-linear basic 5/10 amplifier, standard control unit, stereophonic coupling unit, pre-amplifier Mark1, pre-amplifier Mark 2, fidelity radio tuner Mark 1, and radio tuner Mark 2, four speed stereo player and a range of timber enclosures.

In 1962, the company changed hands, the new owner being Harry Cliff and he immediately set about recovery of the company's manufacturing operations. New products were developed and the inductor manufacturing activities revived and expanded. Mr Cliff maintained ownership of the company until his retirement in the mid 1970s.

Since those beginnings, Aegis has developed to become one of the country's specialist manufacturers of equipment for location of buried services and the detection of underground cable faults.

Aegis was a major contractor to Telecom Australia for underground cable detection equipment for some 20 years, and in that time, improved and expanded its product base. Aegis equipment is now supplied to a range of public utilities and the private sector here in Australia, with newly developed tele-communications fault location equipment being exported to Europe and America.

In 1994, Directors of the company trading as Aegis Pty Ltd and located at Christmas Street, Fairfield, were Lance and Beryl Mitchell.

In addition to marketing its own products, the company is distributor for Seba Dynatronic equipment and Harris Dracon telecommunications products.

ESSANAY MANUFACTURING CO., PTY LTD

The company located at 54 Buckhurst Street, South Melbourne was established by Ernest Austin and Walter Sweeney for the manufacture of radio components and receivers.

Ern Austin commenced work in the radio industry in 1920 following four years service with the AIF in the First World War. He was Works Manager at Radio Corporation Pty Ltd, South Melbourne during the period 1925 to 1928, and left the company in 1928 to establish Essanay with Walter Sweeney.

Walter Sweeney worked for the Marconi Company in England as an Engineer from 1907 until 1912. He migrated to Australia and began work with the Postmaster General's Department, later becoming Construction Engineer of the Commonwealth Wireless Branch involving the erection and commissioning of the network of Coast Radio Stations around the Australian coastline. In 1916, he became a member of the Royal Australian Navy, being appointed Inspector of Wireless Telegraphy.

In 1920, he was Author of the book 'A Complete Course of Wireless for Professional or Amateur Students', in which he described the Commonwealth or Balsillie system of wireless telegraphy.

In 1928, he joined with Ern Austin to establish Essanay. The trade name was derived from the letters of the surnames of the two founders, S and A.

The company produced its first receivers in 1930, and within a short time had built up a reputation for high quality designs.

Just before Christmas 1932, it released a range of Ray-Lite receivers including Model 57, a four valve set employing the new six pin five element valves, and dynamic loudspeaker. A feature was the use of a new gradual type volume control. Another receiver, was a five valve superheterodyne model employing the latest technology providing hairline selectivity and long distance reception capability. Both models were housed in top quality hand-rubbed veneer console cabinets.

Another product was the Essanay Tuning Unit comprising a chassis with three screened compartments with variable tuning capacitors in each compartment and provision for RF transformers and valve socket mountings. The three 0.00045 MFD capacitors were ganged by a bronze strip running over pulleys to a central dial indicator operated by a knob. This technique of ganging capacitors was widely employed with the USA manufactured Atwater Kent receivers at the time. A second knob on the unit operated a volume control potentiometer. Other components required for a three stage tuning unit were mounted under the chassis.

By 1934, Essanay products which could be purchased fully assembled or in kit form included superheterodyne receivers, short wave converters, short wave three valve receiver with adaptor, coil kits, and components such as power transformers, variable tuning capacitors, resistors, voltage dividers, sockets, chassis, valve cans and wiring strip boards. Major items included:

- Master Super Het 5, a five valve receiver employing valve types 2A7 pentagrid converter; 58 IF amplifier; 57 second detector and AVC; 2A5 power amplifier and 80 full wave rectifier.
- Five Valve Super Het, a five valve receiver employing valve types 57 first detector; 58 IF amplifier; 57 second detector, 2A5 output valve and 80 rectifier.
- Six-Seven Valve Super Het available as a six valve or a seven valve model. The six valve version employed a single 2A5 in the output stage whereas the seven valve model employed a pair of 2A5 valves in a resistance-capacitance push-pull output stage. The six valve model provided 3 watts of audio power and the

seven valve receiver produced 6 watts. An RF stage was a feature of both designs.

- Converter No 1, employed a two ganged capacitor with trimmer to keep both circuits in line. Wavelengths covered were 19 to 90 metres. Two 57 type valves plus 80 rectifier were employed.
- Converter No 2, used a unique switching system which used the whole coil at any position thereby creating a type of auto transformer which eliminated dead-end loss and also increased gain. Tuning was carried out by a vernier dial on the oscillator capacitor only, the modulator capacitor not being ganged, was moved in conjunction with the oscillator control and was more or less broadly tuned so that no dial was necessary. Range covered was 19 to 90 metres. Valve types were 57, 58 (two) and 80 rectifier.
- Short Wave Three Valve Receiver and Adaptor comprising a simple, regenerative detector followed by two stages of AF amplification. Plug-in coils were employed for band changing with band coverage being 14 to 200 metres. Valve types were 57, 56, 2A5 and 80 rectifier.
  With the adaptor unit, the power valve and rectifier were not used. The output from the adaptor was connected to the pick-up terminal of a broadcast receiver. This meant that a straight short wave regenerative receiver was provided, the detector and first audio comprising the adaptor and the audio end of the broadcast receiver providing the power valve and loudspeaker. Valve types were 57 and 56.
- Four Valve Battery Super, a four valve superheterodyne receiver designed for country listeners. It employed valve types 234, 232 (two), and 233. Batteries comprised A battery 2 volt Exide or Masse accumulator; three Eveready 45 volt B batteries in series; and a 12 volt C dry cell battery.
- Model P a popular 'two plus R' design employing 6F7 triode-penthode valve, 42 output valve and 80 rectifier. An 8 inch (200 mm) Monitor electrodynamic loudspeaker was employed.

Wholesale distributors for Essanay receiver and components were ASA Equipment Co., Pty Ltd. In 1933, ASA amalgamated with Zenith Radio to form AZ Radio Pty Ltd with Messrs Sweeney and Austin being Directors of the company.

In 1934, Essanay published the 'Annual Super-Het Manual' with technical articles being provided by Ern Austin, Walter Sweeney and Lay Cranch. Articles contributed by Lay Cranch who was Technical Engineer of the company from 1932 to 1938 included Functioning of the Short Wave Super Heterodyne, The Super Heterodyne Receiver and Four Tube Battery Super. Other articles of interest included Essanay 6/7 Valve Super Het; Mica — Its Characteristics and Uses; Essanay 5 Valve Super Het; The Essanay Master Super Het 5; Some Reasons for Using a High Intermediate Frequency; Essanay Variable Condenser; RF Choke; Location of Short Wave Aerials; Essanay Power Transformers; Coil Design for Short Wave Converters; Short Wave Converters; Essanay Coil Kits.

The company was still active during 1937 but appears to have ceased operation the following year having been taken over about that time by the Electronic Industries Ltd group.

EVEREADY AUSTRALIA PTY LTD

Batteries were essential for the operation of broadcast receivers, studio equipment and some transmitter circuits, particularly bias supplies for many years after the commencement of broadcasting, and the Ever-Ready Company was well-placed to meet the demand.

In order to meet the requirement of batteries for torches, telephones and other purposes at the time, the company which had its roots in England, began as early as 1901 to import essential chemicals which were blended and made into dry cells, the appearance of which has remained unchanged with many types, even after 90 years of development. The company was known as The British Ever-Ready Electrical Co., Ltd and was managed by Henry Veen.

The original manufacturing shop was located in Rowe Street, Sydney but after a few moves to other buildings, large premises were acquired in 1908 in Burns Street, Darling Harbour. Even these premises soon became too small, and in 1919 a further move was made to premises in Marshal Street, Surry Hills. Staff was increased to 10 employees and the company was manufacturing four hundred articles which it had previously imported.

With the advent of broadcasting in the early 1920s, and the need to produce large quantities of A, B and C batteries, manufacturing facilities were expanded and by 1926 staff had increased to 180 employees.

The most popular batteries being marketed were the LT5 Radio A battery with terminal voltages of 3 and 4.5 volts and the WP40 Radio B battery with terminal voltages of 18, 21, 24, 27, 30 and 42 volts. Victorian distributors were J L Newbigin Pty Ltd, Queen Street, Melbourne.

However, competition from imported batteries, particularly from American manufactured Columbia batteries, saw sales decline to the extent that by 1929, there were only 48 employees on the staff. The company endeavoured to meet the competition by the manufacture of 45 and 60 volt batteries made from No. 50 and No. 55 cells. In 1933, the manufacture of batteries employing No. 55 cells was discontinued substituting the Superdyne 45 volt battery made with No. 60 cells. New technology was introduced when the battery was constructed in a vertical position. Until then, all batteries were made horizontally.

Tariff policy introduced by the Government in December 1929 caught the company unprepared for the large demand for locally produced batteries. One hundred and fifty extra staff were recruited but even so, production hours were extended to nearly midnight.

In July 1932, the Australian company was taken over by National Carbon Inc., of the USA, the company that had caused so many problems for Ever-Ready in the late 1920s by its aggressive marketing of imported Columbia Radio batteries.

Until 1934, the company traded as The Ever-Ready Company (Great Britain) Ltd with no local Directors controlling company operations. From about this time the company became The Ever-Ready Company (Australia) Ltd with Reg Walter as Managing Director. Reg had come to Australia in 1930 from the London head office to re-organise the factory and sales end of the business.

In November 1934, the company Sales Manager, Bob Herring announced that they had released three new batteries aimed at the radio receiver manufacturing and service industries. They were a Superdyne 60 volt B battery with increased capacity compared with previous batteries of this type; a heavy duty 22½ volt battery which was tapped to enable employment as either B or C battery; and a heavy duty 9 volt C battery which soon became popular with studio equipment staff where amplifiers were fitted with a battery bias system.

During 1935, Ever-Ready purchased two major Australian battery manufacturers, Widdis Diamond Dry Batteries Ltd and Volta Dry Batteries Ltd. At the time, they were its main competitors.

In 1936, the company began the local manufacture of batteries under the Columbia label merchandised through Ellis and Co. (Aust) Ltd, Sydney.

The year 1937, saw a major change when Ever-Ready became part of the Union Carbide group of companies.

The production of batteries to suit radios throughout Australia from a cold wet environment to very hot and tropical conditions required a great deal of research and visits by technical staff to isolated areas to improve performance and reliability of the company batteries. In some cases, special machinery had to be developed and the practices implemented in Australia were quickly taken up by Ever-Ready factories in other parts of the world.

On 25 January 1938, a new factory of three floors was opened at Rosebery, incorporating the most modern production facilities where more than 200 different types of batteries were manufactured. These included 40 types for deaf aid audio amplifiers. At the time, about 500 employees were on the payroll.

One of the most important batteries introduced in the late 1930s for country listeners away from mains power was the Air-Cell battery. It was suitable where receiver drain did not exceed 0.6 amperes. The battery had a long life and needed no attention apart from topping up with water. The batteries were imported from Canada and their introduction did much to halt the swing at the time towards accumulators and vibrators in receivers produced for country listeners.

With the development of 1.4 volt filament valves in 1938, there was an upsurge in the production of portable radios and the demand for small size A and B batteries specially designed for miniature receivers resulted in expansion of business for the company.

The Radio A battery type X250–1.5 volts was produced to meet the demand for a small size long life battery for filament supply for the 1.4 volt valves. It was a new company design and had been subjected to exhaustive laboratory tests before production began. Unlike standard Ever-Ready batteries, the new type was not labelled on all sides, but was enclosed in a black leatherette covered box with a panel label fixed only to the front. The positive and negative tappings consisted of 2BA screw terminals in lieu of the familiar Fahrenstock spring clips. In order to obviate the danger of A battery leads being connected by mistake to the B battery, the company recommended that manufacturers affix 'eye' type lugs terminals to the A battery leads.

At the time of release of the new battery about December 1938, only five 1.4 volt valves were on the market and it was expected that most four valve receiver designs would have a A battery drain of 0.25 amperes and five valve models a drain of 0.3 amperes. For this drain, the X250 A battery was expected to provide up to 970 hours of service for a four valve receiver and 840 hours for a five set, assuming the battery to be discharged no lower than 1.1 volt. The figure of 1.1 volt appeared to be the end point for satisfactory short wave reception but laboratory tests had shown the battery could be taken down to 0.9 volt for local MF stations and still provide reasonably satisfactory reception.

In 1939, the company name was changed to Eveready Australia Pty Ltd.

During the War years, Eveready combined with Melbourne based battery manufacturers Widdis Diamond Dry Cells Pty Ltd and Stan-Mor Dry Cell Co., Pty Ltd to meet the enormous demand of the Services. More than 47 million dry cells were produced for use in 61 different types of batteries. Many battery types were previously unknown in Australia and were produced for radio equipment brought here by the USA Services. One of the important wartime developments was the hermetically sealed metal container for batteries.

In 1946, the company produced the first commercial Mini-Max type battery from plant that had been installed in 1943 for Defence purposes.

Stan-Mor Dry Cells Ltd was purchased in 1947, reducing considerably, competition in the dry cell market.

The company name was changed to Union Carbide Australia Ltd in 1957 following a merger with Trimbrol Ltd.

In 1965, reorganisation of the Rosebery battery and Alexandria zinc and manganese plant was carried out using the latest technology of Union Carbide Corporation plants in other parts of the world to improve manufacturing processes for round and flat cell batteries. Four years later, a new building was constructed to produce alkaline cells, the first produced in Australia.

In 1986, Union Carbide Australia Ltd was acquired by Ralston Purina of USA to form Eveready Battery Company and in 1988, Eveready Australia Pty Ltd was formed following acquisition of Union Carbide Australia Ltd battery operations, by Ralston Purina.

Although battery operated broadcast receivers and valves were marketed under the Ever-Ready brand name by The Ever-Ready Co., (Great Britain) Ltd in England during the late 1940s and 1950s no receivers or valves were produced in Australia or imported by the Australian company.

Receivers under the Eveready label were produced in USA by the American Bosch Magneto Corporation for the National Carbon Co., in 1927. The National Carbon Co., which also produced radio batteries under the Eveready label entered the receiver market in an attempt to take up slack in falling battery sales following the introduction of AC powered receivers. Although Eveready receivers were no longer produced after 1929, the company continued to market battery valves until 1933 by arrangement with Raytheon.

A feature of the Eveready receivers was their diecast aluminium cabinet and support legs often lacquered in green with striping in natural aluminium. The loudspeaker unit was also diecast. They also produced a model of solid gumwood cabinet with antique maple finish to harmonise with Colonial and Early American home interiors.

Although there are very few English Ever-Ready and American Eveready receivers in vintage radio collections today, Jack Trembath of Adelaide had an Eveready model 31 in his collection with loudspeaker.

The receiver manufactured in USA in 1929, was a table type in a cabinet of rich walnut with contrasting carved grill. The receiver which was fully operational at the time driving a loudspeaker with solid gumwood cabinet with antique finish was on display at the Golden Jubilee of Broadcasting Display in the Postal Hall of the Adelaide GPO in November 1973 to mark the Golden Jubilee of broadcasting in Australia. A graph pasted on one of the walls showed that the receiver had been factory tested over the frequency range 60 to 4000 Hz. Output voltage relative to 800 Hz was 60% at 60 Hz and 75% at 4000 Hz. It is not known who imported the receiver but a label glued on the chassis indicated 'Levensons Radio, 226 Pitt Street, Sydney' sold the set.

Many technical and scientific staff were employed by Eveready over the years and include Peter Adams, R W Erwin, Douglas Freeman, Bill Greenhill, George Hawk, G K Herring, Stan Hunter, Bill Johnson, Jack Moran, Stan Newman, David Pike, N Vincent and others.

HEALING A G LTD

The company was established in 1912 by Alfred George Healing before the commencement of broadcasting in Australia and traded in a number of activities, mainly in motor car accessories and bicycles.

By 1925, the company had began the manufacture of broadcast receivers using the brand name Heaco, and were wholesalers for a wide range of radio components including Imperial capacitors, Gilfillan radio products, P & R 'A' batteries, Columbia 'B' batteries and Atwater Kent loudspeakers. A branch at Post Office Place, Melbourne stocked all these items. Later, receivers manufactured by the company were known as Healing Golden Voiced receivers.

One of the early Sales Managers of the Radio Department was Charles Irvine who had commenced in radio work in 1927, and was appointed Sales Manager in 1929.

On 1 July 1927 the organisation became a public company and in that year imported a range of Atwater Kent receivers and loudspeakers manufactured in USA. The range included Models 30, 32 and 35, all table types of TRF circuit design produced during 1926. Models 30 and 35 were six valve receivers comprising three RF transformers, two AF transformers and aerial choke coil. Tuning was effected by three variable capacitors. In Model 35, a single rheostat controlled filament voltage of the three RF valves with a separate rheostat being used with the detector. Fixed resistors were used in series with the two AF stage valves. Anode of the detector valve was powered by a 22½ volt B battery while supply to other valves was 67½ volts. The Model 32 was a seven valve receiver tuned with four variable capacitors with fixed resistors in series with the grids of the RF amplifiers. The Model 35 was one of the most popular Atwater Kent receivers produced by the company at the time. During 1926, production comprised

30000 Model 30, 36000 Model 32 and 200000 Model 35 receivers with large numbers being exported to Australian distributors. Loudspeakers which Healings imported included Model L and Model H. Of the receivers sold to country clients, Bill McLeod a share farmer out from Raywood, north of Bendigo purchased a seven valve Model 32 which was installed by an Electrician from Bendigo. One end of the aerial was fixed to the windmill tower about 70 m from the house. The receiver was powered by a Peto and Radford accumulator and Columbia dry cell batteries. A party was held on the night following the installation, and many local farmers enjoyed listening to the wireless for the first time. One of the purchasers of a Model 30 receiver was a senior Manager in the Victorian Railways who lived at Toorak. He purchased a loop aerial as there was not sufficient space for erection of an external aerial. Good reception was obtained from 3AR, 3LO and 3UZ during the daytime with 4QG, 2FC and 2BL being received at good signal strength during night-time.

From 1928, the headquarters of the company was at 167–173 Franklin Street, Melbourne and although initially there was plenty of room to handle all activities, within seven years, the business had out-grown the premises. Steps had to be taken to acquire nearby premises on a long term rental basis to cater for expansion.

In the mid 1930s, the Designing Engineer and Technical Adviser of the Radio Department was David Plummer who commenced with Healings in 1928 after having worked with Electric Equipment Mfg Co., from 1924 to 1928 and with H J Holst from 1926 to 1928. Prior to the retirement of Cecil Whight he was Factory Manager. Cecil Whight who had been in radio since 1920. was instrumental in producing receiver designs which gave high performance and were highly reliable. Whight left Healings in 1931 to set up business on his own account as Acme Radio Laboratory Pty Ltd.

In August 1931, Healings acquired the Adelaide radio business of Eric McLean who had set up the business in mid 1926 following an extensive overseas visit in which he studied the latest developments in Broadcasting Technology and retailing in the industry. When Healings took over the business, Eric remained as Manager of their new retail outlet but in March 1933 resigned and transferred to Sydney as Sales Manager Radio Department of Smith Sons and Rees Ltd where he had worked some years earlier before moving to Adelaide.

Technical staff who worked in the company Adelaide branch included Ken Adamson, Alick Clarke, Cliff Moule and Kevin Wadham.

Ken Adamson built his first receiver when 15 years of age while living at Port Augusta. He used it to learn reception of Morse Code from Coast Radio Station VIA Adelaide. The receiver was a huge size being built on a breadboard nearly one metre long with the variable capacitors being of Ken's own design and construction. The capacitors consisted of zinc plates about 75 mm by 100 mm sandwiched between glass quarter plates recovered from old photographic equipment. There were 10 fixed plates and 9 movable which were attached to a backplate arm so that the zinc plates moved in a horizontal direction between glass plates. According to Ken who described their operation in later years, it required considerable force to move the plates but fortunately with only one station on air at the time, they needed to be tuned-in once only. One of the capacitors was donated to the radio collection of the Telecommunications Museum, Adelaide. The detector in the receiver was a piece of iron pyrites which Ken obtained from a Ship's Wireless Operator when the ship was tied up at the Port Augusta wharf.

Two years later, in 1922, Ken obtained an Amateur licence and was allocated callsign 5WA. He lost no time in building a transmitter based on a loose coupled Hartley circuit with a single UX210 valve. Tuning capacitors were enclosed in celluloid covers because of a dust problem in the town. High tension of 600 volts DC was provided by a chemical rectifier plugged into the local mains supply. Ken wound the power transformer himself and for the filter circuit used a large choke and 4MFD capacitors. The two valve receiver constructed for use with the station used UX120 as detector and PM4 as audio amplifier. A 'slop' rectifier made with a half gallon tin was used to charge a six volt A battery for the filaments. Ken later built another transmitter and broadcast music programs on the 200 metre band. The inductors which he built for the transmitter comprised three large pancake types of 300 mm diameter mounted on three ply wooden backings.

Ken entered the commercial side of radio in 1923 being Manager of the Radio Department of Duncan and Fraser Ltd, Adelaide, manufacturers of a range of receivers under the Dunfra label. He then moved to A G Healing Ltd, Adelaide branch where he was Manager of the Service Department for four years. In 1932, he established his own business, Radio Services Ltd at 74A Pirie Street, Adelaide initially, to provide maintenance and repair of domestic radio receivers.

Alick Clarke joined Healings as Manager, Radio Department in Hindmarsh Square, Adelaide following the departure of Eric McLean. Prior to joining Healings, Alick had been Manager Radio Department, Harris Scarfe Ltd for seven years. With later development of wire and tape recorders he became interested in the new technology and left Healings to join Ernest Smith and Co., Pty Ltd as Manager, Tape Recorders. In 1946, he was one of the first people in Adelaide to demonstrate the Pyrox wire recorder.

Ken Wadham a well-known South Australian Amateur station operator, inaugural President of The Southern Suburban Radio Club 1925, Honorary Radio Inspector and member of the Wireless Institute of Australia (SA Division) Council 1932–33, joined A G Healing Ltd, Adelaide branch in March 1927 as Manager of the Radio Department. Later, with establishment of an Electrical Department, his responsibilities included being Manager of that Department also.

Following a period of some three years in the Civil Service, Kevin joined the Production Department of Paroso Ltd, Radio Manufacturers and Dealers at their Adelaide branch. He later transferred to the company Melbourne branch as country organiser and general sales work. When the Melbourne branch was acquired by Louis Coen, he returned to Adelaide spending a further two years with Paroso before leaving to take up a position with Mackenzie and Co., Radio and Electrical Engineers and suppliers who had an extensive Mail Order Department to meet the demand of country radio enthusiasts. After two years, he left Mackenzie and Co., to set up business on his own account. In March 1927, he disposed of the business and commenced with A G Healing Ltd. He subsequently left Healings to become Sales Manager in 1934 and General Manager in 1938 of National Radio Corporation Ltd, Adelaide.

When the Commonwealth Government placed an embargo on imported domestic receivers, Healings were disadvantaged by being sole importers and distributors of Atwater Kent radios so they negotiated an arrangement with the USA company to manufacture radios under licence from Atwater Kent employing Healing label.

Early Healing models released in December 1931 included:

- Model 201, a three valve AC powered mantel set with rectifier; and screen grid detector directly coupled to a 247 penthode feeding a dynamic loudspeaker.
- Model 301, an AC powered four valve TRF receiver employing rectifier; screen grid RF amplifier; screen grid detector and penthode power stage.
- Model 41, a five valve TRF set with two stages of RF amplification; screen grid detector; and penthode power stage. Models 301 and 41 were housed in console cabinets with richly grained walnut and blackwood veneers with a high gloss finish. Models 301 and 41 were also available as radio/gramophone combinations and fitted in larger console cabinets.
- Model 403, Minor, a compact superheterodyne receiver in mantel cabinet. It had a built-in aerial and covered the band 190–600 metres.

By mid 1934, the range included two popular battery-powered models:

- Model 64Vm, a six valve superheterodyne console receiver with 175 kHz IF and employing valve types 34, RF amplifier; 32, mixer; 34, IF amplifier; 32, detector; 30, driver and 19 Class B output. A battery was 2 volt 120 Ahr accumulator, while B battery was three 60 volt triple capacity dry cell types in series. Controls comprised tuning, reaction/volume, battery switch and static suppressor.
- Model 34Vm, a three valve TRF console receiver using 34, RF amplifier; 32, detector; 33, output. A battery comprised 2 volt 50 Ahr accumulator with the B battery consisting of three special capacity 60 volt types. A tapped 15 volt dry cell C battery was also provided. Controls were, tuning, reaction/volume, battery switch and static suppressor.

To meet the likely 1937 Christmas period demand, Healings released its Model 447G Electrophone, a five valve dual wave table radiogram. Short wave band covered was 16–50 metres. Features included iron cored 455 kHz coils, Sirufer aerial coil, sliding shelf at base to accommodate electric motor, turntable and pick-up.

In mid 1938, Model 408A was released aimed at country listener market. It was a four valve superheterodyne receiver using valve types 1C6, 1C4, 1K6 and 1D4 and powered by vibrator/6 volt accumulator. Features included mantel cabinet; two colour dial; iron core IF transformers; Sirufer tuning coils; and 7 inch (175 mm) loudspeaker. Seventeen models were marketed during the year.

Just prior to the outbreak of the Second World War, the Manager of the Radio and Refrigerator Department was John Cooper who was one of the early company employees. He had joined Healings as a Junior Clerk in 1920, and obtained wide experience in company activities particularly the administrative field.

Another employee during the late 1930s was Graeme Mackenzie. Graeme had been interested in wireless since the 1920's when he built a crystal set and entertained the family by installing extension headphones throughout the house. His first job was with Eclipse Radio in South Melbourne testing components. In 1932, Graeme enrolled at the Melbourne Technical College, completing the Diploma in Radio Engineering Course in 1935. He joined the Institution of Radio Engineers (Australia) as a Student member in 1934, becoming Associate Member in 1938. He was still in active member of the Institution in 1994, now known as The Institution of Radio and Electronics Engineers, Australia.

Following a period as Radio Serviceman with Frank Harvey and Co., and Airzone (1931) Ltd in Melbourne, he worked in Victorian areas in radio sales and servicing until 1937 when he began employment with A G Healing Ltd in their factory in Franklin Street, Melbourne as Receiver Testman.

After a period of valuable experience with Healings, Graeme joined B R Radio, working in sales and servicing areas. At the outbreak of the Second World War, he was already a member of the Citizens Military Force Signals group but after a period in camp, joined the RAAF as Radio Instructor. After the War, he resumed work in the radio/electronics industry and even now in retirement, still takes an active interest in the technology.

During 1940, the range of Healing Golden Voiced radio models included:

- Models 525E and 575E, both fitted in the same console cabinet design. The 525E was a five valve MF band receiver, while the 575E was a five valve dual wave band receiver covering the MF band and short wave band 12.5 to 38 metres.

  A feature of the cabinet construction was that it enabled the chassis to be suspended from the top of the cabinet allowing for the whole of the cabinet front to act as a large baffle board to enhance the loudspeaker response.

  Valves employed with both models comprised EK2G, frequency converter; 6U7G, IF amplifier; 6B6G, detector, AVC and first AF amplifier; 6V6G, second audio amplifier and 80 rectifier.

  The dial was a clearly calibrated Healing slide rule full vision type.
- Model 575B, a five valve console battery-powered receiver covering the MF band and short wave bands 12.5 to 38 metres. The set was equipped with 1.4 volt filament valves. Features included AVC; bass/treble control with variable selectivity; and slide rule full vision tuning dial.
- Model 550C, a five dual wave receiver designed for AC/DC operation. The set was enclosed in a moulded mantel cabinet.
- Model 5C0B, a five valve MF band portable with tuning and volume/battery switch controls. It was fitted with a 5 inch (125 mm) Rola loudspeaker. Batteries were 1.5 volt and 2–45 volt types providing 250 hours of operation.
- Models 400E and 300E Minor Series. Both were AC powered and covered the MF band. The 400E had four valves while the 300E had three valves. Cabinet was a moulded type available in a range of colours.

  Valve types employed in the 400E were EK2G, frequency converter; EBF2G, 455 kHz IF amplifier and detector; EL3NG, high gain output penthode and 5Y3G rectifier. Loudspeaker was a Rola K5 five inch (125 mm) with field coil resistance of 2000 ohms. Features included permeability tuned LF transformers and air dielectric trimmer capacitors.

During the War years, A G Healing Ltd made a major contribution to the War effort by specialising in the manufacture of ASV receivers and auxiliary equipment for radar installations. Their well-equipped workshops also produced hundreds of capstan lathes and large searchlight projectors.

Domestic receiver production resumed after the War, with models including:

- Models 551E and 551A. The 551E was an AC powered five valve dual wave set with bandspreading on the short wave bands, 16–19, 25–31 and 31–49 metres. The receiver had a large dial; SW band indicator; delayed AVC; 8 inch (200 mm) loudspeaker; and compensated negative feedback. Cabinets were available in colours of walnut or red. The 551A was similar to the 551E except that it was designed to be powered by vibrator/battery system.
- Model 502E, a mantel receiver with in-built aerial and pick-up connection; 8 inch (200 mm) acoustically tuned loudspeaker; variable tone control; base and treble boost; curved Airspex edge lit dial; enclosed vented back; housed in walnut and ivory fluted plastic cabinet.

Like many other factories during the post War era, production ceased when competition from imported domestic radio sets became too great for the business to produce economically viable products.

HOME RECREATIONS (AUST.) LTD

Home Recreations Ltd, 388 George Street, Sydney began the manufacture of radio components and receivers in a small factory in Redfern with only a few workers about the time broadcasting was being established in Australia in the mid 1920s.

In early 1928, the company released a three valve battery-powered Salonola using Philips valves. It was one of the first receivers built on a pressed metal chassis. The unit was fitted with the latest type of single drum control with station selector allowing tuning without interference to other receivers. All batteries and wiring were totally enclosed in the cabinet. An Amplion loudspeaker stood on top of the cabinet. The receiver was guaranteed for one year and was sold with Free Insurance.

In late 1928, the company became Home Recreations (Aust.) Ltd with branches in Parramatta, Newcastle, Goulburn, Orange and Wollongong.

In May 1929, two AC powered Salonola models were manufactured and the company invited owners of battery-operated Salonola sets to have their receivers converted to AC operation for a nominal charge. The new receivers were three and five valve models.

In time for Christmas 1929, the Salonola Shielded Five was produced. It was a five valve AC powered set with dual control and housed in a table type cabinet of two tone maple standing on a four legged table. The loudspeaker rested on top of the receiver.

In 1930, when a staff of over 60 were employed and the company was manufacturing all components except capacitors, it released four, five, six and seven screen grid valve models with fully shielded chassis. By this time, the company had a large office in Brisbane to handle its business in Queensland.

The six valve set was battery-powered and an AC powered version was also available. Other models were two valve AC powered with table type cabinet and a three valve AC powered console set. The three valve model included a 245 type valve and built-in Magnavox loudspeaker.

At the time, the company stocked a large range of components for sale to the public. They included Pilot vernier art dials, Centraline variable capacitors, triple gang capacitors and double drum dials; Formo logarithmic variable capacitors; Amplion loudspeakers; Philips eliminators; tin coil cans; rheostats; and Salonola AF transformers and power packs.

In early 1931, the company transferred to 105 King Street, Sydney with a palatial showroom in which the star display was a new Salonola Three featuring Philips E442 screen grid, penthode and 280 rectifier and Magnavox loudspeaker. An unusual item was an eight-day clock mounted above the tuning dial. Another set on display which attracted a lot of interest by prospective buyers was a four valve screen grid model housed in a beautiful cabinet of fumed maple and in-laid Tasmanian blackwood.

In December 1931, the Salonola four valve Wonder model became available. It employed a variable mu valve as RF amplifier, screen grid detector, penthode output and full wave rectifier. Provision was made for playing records through the AF stage. Cabinet was of herring-bone fumed maple with piano finish.

A six valve model designated Supreme was produced about the same time as the Wonder set. It was housed in a cabinet of inlaid maple with myrtle burr panel and provided with a piano finish. Valve types employed were three 235 screen grid valves; 224 power grid detector; 247 penthode output; and 280 rectifier.

In mid 1932, the company was acquired by Heiron and Smith well-known Newcastle radio wholesale and retail merchants and became known as Heiron and Smith (Salonola) Ltd who added Airzone models to the Salonola range.

The first Salonola superheterodyne receiver was produced in July 1932. By the end of the year, the Salonola deluxe a superheterodyne receiver became available. It was housed in a beautiful console cabinet.

Production of Salonola receivers appears to have ceased about that time.

INNES, JOHN S PTY LTD

John S Innes Pty Ltd is one of a number of more recently established organisations specialising in servicing the technical side of the broadcasting industry.

The business was started in 1976 with John Innes as sole trader, in designing, manufacturing and installing AM broadcast directional aerial systems, importing and supplying RF instruments and transmitting equipment, as well as providing Engineering Consultancy in Broadcast Engineering.

Some of the major activities included:

- Installation of Commercial FM station transmitters and aerial systems in most Capital cities.
- Supplying equipment and conversion of 20 Commercial stations to AM Stereo format.
- Supplying AM Stereo exciters and modulation monitors for National stations transmitting ABC programs.
- Supplying FM SCA sub-carrier equipment to stations in Sydney and Adelaide.
- Supplying AM Stereo receivers and limited amplifiers for the audio system in Parliament House, Canberra.
- Supplying field intensity meters for MF, VHF and UHF to Telecom and Department of Transport and Communications.

The business represented many well-known overseas company products.

In 1996 these included:

Altronic Research Inc., air and water cooled test loads; Andrew Antenna, transmission lines; Belar Electronics Laboratory, modulation monitors; Broadcast Electronics Inc., transmitters, studio/automation systems; Circuit Research Labs Inc., audio processing, digital tests, SCA and RBDS; Delta Electronics Inc., antenna switch monitoring and test equipment; Freeland Products Inc., transmitter tube refurbishing; Kintronic Laboratories Inc., RF components and patch panels; North Hills, video isolation transformers; Polar Electronics Industries, antennae; Potomac Instrument Inc., field strength meters and audio analysers; Surcom Associates, transmitting mica and vacuum capacitors; Svetlana Electron Devices, transmitting tubes; TRT Inc., analog and digital STL's modulation Monitors; Jampro Antennas Inc., FM and TV antennas. The company also distributes John S Innes digital commercial storage systems, News Boss and News Room systems.

The Broadcast Electronics Inc., equipment is widely employed throughout Australia. The company products include Alpha Line solid state FM transmitters with power levels 500 watt, 1 kW, 2 kW, 3 kW, 4 kW and 5 kW; FM high power transmitters with power levels 5 kW, 10 kW, 20 kW, 30 kW and 35 kW; Programming Services comprising complete broadcast programming and fully researched program formats and music libraries; studio products including Mix Trak modular consoles, Airwak Series consoles, rotary mixers, Disc Trak and Dura Trak tape and cartridge machines; audio VAULT digital studio systems and automation; AM solid state transmitters with power levels 500 watt, 1 kW, 2.5 kW, 5 kW and 10 kW; remote and special event broadcast equipment including studio-to-transmitter links, remote pick-up units, digital decoder and encoders and low power exciters. The USA based company is one of the few major manufacturers whose work is devoted exclusively to engineering better radio.

The wide range of Engineering Services offered by John S Innes Pty Ltd included:

1. Assessment and improvement of system technical performance:
   - For maximum signal penetration/coverage.
   - Achieve the cleanest, clearest sound.
   - Coverage survey/signal strength measurement.
   - Signal comparison with that of other stations.
2. Design/construction:
   - AM/FM directional arrays.
   - Site re/location and analysis.
   - AM aerial tuning unit and broadband station combiners.
   - Tourist radio transmitters.
   - Total Engineering Services.
3. Field service and commissioning of all AM/FM valve and solid state transmitters, AM and FM antenna systems.
4. Calibration and service of transmission/monitoring equipment.

In 1997, John S Innes Pty Ltd changed its name to Innes Corporation Pty Ltd, a move which more truly conveyed the nature and capability of the organisation.

As at 1998, the Corporation registered Head Office was located in Cremorne, Sydney and the workshops at Mt Kuring-Gai with John Innes as Manager Director and Glen English formerly with Motorola, as Director of Engineering.

One of the many 1997 projects in which the company was involved was the practical application of FM sub-carrier technology for outdoor advertising on billboards, information displays, data distribution and other applications. Basically, the system involved digital signal processing to deliver a low injection high speed data system having negligible effect of the radio station carrier FM signal.

Innes Corporation was one of the many exhibitors at the National Association of Broadcasters (NAB) Radio Hall at Las Vegas, USA in April 1997. In addition to USA exhibitors, organisations from Italy, Spain, France, United Kingdom, Canada, Ireland and South American countries occupied areas in the Hall.

Product lines by Innes Corporation on exhibition included Audio Vault product line with Cart Killer, a system providing an alternative to cartridges and tapes for studio operation and Quick Start, with capacity to digitally store music and provide up to 40 hours of high quality digital audio. The Delay Master, a PC based digital audio delay system designed to cater for the provision of broadcast programs to stations located in different time zone areas, was also exhibited.

In mid 1997, John Innes announced that after some 30 years of supplying radio and transmission equipment to the broadcasting industry, the Corporation had decided to expand its field of operations by offering solid state UHF TV transmitters to the Australian market. The TT Series made in USA were available in a range of 5 watt units through to 2 kW as well as multiples of 2 kW power.

The latest company products include the FlashLog and Delay Master. The FlashLog is a self-contained digital hard disc audio logger for radio. The Delay Master ensures high quality audio is delayed for up to eight hours.

John Innes served in the RAAF, and was Radio and Radar Instructor with rank of Flying Officer to the Sydney University Squadron. During the period 1953 to 1957, he worked for Pye on VHF Communications followed by service with ATN7 Sydney 1957–59, on microwave system operations and maintenance, and QTQ9 Brisbane 1959–60, responsible for transmitters, aerials and microwave systems. In 1960, John joined RCA as a Field Engineer, working on television, radio and communications in Australia, Thailand, Mexico, Norway, Egypt, Taiwan, Japan, Korea and USA including projects involving transmitters up to 100 kW, and aerial systems up to 250 kW capability.

In 1966, he was appointed Chief Engineer of RCA Australia, responsible for broadcast equipment design and manufacturing operations in Sydney, and supervision of a team of Project Engineers performing maintenance and installations at stations. John was jointly responsible for system design and implementation of Radio Australia Cox Peninsula transmitting facilities comprising development and commissioning of log periodic aerials and test load for power levels to 250 kW.

Some of this development involved work at the factory and aerial test range of C0–E1, Milan, Italy where the components were manufactured.

When, in 1972, a body was set up to advise the Australian Broadcasting Control Board on the technical standards to be adopted for colour television transmission, he was a member of the Working Party on video magnetic recording standards, then on colour camera standards. He served as representative of the equipment manufacturers on the Television Industry Technical Advisory Committee until 1976.

In 1973, John left RCA to become Director and co-founder of Star Delta Co., Pty Ltd working on design of transformers, including power, metering, audio, pulse and ferro-resonant constant current transformers. Additional activities included Consultancy work for radio and television stations, RCA, Page Communications, New Zealand Broadcasting Corporation and Ministry of Defence in Republic of China. The work undertaken for RCA involved installation of 50 kW radio and television transmitters in Korea, and development work in USA on 5 kW AM solid state transmitter.

In 1976, he started his own business, forming the company John S Innes Pty Ltd in 1987.

In 1960, John became a Graduate by examination of the British Institution of Radio Engineers subsequently becoming Associate Member. The Institution recently merged with the Institution of Electrical Engineers.

KINGSLEY RADIO PTY LTD

The company was founded by Howard Kingsley Love who was an early pioneer in wireless telegraphy, having operated a spark experimental transmitting station before the First World War.

He served in the Army during the War as a Commissioned Officer, later graduating as a pilot in the Royal Flying Corps.

When the Government decided to issue experimental licences after the War, Howard Love was one of the early applicants to receive a licence. One of his major activities was experimental broadcast transmissions in the 440 metre band.

He was an active member of the Victorian Division of the Wireless Institute of Australia and while President became Editor of the Institute's magazine Radio Experimenter in 1923, followed by later involvement with other radio publications.

In 1926, he operated one of the most advanced Amateur stations in the State from his home in Ferncroft Avenue, East Malvern and carried out considerable experimental work in improving receiving circuits popular at the time. One of his contributions was to upgrade the performance of the universal, tuned radio frequency receiver circuit which employed one RF stage, detector stage and two AF stages. At the time, there were three broadcasting stations operational in Melbourne — 3AR, 3LO and 3UZ — with many Interstate stations also being capable of reception in Melbourne during the evening, and there was a need to improve the selectivity characteristics of the receiver without sacrificing sensitivity. Howard developed a modified aerial tuning circuit which greatly improved receiver performance. It was work in this area which later caused him to investigate the employment of iron dust cores to improve coil performance.

About 1930, he joined Firth Bros., as an Engineer working on the design of Precedent radio products but left about 12 months later to form Kingsley Teleradio Construction Pty Ltd in Spring Street, Melbourne specialising in custom-built hi-fi receivers.

During this period he was Course Director in Radio Experimental Classes with Bradshaws Business College, and students received their practical training in his workshop under supervision of skilled staff.

Popular Kingsley broadcast receivers available during the late 1930s included K45D, a five valve dual wave set in console cabinet; KD50CD, also a five valve set in console cabinet but featuring a high fidelity amplifier developed by the company; K60CD, a six valve console model; K50MD, a five valve dual wave receiver in mantel cabinet, and K60DP, a six valve console model with dual wave facility and record playing equipment.

Two models were also produced to take advantage of the availability of the 2 volt Eveready Air-Cell power source for valve filaments. Sets were the Air-Cell Four, a four valve MF band receiver in console cabinet and the Air-Cell Five, a five valve MF band receiver in console cabinet.

Models were also produced for operation from 32 volt home lighting power systems.

The company was instrumental in producing one of the most popular and versatile communication receivers employed by the Services during the Second World War. It was the K/CR/11 Communications Receiver manufactured in the hundreds for the RAAF, Army, USA Navy, RAF and Free French Forces. The RAAF model known as AR7 was used after the War for off-air reception of broadcast programs from HF stations for rebroadcast by National MF stations. The peacetime version was known as K/CR/12 model.

Kingsley was a leader in the development, production and employment of IRN Dust (Ferromagnetic) Cores of various types marketed as Ferrotune, Permaclad and Permacore brand products. The cores used as a base, Hemetite iron ore from Whyalla in South Australia. The ore was reduced to powder in Kingsley furnaces.

When the premises in Spring Street became too small for expanded activities, new premises were acquired at 380 St Kilda Road where the company traded as Kingsley Radio Pty Ltd.

Iron dust cores for tuning were first employed in the Kingsley KFT1 receiver which covered only the MF band. Development work resulted in the production of the KF/5CR five channel Ferrotune kit which used a cathode coupled RF stage which operated on the MF band and on four short wave bands. The RF stage employed a twin triode valve, the first half of which operated as a cathode follower input stage while the second section operated as a grounded grid amplifier.

The company was a large manufacturer of Permaclad and Permacore IF transformers. They were designed in pairs or in sets of three to provide optimum performance following correct setting in the factory. They varied from sharp tuned pairs for circuits designed for high selectivity and gain through the range to comparatively broad tuned low gain pairs. At least 20 types were produced for the radio manufacturing industry.

Other components and kit sets produced by Kingsley included Permaclad and Permacore MF band coils; Permacore short wave coils; Ferrotune foundation kit sets with dial, chassis and IF transformers; Ferrotune units for manufacturers; Ferrotune HF converters; Ferrotune variable frequency oscillator; Ferrotune pre-selector for optimum aerial-to-receiver matching plus high gain; capacitor tuned dual wave kits; Ferrotune type dials available in seven models; mini loop aerials; midget gang capacitors; and permag dynamic loudspeakers available in 3, 5 and 6 inch models with input transformer to requisite impedance.

Design, production and testing involved many people and a large range of workshop tools, machines and facilities. For iron cores slug production, equipment included a furnace room for reduction of iron powder, a heavy core press for production of a range of shapes and slugs and high speed automatic presses for production of smaller cores.

In 1947, the company announced that its Research Section had constructed an experimental tuning drum employing iron dust slabs or discs and a special pancake shape coil. It was an improvement on work undertaken some months earlier embodying a drum type turret to which was affixed sets of coils. The turret was rotated in order to bring in a new set of coils for each band desired by the operator. The kit covered five bands under the nomenclature KF/5CR.

The new system designated KF/8CR employed discs or slabs of iron dust material of the right frequency characteristic. Instead of being inserted into a solenoid coil, the discs or slabs were brushed past a pancake type coil in order to effect the tuning. It was an eight band tuning system.

The company ceased operation shortly after the death of the founder Howard Love during 1948.

Included among many staff employed by the company over the years were Johnnie Bremner, Chief Engineer; Jack Gostalow, Chief Designer; Harry Fuller; Lay Cranch; George Nielson; Ron Pollock; Brian Irwin; Lawrie Fitzgerald and many others.

Lay Cranch as Research Engineer played a major role in the development of Permaclad and Permacore products.

After closure of Kingsley Radio he set up business in Sydney as Cranch Products and Trading Company and distributed Vega Radio Products through Telecomponents Pty Ltd. The Vega range included standard and miniature IF transformers; standard and miniature MF band coils; standard and miniature short wave band coils; standard and miniature dual wave coil sets, tuning units etc. He published regular Technical and Data Sheets for Vega Products to assist manufacturers and designers in the use of the products.

KRIESLER (A/ASIA) PTY LTD

The company was founded by Rae Weingott, who had a plan to produce high quality, cheap broadcast receivers which could be purchased like any other item of merchandise from major Department stores as well as the normal radio and electrical goods stores.

Rae had been an experimenter since about 1920, and from 1924, became involved commercially as Manager of Airmaster Radio Co., and later Electric Trading Co., Inevettes Ltd, and Volcalion Ltd.

From about 1926, he began the manufacture of receivers using mainly imported components and produced a number of features which appealed to the public, such as single knob tuning, compact mantel models and many others. He invented and developed a number of features which resulted in good sales. These included all-wave coil devices and a vario-coupled IF transformer.

Early in 1930, the start of the Kriesler Radio Co., Ltd organisation began to take shape with the establishment of a small factory in Yurong Lane, off William Street in Sydney. The Kriesler brand receivers were made as simple as possible and sold at a competitive price, which resulted in high demand. At the same time, they produced chassis with any name selected by firms which purchased them. Department stores saw an opportunity to add radio receivers to their other merchandise with their own brand name. The idea was a great success for both the Department store owners and the buying public, many of whom felt more confident in dealing with their favourite Department store than specialised Electrical Shops.

The demand for receivers was far beyond expectations, and in order to meet orders, a three storey factory was established in Levey Street, Chippendale. Even though many businesses were closing down because of financial restrictions resulting from the Depression, the company operated at maximum capacity. In addition to supplying Department stores and Radio Distributors, they produced a number of coil sets which were popular with home constructors.

Chief Engineer was James Edwards who had transferred from Custom Built Radio where he had been Manager. Prior to that he had been a radio experimenter since 1919, and had a number of jobs in the sound, servicing and broadcasting fields in Adelaide. He moved to Sydney during 1930. After leaving Kriesler, he held positions of Chief Engineer with Paramont Radio Manufacturing Co., radio component manufacturers; and Crown Radio Manufacturing Co., Pty Ltd, manufacturers and wholesalers of radio components, receiver kit sets, coil kits etc. In 1935, he joined Australian Radio Publications Ltd. He was also Executive Secretary of The Institution of Radio Engineers (Australia) and Editor of the 'Proceedings of the IRE'.

Included in the 1931 releases were designs featuring Quick Vision dial; 235 variable mu valve; 247 pentode valve; acoustic control; static modifier; invisible tuning; electrolytic capacitors; electrostatic shielding; Jensen dynamic loudspeakers and a range of console type cabinets.

The company also produced the five valve AC powered 'Kriesler Meccanoized Kit' to meet a strong demand by do-it-yourself set constructors. The kit was marketed in a large cardboard box and comprised all radio components; nuts, bolts and screws; tools; solder and flux; complete wiring harness; drilled chassis; valve shields, but did not include valves, loudspeaker and cabinet. The circuit comprised two variable mu valve type 235 RF amplifiers, screen grid detector valve type 224A employed as an anode bend detector, resistance-capacitance coupled to pentode valve type 247. Full wave rectifier was 280 type. Nearly 400 kits were produced in one week to meet a sales peak demand.

In 1933, the company was in serious financial difficulty. A notice in the Press advised that tenders had been called by the liquidator Robert Newton, and would be received in his office up to Monday 9 October 1933 for the purchase of the business of Kriesler Radio Co., Ltd in liquidation as a going concern comprising assets (1) Stock, (2) Plant, (3) Patent Rights and Goodwill.

About that time Percy George Tuit a well-known financier joined the company. He became Chairman of Directors and Rae Weingott became Technical Director. Tuit introduced a major reorganisation of the company and changed the name to Kriesler (Australasia) Ltd. The new company set about building up an enlarged dealer organisation which paid cash for the right to sell Kriesler receivers and products in every State.

Many new designs were introduced including All Wave and Dual Wave types. With a vigorous marketing program many new words appeared to describe the products. Such descriptions as 'Triple Throat', 'Three Dimensional Sound', 'Microscopic Tuning' and others were used to describe Kriesler receivers. At the time, the company claimed to have the only receiver fitted with three dynamic speakers in Australia. The company manufactured its own loudspeakers.

About this time the company produced the 'Super Heterodyne' Kit. It was one of a series of standard boxed Kriesler superheterodyne kits and included a gang capacitor, all cans as well as the coils, padding capacitor and its shunt capacitor, and knobs. The kit was purchased by many hobbyists who constructed the 9–58 Super, a nine valve superheterodyne receiver for 58 type valves described in the Superheterodyne Book 1932–33 issued by Wireless Weekly. Doug Whitburn of Adelaide constructed the 9–58 Super using the Kriesler kit and donated it to one of the local Radio Clubs. At the time, Doug was Secretary of the local Wireless Institute.

One unusual design introduced for the 1934 Christmas trade was the patented Easy Chair Radio. A control panel situated in a sunken pocket of one arm of the chair consisted of dial and cable drive to the receiver tuning unit with 57 type valve as autodyne and built upon a small chassis located inside the chair arm. A second chassis was located under the seat. This chassis contained valve types 58, IF amplifier; 2B7, 2nd detector; 2A5, output; and 80 rectifier. The loudspeaker was mounted on a baffle set into the back of the chair.

The 1935 range comprised 14 models including Model 10A3 an AC powered triple wave 10 valve superheterodyne receiver employing an IF of 175 kHz. The company claimed it to be 'the most powerful receiver ever built'.

Kriesler took advantage of the newly developed metal valves and manufactured models with metal valves in all sockets.

By 1936, there was a large range of models in production with such features and devices as moulded cabinets, magic eye tuning, synchro-silencer, vertical slide-rule edgelet dials, wonder dial, timer recorder, tone and volume indicators, turret top shielding and tone expander. Probably the most noteworthy of these features was the wonder dial. It had a time chart which enabled the operator to check the time in any part of the world. This was valuable for listeners tuning in on short wave bands to hear broadcasts of Tests being played by touring Australian cricketers. Another popular, although expensive model of the period, was a combined cocktail bar, radio receiver and gramophone.

Like a number of other manufacturers, Kriesler made a range of superheterodyne receivers employing an intermediate frequency of 175 kHz. Models produced during 1937 included 710, 711 and 712, five valve dual wave AC powered sets in console cabinets; 731, 732 and 733, six valve dual wave AC powered sets in console cabinets; 740, 741, 742 and 743, eight valve dual wave AC powered console cabinet sets; 830, 831, 832 and 833, five valve dual wave receivers in console cabinets and designed for Universal power supplies. All other designs produced during the year employed an IF of 458 kHz.

In April 1937, Kurt Landecker a German Engineer took up an appointment as Design Engineer and Scientist with Kriesler.

After studying at Danzig University he moved to the University of Berlin where he was awarded a Diploma in Engineering. In 1927, he worked for the AEG Company as Design Engineer where he was in charge of company radio and television patents. In 1933, he left AEG to undertake research and developmental work on cardiographs.

Immediately on taking up duty with Kriesler, he undertook an extensive study of the entire design, production, testing and delivery processes at the company. Many of his recommendations were implemented resulting in improvement in technical design features in receivers, in productivity and in lower production costs.

The organisation was so successful in marketing its receivers that in 1938, plans were developed to build a new factory. At the same time it became a Proprietary company.

The Company produced a wide range of receivers aimed at the country market. Included in their range of 88 models in 1938 were 52 models designed for battery operation. Power supply requirements for these models included 1.4V A battery/90V B battery, 2V A battery/135V B battery, vibrator unit with 6V battery and Air-Cell A battery/135V B battery.

One of the key staff in the Company's successful marketing was Clem King, the Sales Manager. Clem had had considerable experience in Electrical Engineering before transferring to commercial activities. Clem was educated at the Sydney Technical College and before joining Kriesler had worked with B W Electric Co., and Electrical Plant Manufacturing Co., before transferring to the British General Electric Co., to engage in the commercial side of the business.

During the War years, a relatively small number of receivers for the domestic market were produced. In 1940, four triple wave band models were released to meet the demand for reception of overseas broadcasts because of interest in the War in Europe. Two were seven valve AC powered and two were six valve vibrator/accumulator powered designs.

However, the major resources of the company were directed towards the manufacture of equipment, facilities and components for the Services. Some of the items produced in the factory were not related directly to radio but the diversity of the factory facilities enabled these to be made without any great difficulty. Overall, some 473 projects were undertaken and included such items as transmitter No. 123, RAAF AT19 1000 watt static ground station HF transmitter, waterproof reception set No. 7, resistance units, rectifier units, magnetic switches and relays, radar equipment, six valve dual wave AC mantel receivers, push-buttons, plugs, suppressors, telephones and a range of switch boxes for the Mosquito airplane.

After the cessation of hostilities, the company prepared plans to produce new receiver designs and to begin manufacturing operations as soon as possible.

On 28 November 1945, the company displayed some of the new models proposed when about 200 Dealers attended a function at Vere Mathews in King Street, Sydney.

Models on sale in early 1946 included three AC powered models, three accumulator/vibrator powered models and an AC powered radio-gramophone combination. Best known was Model 11-4 a dual wave reflex ¾ valve superheterodyne known as the 'Beehive' because of its appearance.

Cabinets were Bakelite midget, table and console type cabinets. A feature of cabinet designs was that they were sealed by enclosing the backs of the cabinets. They were advertised as 'Sealed Radio' models.

The 1947 releases included:

- Model 11-7, a five AC powered dual wave table receiver in moulded cabinet, sealed and styled same back and front. Loudspeaker was a 6 inch (150 mm) permag type with baffle extended across the top of the set. Components were tropic proofed. Short wave band coverage was 6–18 MHz. Valve types were ECH35, mixer, local oscillator; 6U7G, IF amplifier; 6B6G, detector, AVC, AF amplifier; 6V6G, output; and 6X5G, full wave rectifier.
- Model 11-10, Grand Combinette, a five valve AC powered dual wave table type receiver fitted with record player and 8 inch (200 mm) loudspeaker. Cabinet was a highly polished veneer cabinet with attachable legs being available.

In the 1950s, Kriesler was incorporated in the Philips organisation but continued to produce equipment under the Kriesler label. At that period, the factory was located at Alice Street, Newtown and began to produce television receivers as well as transistor radio receivers and a table model radiogram with a high impact polystyrene cabinet.

One of the 1955 releases included Model 11-49, a four valve AC powered superheterodyne receiver fitted with a clock. Valve types comprised 6AN7, 6AD8, 6M5 and EZ82. Chief Technical Engineer at the time was Arthur Bennett.

The Alice Street factory was burnt down in late 1950s, and a new factory established at Caringbah.

In 1960, Kriesler marketed Model 11-85, a six valve MF band radiogram designed for reproduction of monaural or stereophonic records. It was equipped with dual AF amplifiers and two twin cone loudspeakers. The Garrard Model 210 record changer was a four speed automatic type with separate pick-up cartridges for monaural and stereophonic records. An in-built plate aerial provided adequate signal reception for listeners within reasonable distance of a transmitting station. Valve types were 6AN7, 6N8, 12AX7, 6M5 (two), and 6V4.

In June 1960, Kriesler produced Model 41-23, a six transistor battery-powered portable receiver for MF band reception. A reversible dial scale was fitted with NSW and QLD stations on one side and stations of other States on the other side. Battery was Eveready 9 volt type 2362 or equivalent. Battery consumption varied from 10 Ma with no signal to 60 Ma with maximum volume. Transistors employed were OC170, mixer, oscillator; OC169, 1st IF amplifier; OC169, 2nd IF amplifier; OC75, audio amplifier; OC74, audio output. Germanium diode OA80 was used as AGC limiter and OA79 as detector/AGC.

In February 1963, the company held a four day conference at the Caringbah headquarters to discuss company goals and plans for the next few years. Technical, Commercial and Managerial staff from all States attended and included Doug Perry (NSW), Merv Hardy (Newcastle), Arthur Hayward (Perth), and Australian Field Engineer Frank Tregurtha.

By the mid 1970s, the company operations included the manufacture of radio and TV receivers, stereo equipment and tape recorders. Factory Director was W A Bailey and Technical Director was Angus (Gus) Fowler. Rae Weingott, founder of the company was Chairman. Products were distributed through branches in all States except Tasmania.

Due to declining business, production facilities closed down in 1982 and by the end of 1983, the name Kriesler disappeared from the radio scene. Today, Kriesler is one of the many trade labels of Philips Industries Holdings Ltd.

Many Engineers passed through the company over the years with some retiring from the company and others moving to other organisations. They included Fred Lane, Leo Buduls, Oscar Lerve, Frank Atherden, Bert Mangold, Douglas Mowlett, Arthur Bennett, Angus Fowler, John Starr, Robert Woodall and others.

Angus Fowler occupied the position of Chief Engineer for many years and during 1970-71 he was President of The Institution of Radio and Electronics Engineers, Australia.

John Starr subsequently took up a position with the Australian Broadcasting Corporation, becoming Director Technical Services in South Australia before retirement.

LEKMEK RADIO LABORATORIES

Lekmek Radio Laboratories was founded by Norman Stanley Gilmore in 1931 at 75 William Street, Sydney.

Norm Gilmore had been involved with wireless experiments before the First World War during the wireless telegraphy era. He entered the Postmaster General's Department as Telegraph Messenger at Horsham in 1904. He completed an Engineer's Course in 1915 and served in the Department's Professional Division while based at Sydney, Newcastle and Maitland over the period 1915 to 1922.

In 1922, he left the Department to become a Director of L P R Bean and Co., until 1927 when he accepted a similar position with Stromberg-Carlson A/Asia Ltd.

In 1931, he left Stromberg-Carlson to found Lekmek Radio Laboratories occupying the position of Managing Director.

Within a short period of setting up the business, a range of locally designed receivers and kit sets were being marketed. John Paton was Works Manager and Arthur Everitt was Service Manager.

John Paton began his career as an Electrical Engineer following five years as an Apprentice. He spent one year in charge of the Test Room at Ferguson Palin Ltd, four years as Design and Production Engineer with Stromberg-Carlson and a period with Thom and Smith Design Section before taking up a position with Lekmek in charge of Design Section.

Arthur Everitt began work with AWA completing an Apprenticeship during 1923-28. He moved to Stromberg-Carlson as Chief Tester and later transferred to New System Telephones as Assistant Engineer before taking up a position with Lekmek. He was a founding partner in the business Borthwick, Everitt & Co., Newtown manufacturers of Beco brand receivers.

By 1933, Lekmek produced a range of popular superheterodyne kits. They included:

- Universal Kit 53-B, a four valve kit intended for motor car sets and battery-powered home receivers. It operated from a 6 volt accumulator or a 6 volt AC transformer. Valve types included 2/236, 1/239 and 1/238.
- Simplicity Kit 52-E, a simple five receiver for AC operation but not recommended for use at sites close to transmitting stations owing to double spot tuning characteristics. Valve types were 2/224A, 1/235, 1/247 and 1/280.
- Super-Six Kit 60, a six valve receiver using an RF stage and designed for country reception. It had two IF stages and valve types were 2/224A, 2/235, 1/247 and 1/280.
- Super-Four Kit 42-E, a four valve 'Baby Super Het' with valve types 1/57, 1/58, 1/47 and 1/280.
- Super-Five Kit 51, a five valve receiver designed for use in the metropolitan areas. Designed to produce low noise level, it employed valve types 2/224A, 1/235, 1/247 and 1/280. It was equipped with a selector circuit.

All of the kit sets were provided with all components parts to make the set operative and included hook-up wire, instructions and circuit diagrams.

The range of fully assembled Lekmek receivers during early 1933 included:

- Consoles.
  Models 61EC, six valve receiver, AC powered; 70EC, seven valve AC powered receiver with push-pull output stage; 51EC, AC powered five valve receiver; 62EC, six valve AC powered set; 54BC, five valve battery-powered receiver; 80BC, eight valve battery-powered set, and 56EC, five valve AC powered unit.
- Mantels.
  Models 43EM, four valve AC powered receiver; 53BSM, four valve battery-powered set; 56EM, five valve AC powered receiver; 51EM, five valve AC powered unit; 62EM, six valve AC powered receiver; 61EM, six valve AC powered set and 54EM, five valve battery-powered receiver.

Receivers available through Dealers for the 1933 Christmas period included:

- Model 58EC, a five valve AC powered receiver housed in an artistic piano finished consolette cabinet.
- Model 71EC, a seven valve AC powered resistance coupled receiver with push-pull output stage, and enclosed in a console cabinet.
- Model 62EC, a six valve AC powered superheterodyne receiver in a high quality console cabinet.
- Model 44EM, a four valve superheterodyne mantel receiver designed for local station reception.
- Model 59EM, a five valve superheterodyne mantel receiver designed for interstate reception.

All these models were AC powered designs with full wave rectifiers, but a six valve battery-powered model employing 2 volt filament valves was also available.

The top of the Lekmek range available at the time was Model 1101, an 11 valve AC powered superheterodyne receiver covering the complete band 10 to 550 metres. It was one of the first Australian built receivers covering the designated band without skipping. Valve types were 57 (two), 56, 58 (four), 2A6, 2A5 (two) and 80 rectifier. Separate detector and oscillator were used on short wave band with an IF 595 kHz. A coupling arrangement developed in the Lekmek Laboratories provided exceptional sensitivity. The Efco Aero type dial was calibrated in metres from 10-20, 20-40, 40-80, 80-200 and 200-550. Controls were tuning, wave change switch, short wave trimmer, tone and volume. The high quality cabinet was specially designed for the chassis.

One of these receivers was purchased by 3WR Wangaratta for rebroadcast of the Cricket Test series in England in 1934.

During 1938, Lekmek released its Anniversary Series of receivers. Designs featured:

- Visiongraph dials with the main stations projected on a screen to a height of over 1 inch (25 mm) and visible from a distance.
- Tunerlight, a new magic beam automatic tuning device.
- Improved Sirufer iron core intermediates providing improved sensitivity and power.
- Latest Lekmek 1938 Coil Unit, full AVC, specially designed Lekmek dynamic loudspeaker, triple wave 13 to 51 metres on short wave bands and band-spreading on short waves.

Over 25 models designed for operation from AC, battery, Air-Cell or vibrator/accumulator power sources were available. The range included:

- Model 540 in Euclid console cabinet with large edgelit dial.
- Model 402, a four valve portable set in leatherette covered cabinet.
- Model 430V, a four valve set in Elf cabinet designed for country areas and powered from vibrator/6 volt accumulator source.
- Model 541T, a five valve triple wave AC powered set in Homer cabinet with Visiongraph edgelit dial, Lekmek 10 inch (250 mm) loudspeaker and Tunerlight automatic tuning beam.

One of the receivers released for the 1935 Christmas period which produced good sales, was Model 615 deluxe, an all metal six valve dual wave set with Magic Eye tuning. Valve types were 6A8, frequency converter; 6K7, 460 kHz IF amplifier; 6K7, reflex and AF amplifier; 6H6, duo-diode demodulator and AVC rectifier; 6F6, output pentode, and 5Z4 receiver. Features included 10 inch (250 mm) Amplion loudspeaker, Miracle Eye Control for accurate tuning even on short wave stations, tuning by Micro-Master dial with high ratio vernier tuning, cabinet with sloping Arcturus design incorporating separate panels for loudspeaker grille and the control panel.

With the availability of the Eveready Air-Cell A battery-power source, Lekmek produced a range of five models in 1937. They comprised:

- Model A402, Orion, a four valve MF band table receiver.
- Model A403, Strauss, a four valve MF band console cabinet receiver.
- Model A534, Schubert, a five valve MF band console cabinet receiver employing two Air-Cells.
- Model A535, Schubert, a five valve dual wave band receiver employing two Air-Cells.
- Model A632, Schubert, a six valve dual wave console cabinet receiver employing two Air-Cells.

By the late 1930s, the company name became Lekmek (A/Asia) Ltd, to accommodate its distribution interests in New Zealand.

By 1936, the company was producing an extensive range of components and other radio type equipment. These included high fidelity audio transformers, faders, potentiometers, pick-up amplifiers, power transformers, equalisers, alternators, intercommunication speaker systems and broadcast studio equipment. At the time, Factory Chief Engineer was John Paton and Factory Superintendent was Arthur Bates.

The studio equipment was widely employed in both Commercial and National services. One of the Commercial stations to be fully equipped with Lekmek studio equipment was 2MW Murwillumbah, in 1937. Other stations with equipment at either main studios or the emergency studio at the transmitter included Commercial stations 2CA, 2DU and 2MG and National stations at Canberra, Derby and Lyndhurst.

Manufacturing ceased during 1940 and one of the receiver models produced during the last years of operation was the Model 54IT Homer, a five valve triple wave set with 'Visiongraph' edge-lit dial, Lekmek 10 inch speaker, 'Tunerlight' automatic tuning beam, Sirufer IF transformers and a luxurious console cabinet.

In the 1930s, the company Sales Manager was Sam Conlon who had trained as an Engineer but later moved into the commercial side of the industry. He had a Bachelor of Science Degree and an Expert Electrical Engineers Certificate and had worked in the PMG's Department as a Telephone Engineer on exchange and subscriber services. He made a number of overseas visits to establish contacts and subsequently became Australian representative for a number of overseas products. On his return from a visit to radio exhibitions in Europe in the early 1930s he took up a position as Sales Manager with Lekmek Radio Laboratories. In the mid 1930s, he left Lekmek and established S M Conlon Radio Co., in Kippax Street, Sydney to begin manufacturing radio receivers with W P Lynch being the Works Manager.

Following closure of Lekmek Radio Laboratories in 1940, Norm Gilmore became a Consulting Engineer to the broadcasting industry working on a number of important projects.

In 1951, he was appointed Chief Executive Officer of Australian Radio Technical Services and Patents Co., Pty Ltd, Sydney.

Norm had a long association with the Institution of Radio Engineers (Australia). He was a member of the Provisional Council 1932 when the Institution was formed. He served as President 1938–39 and was General Secretary for many years until 1960.

NATIONAL RADIO CORPORATION LTD

The National Radio Corporation Ltd, was one of the few large receiver manufacturers located outside of Sydney and Melbourne. It was an Adelaide-based organisation with branches in Melbourne providing sales and service throughout Victoria, New South Wales and Tasmania; in Perth covering Western Australia; and Brisbane with distributors servicing Queensland and Northern New South Wales.

The founders of the company were Ernest R Smith and Oswald J Smith who initially operated a Land Agent business off Currie Street in Adelaide. In the mid 1920s when broadcasting had become well-established in South Australia with 5CL, 5DN and 5KA providing service, the Smith brothers saw the need to be in at the ground floor to provide for the needs of the public eager to purchase good quality commercially produced broadcast receivers.

Trading as Ernest Smith and Co., Ltd they first began marketing sets obtained from manufacturers in Sydney and Melbourne as well as models produced locally by Reg George at Brooklyn Park in 1929.

The radio business expanded so rapidly that operations were transferred to premises at 114 Grenfell Street corner of Adelaide Arcade. Here they assembled Scharnberg-Strauss receivers on site using components purchased outside and also provided service and repair work to the public.

By the end of 1932, radio had expanded rapidly throughout the nation. The number of broadcast listener's licences had passed the 400000 mark with more than 6 people per 100 population possessing a licence. In South Australia, there were six broadcasting stations on air with four servicing the Adelaide area with over 36000 licences being held by listeners within 50 miles (80 km) of the city. The Smith brothers saw this as a golden opportunity to set up large scale radio manufacturing business to supply demand throughout Australia.

The founders were fortunate to have a group of talented experimenters on the design side of the business and prototype receivers constructed had a number of technical improvements on sets made by others. By this time, operations were being conducted at Worando Building in Grenfell Street.

On 16 March 1933, National Radio Corporation Ltd was registered with a nominal capital of £5000 and in order to provide for large scale operations, a building was acquired at 96 Pirie Street, Adelaide in 1934 and fully equipped so that the company was as self-sufficient as possible in carrying out its design, development and manufacturing activities. Ernest Smith was Governing Director and Oswald Smith a Director. By 1937, other members of the family, Ward Smith and G J Smith had become Directors.

Engineer and General Manager was Elof Lindberg who received his early training and experience in Radio Engineering in Denmark and USA. He came to Australia in 1922 and was engaged in Radio and Electrical Engineering activities before joining the National Radio Corporation Ltd on its establishment.

Elof was a driving force in adopting innovative production procedures making the factory to a large extent fully self-supporting in most of its research, development and manufacturing functions. A large machine shop allowed efficient production of all the different chassis, a coil winding shop produced all requirements for coils and transformers, and a well-equipped laboratory, suitably staffed, ensured on-going product improvement. The large receiver test area was fully screened with copper wire mesh to ensure testing operations could be carried out without suffering interference from external sources. An area in which the company played a leading role was in the employment of German iron dust material Sirufer in coils.

At the time, there were at least 50 people on the payroll.

The company manufactured a large range of receivers including broadcast MF and dual wave band mantel and console models powered from AC mains, DC mains, dry cell batteries and accumulator/vibrator sources. Portable receivers were also produced, with one of the models being one of the first designs in Australia to incorporate the aerial in the shoulder strap. Scharnberg-Strauss models were manufactured for sale through local Ernest Smith and Co., Ltd outlet and National brand models manufactured for distribution throughout Australia. Large numbers were also produced as Badge Engineered models for local and interstate businesses.

Amongst the models produced during 1935–36 were receivers operated by 6 volt accumulator supplies. They included three valve console; four valve console; five valve MF band console and five valve dual wave console models. Features of the range included maximum drain of 1 ampere; Ferrocart rectifier unit; AVC on all models except the three valve model; fully calibrated edgelit dial with dial switch; high sensitivity and selectivity characteristics; 8 inch (200 mm) Rola loudspeaker; all models fitted with Philips Metal Clad Golden Series valves provided with P bases; cabinets in modernistic designs of polished hardwoods or iridescent lacquer in combinations of gold and blue.

Models released during 1937–38 comprised many new designs with at least 12 models being manufactured. They included Model 43, an AC powered five valve receiver incorporating a motor driven tuning unit. The mechanical arrangement employed — somewhat novel at the time — was not entirely reliable and satisfactory for accurate tuning, and no other models employing the technology were produced by the company.

In May 1939, the company made a further shift when it relocated to premises at 90 Grote Street, Adelaide after being taken over by Electronic Industries Ltd.

During the War years, National manufactured, among many items, remote control units for the Army type 22 Wireless Set.

Some receivers were produced during 1939–40 with the 1939 range including a five valve portable set fitted with 1.4 volt filament valves, and a five AC powered triple wave band receiver in console type cabinet for receiving short wave broadcasts from the BBC because of the growing interest in progress of the War in Europe.

Production of receivers resumed after the War with a series of four and five valve designs being marketed. They included models made for AC and accumulator/vibrator power sources housed in mantel and consol cabinets with one being a portable model.

Receiver manufacturing operations were scaled down from about 1950 and the plant subsequently closed down.

Besides Elof Lindberg, other staff who served with National Radio Corporation Ltd at various times include John Allan, Ralph Baker, Arthur Bate, Don Beaty, Percy Cockington, Jack Dorsett, Max Farrell, Jack Ferry, Jack Forby, George Ford, Betty Geisel, Doug Holt, Reg Hunter, John Lee, Leo Marks, Lyn McKay, Ted O'Neill, Peter Price, Jim Shannon, Ralph Smith, Al Smythe, Doug Strangway, Ray Tucker, Kevin Wadham and Len Wurfel.

In late 1938, Elof Lindberg transferred to the Adelaide branch of AZ Radio Pty, distributors of Essanay receivers, components and kit sets.

Kevin Wadham well-known in Adelaide radio circles was Sales Manager for many years having previously worked with A G Healing Ltd, Paroso Ltd and H C McKenzie and Co. When Elof Lindberg left National Radio Corporation Ltd, Kevin was appointed General Manager.

One employee who joined the company shortly after it began operations was Arthur Bate. Arthur's interest in radio began in the school room during science lectures. Following the acquisition of a cat's whisker, a piece of galena from a local mine at Glen Osmond, a 201A valve, some batteries and a pair of headphones he wound coils on cardboard formers and constructed his first battery-operated receiver.

After leaving school, he was apprenticed to his father as a watchmaker. However, Arthur's mind was on more scientific things and when he began to magnetise workshop screwdrivers, he was 'shown the back door'.

In 1934, his father accepted the situation and allowed Arthur to take up a position with the National Radio Corporation Ltd which had been formed. The company was expanding rapidly and Arthur found the work very interesting. He advanced through various sections rapidly, and soon became Production Foreman.

During the Second World War, he served with the RAAF, installing and operating HF/DF and Radar equipment.

In 1947, Arthur joined the Postmaster General's Department as a Technician and worked at the Adelaide Studios of the ABC and the NBS Metropolitan Transmitting Centre 5CL/5AN Brooklyn Park. With the establishment of a new NBS transmitting station at Pimpala in 1961, he worked on the installation of the facilities which included 50/10 kW transmitters for 5CL, 10/2 kW transmitters for 5AN and a 169 m high dual frequency radiator. After commissioning of the station, Arthur remained as a member of the operating staff.

Arthur later transferred to the Posts and Telecommunications Department, and retired in 1977 when he was Principal Technical Officer, Radio Frequency Management Division.

Another of the Corporation's early employees was Ralph Baker. After a period of working on the assembly and testing of receivers in the factory, Ralph was transferred to the Radio Service Group which serviced receivers in the field. He served with the RAAF during the Second World War years and after discharge, began work with Ernsmiths in Gawler Place making Scharnberg-Strauss receivers. Later, a factory was established at Brompton with Ralph becoming Factory Manager controlling manufacture of radio receivers, radiograms and later TV receivers until 1978 when manufacturing ceased.

Al Smythe joined the Postmaster General's Department after leaving National Radio Corporation Ltd and for many years was associated with installation and operation with the National Broadcasting Service in South Australia. After retirement he was a volunteer worker at the Telecommunications Museum constructing, renovating and restoring early experimental transmitters and receivers.

In 1936, John Allan joined National Radio Corporation Ltd. At the time, he was attending night class on Wireless subjects at the School of Mines and was given the opportunity of working in the Corporation's Radio Laboratory to investigate some technical problem with DC mains powered dual receiver models. He solved the problem and was invited by the company to join the staff as a full-time employee. He worked under Elof Lindberg in the development and production of a range of receivers until 1941 when he took leave to join the RAAF working on development of Radar. After the War, John returned to National Radio Corporation Ltd but left in 1950 when receiver production activities were being wound down, and set up his own business which he operated for some 35 years before retiring.

National Radio Corporation Ltd had branches in Melbourne and Perth and a major distributor in Brisbane giving Australia-wide distribution and servicing of receivers produced by the company.

The Melbourne Branch located at Roma House, Elizabeth Street, Melbourne was responsible for sales and service of receivers throughout Victoria, New South Wales and Tasmania.

It had a well-equipped workshop staffed by qualified Radio Mechanics to handle all service requirements. The Manager was H L (Bert) Little, who had been associated with radio for many years. Prior to joining the National Radio Corporation Ltd, he had worked with Louis Coen Wireless, New System Telephones, Noyes Bros., and William Buckland Pty Ltd. At William Buckland, he had been Sales Manager responsible for distribution and sales of Emmco, Airmaster, Essanay, Astor, Celebrity, Mastermade and other brands of receivers. He later established his own business, H C Little and Co., Ltd, in Perth, where he was distributor for Lekmek radio products and Siemens products.

The Perth Branch was also equipped with workshop facilities staffed by Radio Mechanics to handle all sales and service requirements. Manager of the Branch was Mr T F Hantke.

Radio and Television Pty Ltd, Perry House, Elizabeth Street, Brisbane was established to handle the sales and servicing of National receivers throughout Queensland and the Northern Rivers Districts of New South Wales. Mr F Farr was Sales Manager and Director of the company. In order to handle the growing volume of sales and service requirements in New South Wales, a Sydney office was later established at 38 Carrington Street, with Ray Evans in charge. Mr Evans had been a licensed experimenter before the First World War in the days of spark wireless telegraphy with his station XAZ. During the War, he served with the Technical Wireless Civilian Service of the Navy Department and after the War, became associated with the radio parts business, occupying various executive positions from 1919 to 1929. He later worked with Eclipse Radio Pty Ltd, being responsible for distribution of radio parts, chassis, valves and receivers and also with Zenith Radio Co., Ltd, in the distribution of Zenith receivers, coils, potentiometers, dials and other products.

NOYES BROS.

Noyes Bros., Electrical Engineers and Hardware Merchants became involved in the distribution of radio components and assembled receivers some years before the commencement of broadcasting in Australia. The company traded as Noyes Bros., (Sydney) Ltd, and Noyes Bros. (Melbourne) Pty Ltd as wholesalers in radio, electrical and engineering lines and as sole representative for many overseas and Australian products. The company had been registered since 3 September 1907.

At the Radio and Electrical Exhibition held in Adelaide in December 1925, the local Manager Mr P L Morcom who managed a Branch office in Darling Building, Franklin Street, Adelaide mounted an extensive display which included a wide range of Igranic components and a fully-assembled and operational receiver employing an Igranic six valve superheterodyne kit set.

The kit comprised two boxes. One, the Supersonic Heterodyne Receiver Outfit contained all the components, while the Constructional Carton contained as illustrated descriptive handbook, full-size working drawings, wiring diagram and drilling template.

About this time, the company began assembly of receivers in their workshops using imported components under the Seyon (Noyes spelt backwards) label.

In 1927, the Seyon two valve regenerative receiver was a popular set capable of long distance reception. Controls included tuning and reaction controls with a jack outlet enabling operation with either headphones or loudspeaker. The receiver was housed in a small wooden cabinet with bakelite front panel. Local stations could be received at loudspeaker strength.

Included among the large range of components sold by the company were Oldham HT accumulator and Brown electrical pick-up. The English made Oldham HT accumulator was manufactured in standard 20 volt units and for higher voltages, units were stacked together like an expanding bookcase and wired in series. The Brown electrical pick-up was designed to fit on the tone arm of a phonograph and was popular with phonograph owners.

In 1929, a range of one dial control models housed in metal cabinets with black and gold finish were produced. Sets included three valve battery-powered set, three valve AC powered set, six valve AC powered set, and six valve battery-powered set. A selection of Brown cone loudspeakers were available comprising Concord, Sanpareil and Universal models.

The range was expanded in 1930 and included metal cabinet table and console types. The console featured Italian burl walnut veneers with a sunken recess panel and attractive ornamentations finished in gloss lacquer. Jensen dynamic loudspeakers were fitted.

The Seyon range comprised:

- Model A34, an AC powered three valve receiver.
- Model A44, an AC powered screen grid four valve receiver.
- Model A62X, an AC powered six valve receiver.
- Model A54, an AC powered screen grid five valve receiver.
- Model A63, a battery-powered six valve receiver.

About this time, Noyes Bros. came to an arrangement with Stromberg-Carlson whereby Noyes became a distributor of Stromberg-Carlson receivers and Stromberg-Carlson assembled Seyon receiver designs to rigid Noyes Bros. specifications.

Besides receivers, the company had a wide range of radio components and accessories in stock including Magnavox, Amplion and Jensen loudspeakers; Philips valves, eliminators, AF transformers and loudspeakers; Diamond dry cell B and C batteries; Clyde accumulators; knobs and dials.

They also stocked a range of TCC capacitors made in England by The Telegraph Condenser Co., Ltd. Types 87 and 101 were in high demand as they had a high factor of safety and were in demand for use in receivers which operated in towns off the mains where there was a wide variation in the supply voltage.

Two popular console models distributed the following year were:

- Dante 45 with chassis designed with two stages of screen grid amplification; screen grid detector; 245 type power output and 280 type rectifier. Features included built-in dynamic loudspeaker; single dial tuning; volume and tone controls; local/distant switch and automatic pick-up switch.
- Chaucer 55 phone-radio combination with chassis designed with three stages of screen grid RF amplification; screen grid detector; 245 power output; and 280 full wave rectifier. Features included dynamic loudspeaker; low impedance pick-up; electric motor with automatic stop; single dial tuning; tone and volume controls; local/distant station switch; and automatic pick-up switch.

A feature of the manufacture of Seyon receivers was that the normal mass production line techniques whereby each assembler added a few components and then passed the chassis down the line for the next assembler to add a few more components or wiring, was not practiced with Seyon chassis. Each chassis was assembled and wired by one worker from start to finish. Also, resistors and capacitors were wired in accordance with a well-designed layout plan for each design and not grouped together on strips or panels as was the practice in some factories.

About this time, Noyes Bros. began distribution of other brands of receivers including STC.

Just before Christmas 1934, the company released a new range of receivers including:

- Model 71, an AC powered all wave seven valve superheterodyne receiver with the cabinet incorporating Celotex sound absorbing material.
- Model 61B, a battery-powered six valve receiver with AVC.
- Model 61, an AC powered six valve superheterodyne receiver in console cabinet featuring AVC, magic eye tuning and high quality loudspeaker system.

- Model 51M, an AC powered five valve midget superheterodyne set.
- Model 51, an AC powered all wave five valve superheterodyne receiver with Aero dial and Celotex lined console cabinet.
- Model 37, a seven valve AC powered set employing valve types 56, oscillator; 57, 1st detector; 58 (two), IF amplifiers at 465 kHz; 2A6; 2A5, output; and 80, full wave rectifier. A 10 inch (250 mm) Magnavox loudspeaker was employed. Controls included tuning, volume and wave change switch. Dial was an Efco Aero type with three coloured scales. The receiver was housed in a console cabinet with vertical fluted fret and finished with high glass lustre.

At the time, Noyes Bros., (Sydney) Ltd, Radio Department was located at 78 Clarence Street, Sydney with Branches being located at Newcastle and Brisbane. Manager of the Radio Department was Charles Dunn. Charles joined Noyes Bros. as Queensland Manager in 1921 occupying the position until 1929 when he was transferred to Sydney to become Manager of the Radio Department there. Prior to joining Noyes Bros., he had worked in the UK and Australian offices of Union Cable Pty Ltd which he joined in 1901. In 1934, Charles left Noyes to set up a Radio Shop in Parramatta.

The Noyes Bros. (Melbourne) Pty Ltd Radio Department was located at Lonsdale Street, Melbourne with Branches being established at Adelaide, Hobart, Launceston and Perth. Radio Sales Manager was Dan Hargrave. He joined the company in 1920 at the inception of the Radio Department before the commissioning of broadcasting stations in Melbourne. He took over management of the Department from Bill Hill who left to establish his own business. Bill Hill had been associated with radio following discharge from the Army just prior to the end of the First World War. He served at sea as a Ship's Wireless Operator, later joining the commercial staff of AWA, and being appointed Manger of 7LA Launceston.

The 1935 range of receivers included many noteworthy designs. Included were:

- Model 52F, a five valve AC powered MF band receiver with valve types 6C6, autodyne detector; 6D6, IF amplifier; 85, duplex-diode-triode; 42, power penthode; and 80, full wave rectifier. Features included hand-rubbed cabinet of walnut and coachwood with Seyon patent sound chamber; provision for gramophone pick-up; octagonal Efco Aero dial; low ripple HT power supply unit; tuning floated on rubber base to reduce microphonic problems.
- Model 62DF, a six valve dual wave superheterodyne AC powered receiver in console cabinet and employing valve types 6D6, RF amplifier; 6A7, frequency converter; 6D6, IF amplifier; 85, duplex-diode-triode; 42, power penthode; and 80, rectifier. Features included Ferranti AF5 transformer coupling the 85 and 42 type valves; litz wire wound 460 kHz IF transformers; and provision for connection of a transposed aerial feeder system.
- Model 72 BDF, a seven valve dual wave superheterodyne console receiver employing RF stage on both hands followed by frequency changer; two 460 kHz IF stages; second detector, AVC and AF amplifier; driver; and Class B output.

Others included Models 52M, 52, 62F, 62UF, 52B and 62BF.

The production of receivers with the Seyon label apparently ceased about this time.

In 1937, Noyes Bros. stocked a range of Ferranti receivers which featured Magnascopic Dial, an optical device where a scale was magnified to an effective length of about six feet (1.8 m). It enabled precision tuning of any station within range.

In late 1939, at the outbreak of the Second World War, the company were distributors of Kriesler receivers. The following year they were handling Peal brand receivers manufactured by Airzone.

John Bull was Manager of the Electrical Supplies Department handling radio, and electrical accessories.

During the War years, the company supplied a range of electrical accessories for the Services.

PARAMOUNT RADIO MANUFACTURING CO., LTD

The Paramount Radio Manufacturing Company, Citroen House, 301 Castlereagh Street, Sydney was founded by Donald Maskall in May 1932. It was formed into Paramount Radio Manufacturing Company Limited, in April 1934.

Donald Maskall became interested in radio about 1923 when only 12 years of age and at a time when the two A Class broadcasting stations 2BL and 2FC began operation in Sydney. It was an exciting period for boys, and great numbers bought magazines describing the new technology, and purchased components from the many Radio Shops already established in Sydney and built their first receivers.

After leaving school, Donald worked for Messrs Grose and Daniell, George Street, Sydney where he obtained experience in assembling receivers and manufacturing kit sets. The company were agents for Grodan radio products and a range of kit sets including Solodyne, Browning-Drake and Neutrodyne.

When only 21 years of age, he established a business on his own account. The company lost no time in establishing production facilities and soon had a series of AC powered Paramount models available for purchase through The Radio Inn, T & G Building, Elizabeth Street, Sydney.

Sets included:

- Five valve receiver employing valve types 235 (two), 224, 247 and 280.
- Four valve set using valve types 235, 224, 247 and 280.
- Paramount Cub with valve types 235, 247 and 280.
- Paramount Phono-Radio employing valve types 235 (four), 247 and 280.
- Paramount Pylon a table model using valve types 235, 247 and 280.

A phone-radio employing a superheterodyne circuit was also available. All cabinets were walnut veneer wooden types with a piano type finish.

By 1933, Paramount products had been well-accepted because of their high quality and reliability and were being distributed by a network of Agents including South Australian Phono-Radio Co., Adelaide; Gerard and Goodman, Adelaide; Edgar V Hudson Pty Ltd, Brisbane; Henry G Small and Co., Melbourne; Carlyle and Co., Perth.

Products being manufactured at the time included Paramount All-Wave kits covering the range 10 to 550 metres and provided with RF stage, bandspread facility, air dielectric IF transformers employing a patented adjustable coupler; a range of superheterodyne circuit kits; TRF coil kits; RF chokes; wire wound resistors; voltage dividers and full vision dials. Most of these products were incorporated in the receivers made by the firm, and also sold to the public.

In 1935, one of the popular receivers manufactured by Paramount was a five battery-powered model with RF stage, AVC, tone control, three gang tuning capacitor; 175 kHz IF channel; permag loudspeaker; and batteries consisting of heavy duty A accumulator, and Superdyne B batteries.

During 1936–37, the range of receivers available through Radio Shop outlets included:

- Model DW 5/6, a six valve AC operated console set with dual wave capability. A 6E5 tuning indicator and 8 inch (200 mm) loudspeaker with 1650 ohm field coil were provided. Valve types were 6D6, 6A7 , 6D6, 6B7S, 42 in line plus 80 rectifier. Intermediate frequency was 175 kHz. This set was marketed in 1936.
- Model DW5, a five dual wave battery-powered console marketed during 1937. Power was provided by 2 volt accumulator (A battery); three 45 volt dry cell batteries (B) and a 9 volt dry cell battery (C) tapped at 6 volts. The set was fitted with tuning, wave change, volume, tone and battery saver controls. An 8 inch (200 mm) loudspeaker was employed. Valve

types were 1M5G; KK2; 1M5G; 1K7G and 1H4G in line. Intermediate frequency employed was 390 kHz.

The DW5 was also available for power supply using a 6 volt accumulator and split reed synchronous vibrator. As valves were 2 volt filament types, a series/parallel network was used with voltage drops across sections of this used for biasing purposes.

Seven and eight valve receivers in deluxe console cabinets were also available in the range. Six battery-powered models were designed for operation with Eveready Air-Cells.

The company released three new models in time for the expected Christmas buying period of 1938. They comprised:

- Model 6V6, a six valve dual wave battery-operated superheterodyne receiver intended for country listeners located a long distance from a broadcast transmitter. It was powered by a heavy duty accumulator and vibrator system.
- Model 656, an AC powered six valve dual wave superheterodyne set with a highly polished veneer wooden cabinet.
- Model 5B5, a five valve superheterodyne receiver powered by a 2 volt storage battery or Air-Cell. Features included dual wave capability; new edge-lit dial; AVC; 10 inch (250 mm) permag dynamic loudspeaker and battery saver switch.

During 1940, Paramount produced a range of five portables operated from dry cell batteries. Several vibrator/batteries models were also available in the range. The portables included both closed and open front case types employing five valves and providing either MF band or dual wave reception capability. A six valve 'super sensitive' receiver was one of the most popular sets sold. The receivers normally operated from self-contained batteries but an AC power unit was also available.

Included in the range were:

- Model 54, a five valve MF band receiver with volume, tuning and battery/AC switch controls. It was available in cabinet finishes of airplane cloth, maroon or green crocodile leatherette.
- Model 71, a five valve dual wave set with dual wave capability and provided with two IF stages.
- Model 82, a six valve dual wave receiver with RF and two IF stages.
- Model 505, a five valve MF band set with case finishes or green or brown leatherette.
- Model 656, similar to Model 505 but with dual wave coverage.

A range of console models was also produced during the year.

One of the early Chief Engineers of Paramount was James Edwards who later became Technical Editor and Director, Australian Radio Publications Ltd.

PATON ELECTRICAL PTY LTD

The founder of the company was Frederick Henry Paton with the business being located alongside his residence at 90 Victoria Street, Ashfield, a Sydney suburb.

Fred Paton when 15 years of age, began a four years Apprenticeship in 1910 with the Maritime Wireless Company Ltd, Randwick. The company was Australia's first manufacturing business engaged in the production of radio equipment. It had been set up in 1911 and provided facilities for the majority of Coast Radio stations around the Australian coastline prior to the First World War. At the time, it was the only place where youths could be trained in the practical application of Radio Technology. Later, the Marconi School of Wireless was established by AWA to train Wireless Operators for ships and Coast Radio Stations operations.

At the outbreak of the First World War, Fred enlisted as a Field Engineer in the 1st Australian Division in the 35000 strong Australian and New Zealand Army Corps (ANZAC) and served at Gallipoli under General Birdwood. In the first week of fighting, there were over 6500 casualties. One of his important activities on Gallipoli was the setting up of a large bank of water condenser units to provide fresh water for the troops. In 1916, Birdwood took the ANZAC contingent to France where Fred Paton was seriously wounded in the conflict and invalided back to Australia in 1917.

In the post War years, although badly disabled as a result of his War injuries, Fred rekindled his pre-War interest in radio and had ambitions of entering business on a commercial scale. With the help of a colleague, he purchased and installed receivers from about 1928 and after some years decided to specialise in the field of test equipment.

On 24 April 1935, he registered The Paton Electrical Instrument Company.

However, in 1934, the year before company registration, the technical press carried advertisements of instruments made by Slade-Paton Radio and Test Equipment Manufacturers, Lang Street, Croyden, the address of Slade's Radio Pty. Ltd.

By 1937, the range of test equipment and components included cathode ray oscillographs and D'Arsonval type moving coil meters. The D'Arsonval movement consisted essentially of a circular or rectangular coil of many turns of fine wire suspended between the poles of a permanent magnet. Later, moving iron types were added to the factory output. Chief Engineer Eric Packer, played a leading role in designing the meters which had a reputation of high quality.

Included among the popular test instruments of the period were the Palec Model M1 Oscillograph using a one inch cathode ray tube and Model M3 with a three inch tube; the Palec Model DR Oscillator covering in five ranges, 150 kHz to 16000 kHz; the Palec Valve Tester which tested most popular valves in use at the time including American glass and metal series, English valves and octode types without an adaptor; and the CM and SM Model Multimeters. One of the features of the multimeters was their ability to measure DC potentials up to 25 volts without drawing current from the load resistor. This was important for Servicemen when checking the receiver AVC circuit.

In 1938, the company became Paton Electrical Pty Ltd with Fred becoming Managing Director and Manager. Other Directors were his wife, Charlotta Paton and Noel Rose who had joined the company in 1932. Factory Manager at the time was Arthur Edwards. Another employee was Vic Harris who later set up business to manufacture MBH pick-ups.

During the War years, the company manufactured a range of measuring equipment for the Services and industry using a well-equipped workshop. An additional building was constructed to meet the demand. Practically all components and parts required for manufacture and assembly were manufactured on the premises. In addition to a machine shop the factory had a plating shop with Bert Meyer in charge.

After the War, the range of test equipment included signal generators, multimeters, valve testers and a power analyser. Non-radio type materials and devices were also manufactured and included hearing aids, exposure meters and oven temperature gauges. Among the staff recruited to handle upgrading of designs to meet the post War demand were Eric Palmer and John Larkin. John Larkin was a member of the Institution of Radio Engineers (Australia) having entered as Student in 1941 and becoming Associate Member in 1944.

Following the death of Fred Paton, the company merged with University Graham Instruments Pty Ltd with a new company, University Paton Instruments Pty Ltd being formed. A holding company University Paton Limited was established in 1981.

The company business included the manufacture and importation of electrical and electronic measuring, testing and control instruments. Trade names included Paton (meters, test equipment and transducers) and University (meters, insulation testers, transformers, transducers and electrical test instruments).

Associate companies included University Paton Systems Pty Ltd, Pegasus Electrical Components Pty Ltd and Advanced Component Distributors Pty Ltd. University Paton Systems Pty Ltd, formerly Itronics Pty Ltd, was established in 1987 for the purpose of design and development of microprocessor products and manufacture of intelligent security and environment control devices.

In 1990, company Directors included Michael Crismale (Chairman), Barry Langworthy, Michael Kuenzie, Leslie Miller and Jim Chilvers. Managing Director was Barry Langworthy, and Chief Engineer Jim Chilvers.

PHILIPS LAMPS (A/ASIA) PTY LTD

Although today, trading as Philips Industries Holdings Limited, the company started business in Australia as Philips Glowlamp Works about the time broadcasting was being established here. The company later made a major contribution to the Radio Broadcasting industry being a manufacturer of transmitters, receivers and components, particularly valves, for many years.

The first components imported from Philips, Holland were lamps, the first of which arrived in 1905. They were distributed by Lawrence and Hanson. Valves arrived in 1920 but were in short supply and it was not until about 1923 when Philips produced a range of valves branded 'for Amateur and experimental use only' that experimenters were able to obtain regular supplies of Philips valves in local Radio Shops.

In 1925, Anton Den Hertog arrived in Sydney from Eindhoven and set up business as Philips Glowlamp Works in Kembla Building in Margaret Street, Sydney. The first employee was H A Leighton Lord who was to stay with Philips for 40 years. He later became Chairman of Directors of Philips in New Zealand where the company had opened a sales office in 1927.

In December 1926, Philips Lamps (Australasia) Ltd, was formed with staff numbering seven at the time. The company's nominal capital was £50000 ($100000). Within 50 years, the capital value had grown to $24 million and there were thousands of employees on the payroll.

For the first few years, the company imported all of its radio equipment from Holland. Radio Shops were kept supplied with a wide range of valves, components and fully assembled receivers. The A series of receiving valves manufactured between 1925 and 1929 comprised more than 30 different types, all of which were directly heated types. The majority of valves had UX English bases with some having screw terminals on the top or the side. Five tetrodes were included in the range. There were also B series types available at the time. A number of transmitting types were imported to meet the demands of Amateurs and Commercial broadcasting stations and included Types Z11A, Z11B and Z111.

The factory in Holland began manufacturing components some time before producing fully assembled receivers. With strong competition from factories in USA, Great Britain, France and even in Australia, the company set out to produce high quality components and Philips parts soon became very popular with the buying public. The fact that great numbers of Philips radio products are to be seen today among vintage radio collections bears witness to the high quality and sound workmanship which was company policy at the time. An example of the effort to which the company went to produce top class products can be seen in their interstage audio frequency transformers. They were shielded by a seamless pressed case, the primary winding comprised silver wire to reduce voltage drop to the valve anode and the secondary wire usually connected to the grid, was nickel, which had a resistance some 4.5 times higher than silver. Other noteworthy components included the type 1009 battery charger which used a 1010 rectifier and a regulator valve. This was followed by the type 450 charger in a cylindrical slotted metal case using a type 451 rectifier plus regulator. The type 1016 trickle charger using a mercury valve was also popular. The Philips Type 372 'B' battery eliminator was one of the first 'B' eliminators on the Australian market. Among the speakers available, was the PCJJ model using a balanced type drive unit which actuated a full floating cone.

The first Philips receivers, the battery-powered Models 2501 and 2502 were manufactured in Holland in 1927. The following year, the mains powered Model 2514 became available with about 200000 being manufactured and distributed throughout the world, with many being sold in Radio Shops in Australia.

By early 1930, large numbers of Models 2510, 2516 and 2802 were being marketed in Australia. They had facilities for record reproduction and were publicised as Philips Radioplayers. The 2510 was provided with either Sevenette or Permagnetic loudspeaker, the 2516 with either Baby Grand or Peter Pan loudspeaker and the 2802 with Peter Pan.

The Sevenette, Baby Grand and Peter Pan were magnetic types operating on Philips patented balanced armature system and fitted with full floating parchment cones. The Permagnetic was a moving coil design. Other Philips moving coil units were Campanilla floor and table types.

Brief details of these three models are as follows:

- Model 2510 was a four valve receiver with Philips valve types E442 screen grid RF amplifier; E415, power detector; C433, output pentode and 506 rectifier. The equipment was housed in a triple bulkhead metal cabinet providing excellent shielding. Features included tuning and volume controls on side of the cabinet, illuminated dial, variable tuning capacitor, built-in mono pressed steel housing with shaft mounted in low friction bearings, all coils enclosed in evacuated copper containers, single control tuning, and gramophone pick-up attachment. As well as a standard table type, the model was available as a consolette with loudspeaker fitted below the receiver shelf.

  The case or cabinet housing the receiving unit consisted of a metal frame and panels manufactured from sheets of paper impregnated with thermosetting resin. A gloss imitation wood grained pattern on the outer paper sheet provided a decorative finish. The panels were known as 'Vanherite'.

  Resistors were made using small glass tubes, with wire being wound or a carbon compound deposited on the glass tube. Metal rings were provided at the ends to serve as contact points.

  When using the receiver to replay records, the action of plugging the pick-up into the appropriate socket, automatically converted the detector valve into an amplifier stage.
- Model 2516, a two valve receiver designed for local station reception and fitted with internally driven drum tuner, wire wound resistors, and quad selector providing four degrees of selectivity.
- Model 2802, a compact All-Wave set with one stage of screen grid amplification on all wavelengths, one spot reaction, full shielding, special Philips short wave/long wave detector, and provided with gramophone pick-up terminals.

In 1929, the company made plans to begin local assembly of radio receivers, and moved into premises in Missenden Road, Camperdown, previously a motor car body works.

Ir Y B F J Groeneveld, Chief Engineer of Philips Radio Laboratories in Holland came to Australia to oversight the establishment of the production facilities. However, he left Philips in August 1932 to take up a position with Thom and Smith, where he stayed until 1935. He later returned to Philips, Holland where he took up a position as Development Engineer. During the World Radio Conference held in Sydney in April 1938, Ir Groeneveld was one of the speakers at the Conference and presented his talk 'Refining Radio Reception' from Holland by means of the short wave station PCJ which he had designed some years earlier. He spoke mainly of noise interference with radio reception and outlined means whereby it could be minimised. The speech had been recorded some hours earlier and replayed to the meeting over the Raycophone sound system installed at the venue.

The company appointed David Wyles as Technical and Commercial Manager to take charge of operations in 1929. In 1932, he transferred to the company Head Office in Sydney and during 1933 and 1935 made extensive visits to England, Europe and USA to study the latest developments in receiver designs and manufacture. During the visits he had discussions with Engineers of the Philips Laboratories in Holland concerning particular design problems for receivers for the Australian market. Prior to joining Philips he had worked with AWA, was Chief Engineer at 2BL and worked with Briton Electrical and Radio Pty Ltd.

Unfortunately, as events turned out, the marketing people had not properly gauged the local market for the type of receiver required by Australian listeners and the likely quantities. Sales were disappointing and the assembly line was closed down. No further receivers were manufactured in Australia by Philips until 1934.

The first locally manufactured receiver was produced about September 1931. It was Model 1203, a three valve receiver housed in a registered cabinet design. It employed valve types E442S screen grid detector, C443 output pentode and 506 full wave rectifier. Features included impregnated power pack; dual drum control with the left drum controlling volume and right drum the tuning selector; Philips loudspeaker with full floating cone built-in beneath the cabinet base; and wooden veneer piano finished console cabinet.

Two young University Engineering graduates Philips employed on receiver design work were John Briton and Bert Wood. John Briton later formed his own manufacturing business while Bert Wood later worked with the Radio Research Board, Standard Telephones and Cables and ITT Headquarters in Hong Kong where he was Area Technical Director.

Many of these receivers can be found today in vintage radio collections. One was fully operational at the Golden Jubilee of Broadcasting Display held in the Postal Hall of the Adelaide GPO in November 1973. The Display was opened by His Excellency the Governor of South Australia, Sir Mark Oliphant, well-known for his work in the development of the magnetron during the War years.

When production of receivers was resumed by Philips in 1934, the market had been well-researched and production began with a small range of models.

Only one model was released in 1934, and although it had received considerable publicity in the technical press as early as July of that year, it was not until September that models appeared in Radio Shops. It was a five valve superheterodyne chassis in a walnut veneer console cabinet. The circuit comprised frequency changer, IF amplifier, detector and AVC, penthode output and full wave rectifier. The main feature was the Micrometric Station Selector. It consisted of two discs, one in front of the other rotating in opposite directions and at different speeds. The dial was divided into six sections designated A, B, C, D, E and F with each section representing a zone of the broadcast band. The front fast moving disc was arranged to divide each section or zone in to 100 portions. This meant that the range of the dial was virtually divided into 600 separate sections.

It took the company some time to establish full production but by mid 1935 there were 10 models on the market. They included five, six and eight valve designs. The five and eight valve models were available as AC or battery-powered versions. A feature of the designs was the Micro Index dial which facilitated change of dial plate as new stations came on air. Fourteen new broadcasting stations including two National stations were commissioned during the year.

The Manager of the Radioplayer Factory which was located at 10 Dowling Street, Woolloomooloo, was W A Stewart. He had been employed in radio since 1921, having served with Wireless Supplies Ltd and later established his own business importing radio components and parts. In 1929, he joined Western Electric as Sound Engineer and in 1932 took up a position with Zenith Radio. Mr Stewart became the Sydney representative of Philips in 1935 but shortly after was appointed Manager of the Receiver Factory.

In mid 1936, Philips released Model 6709, a seven valve AC powered console receiver. The valves employed were the new Philips six volt series and comprised EF5, RF amplifier; EK2, octode frequency converter; EF5, 462 kHz IF amplifier; EB4, independent duo-diode as demodulator and AVC voltage rectifier; EBC3, AF amplifier; EL2, power pentode and EZ3, indirectly heated full wave rectifier. Features included 6E5 magic eye tuning; Rola K7 loudspeaker with 1000 ohm field coil; three 8 MFD electrolytic capacitors in power filter circuit; line voltage switch giving adjustment for AC inputs of 220, 240 and 260 volts; facility for balanced aerial connection; large edgelit dial illuminated by six lamps; wave change switch concentric with the tuning knob; short wave band coverage of 16.2–52 metres.

The first battery-powered model released in 1936 was Model 6517, a five valve MF band receiver featuring the new two volt series of P based Philips valves. Valve types employed were KF3, RF amplifier; KK2, octode frequency converter; KF3, 460 kHz IF amplifier; KBC1, duo-diode-triode demodulator, AVC voltage rectifier and AF amplifier; and KL4, output pentode. Loudspeaker was a Rola 8.5 inch (212 mm) permag type. A battery was a Vesta 2 volt accumulator, and B battery comprised three Ever-Ready 45 volt dry cell types in series.

By mid 1937, there were at least 13 models available in Radio Shops. The range included seven dual wave models and a seven valve radiogram. The Twilight tuning dial was a feature of all models. The Model 6713 included in the range was a seven valve battery-powered receiver provided with a Philips type 148 power unit. It was designed to provide 140–150 volts DC from a 6 volt accumulator. The unit was housed in a rubber mounted sheet steel case. The vibrator was a non-synchronous type with rectification being provided by a Philips KDD1 Class B operating as a full wave rectifier.

The series also featured Audioscopic reproduction, resulting from special audio channel arrangements.

At that time, Chief Designing Engineer was Eric Moore who joined Philips in 1936 after holding a similar position with Stromberg-Carlson (A/Asia) Ltd.

After many years of planning by the company, valve manufacturing began in March 1937 at a factory at Camperdown, Sydney giving Australia two factories engaged in the production of radio valves.

In 1937, Charles Tyrell who was Technical Superintendent, Radio Division, became the Radioplayer Factory Manager. After a period of two years in charge of factory operations and management he was appointed Manager, Service Division. Before joining Philips in 1930, Charles had been Service Manager of Harringtons Ltd 1926 to 1927, and Service Manager, Australian General Electric Co., 1927 to 1930.

One employee who joined Philips in 1937 was Charles Tapp. He had been with the Coast Radio Station service for some 10 years in charge of installation and operational activities and then transferred to Amalgamated Wireless (A/Asia) Ltd where he worked for about 11 years on broadcast receiver development and technical research projects before transferring to the patent field. He later became head of the AWA Patent Department. He made a number of visits to Europe and USA in the mid 1920s to study developments in Radio Technology. By 1939, he was Secretary of Philips Lamps (A/Asia) Pty Ltd and Philips Radio Works (Aust) Pty Ltd and in charge of the Patents and Legal Department of Philips Lamps (A/Asia) Pty Ltd.

Another employee who joined the company in the same year was Sam Rubenstein who was appointed Assistant to the Manager, Communications Department after coming to Australia from New Zealand where he had been associated with broadcasting for many years after joining the New Zealand Post and Telegraph Department Engineering Division as Cadet Engineer in 1923. At the time, broadcasting was being introduced, and the Post Office played a leading role in the preparation of specifications for imported receivers, and the design and development of studio and transmitting equipment. In 1935, he joined Radio Corporation of New Zealand, later becoming Chief Engineer.

Shortly after taking up a position with Philips in Sydney, he became Chief Engineer, Transmission Department.

During the years of the Second World War, Sam was seconded to Commonwealth Engineering Pty Ltd where he worked on contracts and training programs for the Services.

After the War he became assistant to Director of Engineering, F W Clark with Electronic Industries Ltd occupying senior positions until retirement in 1972.

Sam played a leading role in the activities of The Institution of Radio and Electronic Engineers Australia. He became a Member on taking up duty in Australia in 1937 and was associated with organisation for the World Radio Convention sponsored by The Institution of Radio Engineers (Australia) and held in Sydney during April 1938. In 1969, Sam was elevated to Fellow of The Institution and in 1977 was presented with the Award of Honour and the Long Service Award.

One of the noteworthy designs of radio receivers released by Philips during 1938 was Model 1362, a special Chairside cabinet designed to stand alongside an armchair or lounge couch. It was a six valve AC powered dual wave set employing an IF of 472.5 kHz. Another unusual feature of some 1938 designs was employed with Models 1044, 1046 and 1052. The chassis were in three sections disposed around the interior of the mantel cabinet.

By 1939 at the outbreak of the War, the company had diversified into a number of Radio Engineering activities particularly in supplying equipment developed mainly by the Philips Laboratories in Holland. These included:

- Transmitting, receiving, rectifying, repeater and grid controlled valves.
- Broadcast, aircraft, radiotelephone, marine transmitters.
- Components for transmitters, receivers, amplifiers, line communication and industrial equipment.
- Domestic, communications and aircraft receivers.
- Direction finding equipment, course beacons, marker beacons, landing beacons and other navigation equipment.
- Sound film theatre equipment, portable equipment, arc rectifiers and photo-electric cells.
- Philips-Miller recording system.
- Line communication equipment comprising carrier telephone systems, voice frequency telegraphs, loading coils, repeaters and echo suppressors.
- Test equipment, power factor capacitors, protective apparatus and welding equipment.

In 1939, Philips supplied the receiver requirements of Mullard (Aust) Pty Ltd. Except for a time during the War years, the arrangement continued until the 1960s when Philips wound down its receiver production facilities.

During the War years, several factories were engaged in Philips production activities — the main apparatus and valve works being in Sydney with another factory making sound equipment in Adelaide. Among other things, their valve producing factory undertook the job of developing and producing the first cathode ray tubes made in Australia.

During the early years of the War, Philips like many other manufacturers of domestic receivers produced some new models. Three new Radioplayers were released in early 1940 with plans on the drawing board to produce a series up to 14 models. The first release included:

- Model 2262, a six valve dual wave AC powered receiver in a polished veneer wooden mantel cabinet.
- Model 2740, a four valve dual wave battery-powered console.
- Model 2752, a five valve dual wave AC powered set in veneer wooden console.

Features of the 2752 included new audioscopic reproduction; negative feedback network; new high quality loudspeaker; low-volume tone compensation circuit; distortion free AVC circuit; negligible frequency drift on short waves; static reducing tone control; 'Qumulative' wound prematched coils; 'Legiline' dial incorporating window tuning and a special system of short wave station relocation.

Although the range was restricted, Philips produced domestic receivers throughout the War years except during 1944. Amenities receivers for the Services were also manufactured during the War and included dual wave and all wave models.

In 1942, ten models were released but in 1945 the number of models was restricted to three.

After the War, Philips moved a number of its activities to Hendon in Adelaide, in a former Munitions Factory, where they began production of picture tubes to meet demands on the introduction of television in Australia in 1956.

When domestic receiver production began after the War years, the first model off the production line was Model 3052A, a five valve AC powered dual wave mantel set. It was available just before Christmas 1945.

The following year, Model 100 was available in Radio Shops. It was a four valve MF band mantel set with in-built mains aerial and housed in a moulded cabinet available in colours of walnut, mahogany, ebony, ivory, apple green and ice blue. It was followed by Model 101, a five valve dual wave version.

In 1947, Model 3362, a six valve AC powered dual wave table receiver in moulded cabinet became available. It was fitted with line-of-light tuning and provided with an 8 inch (200 mm) loudspeaker.

In 1951, Philips introduced its Model 124 Jubilee Bandspread Special claimed to be the only five valve dual wave table radio in Australia at the time with electrical bandspread tuning with complete short wave band coverage. It employed multipurpose valves, four position tone control, in-built on/off switch, pick-up terminals, with the complete receiver being enclosed in a deluxe moulded cabinet.

Included among Philips receivers available in 1958 was the Super Quintet, a five valve mantel set with permeability tuning and available in colour combinations of coral, carmen, red, grey, primrose, charcoal and charcoal facia with opal white.

With the introduction of transistor technology in the early 1960s, Philips produced a range of models incorporating transistors. Two popular portable models released in 1964 were Model MT9 and Model PP2.

Hendon was also the centre for the manufacture of MF broadcast transmitters. Although most have now been taken out of service, station 4MI Mt Isa still had a pair of Philips 200 watt valve transmitters in service in 1993. The Miniwatt, Mullard and Elcoma components operations, known as Philips Components still had the design and production plant at Hendon in 1990, although headquarters were at Artarmon in NSW. The broadcast and professional TV instrument business was part of Philips Scientific and Industrial Pty Ltd in North Ryde, Sydney.

In 1970, Electronic Industries Ltd (EIL) became part of Philips Industries Holdings Ltd and some activities were transferred from Hendon to Clayton, a Melbourne suburb. The EIL takeover brought in extra broadcast expertise which was mainly based in Melbourne.

In 1939, EIL was one of the largest radio organisations in Australia, controlling Radio Corporation Pty Ltd, Eclipse Radio Pty Ltd, National Radio Pty Ltd and Homecrafts Pty Ltd.

At the start of the 1990 decade, the organisation was known as Philips Industries Holdings Ltd having been established in 1965 with subsidiaries including Eclipse Retail Rental Pty Ltd, Electronic Industries Ltd, Philips Components Pty Ltd, Philips Consumer Products Ltd, Philips Defence Systems Pty Ltd, Philips Investments Ltd, Philips Lighting Pty Ltd, Philips Scientific and Industrial Pty Ltd, Pye Industries Ltd, Pye Pty Ltd, United Customer Service Ltd. Trade names included Astor, Kriesler, Marantz, Philips and Pye. Philips Components Pty Ltd supplied a broad range of components to the broadcasting industry capacitors, inductors, resistors, IC's, printed circuit boards, transformers, teflon wire etc. Today, the company is known as Philips Electronics Australia Limited.

Many Engineers and senior Technical people have been associated with Philips activities over the years. A full listing is not possible but would include: B M Bartlett, W G Beard, Keith Blackwell, Francis Bollard, John Bourne, Harold Brown, John Briton, Evered Burnett, George Davidson, Alex Dening, Victor Dudman, D N Ferrie, W M (Chum) Ferris, R Fitzgerald, John Fletcher, Charles Fry, Clement Gee, W van Gelder, Karel van Gessel, Graham Gipps, Lance Graham, Tom Grierson, Bill Griffiths, Y B F J Groenveld, Bob Hill, Ken Horan, L Horvath, Geoffrey Hume, M J Kay, Bob Keukenmeester, P G Krastev, John

Lamplough, Graham MacDonald, John Masden, Gerry Mak, A J Marriage, Ken McIlvride, Hendrik Meyer, Eric Moore, Ian Muir, Keith Nicholls, Reeder Nicholls, Dr Angus Nicholson, Charles Norville, J A Overdiep, Philip Parker, Tom Pascoe, Louis Pogonowski, Albert Poll, E Roberts, Sam Rubenstein, B H Sheehan, W A Stewart, G J Stockdale, Charles Tapp, Donald Tonkin, Arthur Treglown, Charles Tyrrell, R N Wheaton, Ian Williams, Bert Wood, David Wyles, H H Wade, J A Walton, S W Wardle, J S Wilkins, G Williams, J Willis and others.

Harold Brown who became Technical Director of Philips Industries Pty Ltd in 1961 had wide experience in research and industry. He was educated at Sydney University and worked as Research Officer at Amalgamated Wireless (A/Asia) Ltd 1935–37 before transferring as Electrical Engineer with the Tasmanian Hydro Electric Commission for two years. During the War years 1939–45, he was Principal Scientific Officer in Radiophysics Laboratory of CSIRO. After the War, Harold became Superintendent Communications, Australian National Airways until 1947 when he became Professor Electrical Engineering NSW University of Technology until 1951. Subsequent appointments included Controller Weapons Research Establishment, Salisbury South Australia and Controller Research and Development, Department of Supply, Melbourne 1952–55.

Over the years, Philips made a considerable contribution to advancement of Broadcast Technology through its many publications mainly produced by the parent company. These included 'Philips Technical Communications' which was published over the period 1932 until about 1955; 'Philips Technical Review' a monthly magazine first published in 1936 and continued until about 1970 with a break during the War years and 'Philips Research Reports' published from 1945. A booklet, 'Radio Sir! 1930–31' published in 1931 was widely distributed throughout Australia and many can be seen today in radio literature collections.

RADIO CORPORATION PTY LTD

The giant Radio Corporation Pty Ltd, one of Australia's largest receiver and component manufacturers, began as a small retail store in Melbourne in 1922 under the business name of Louis Coen Wireless Co. (some early references give the name as Louis Cohen Wireless).

In February 1923, the business expanded when it was joined by Wireless Tasmania Pty Ltd which had been established by Arthur Warner in 1922. Directors of the new organisation were Messrs Louis Abrahams and Arthur Warner.

Louis Abrahams served with the AIF in France, and having witnessed the development of wireless and aviation for military purposes during his four years service in Europe, was keen to pursue a career in these fields after return to civilian life. He became Chief Executive of Louis Coen Wireless Co., the largest distributor of radio parts in Australia with a major branch in South Australia trading as Louis Coen Wireless (SA) Ltd with a wholesale outlet in Gay's Arcade and a retail outlet in Rundle Street, Adelaide. As part of his activities in aviation he won a number of trophies and during 1927–28 combined his aviation and radio interests by backing the Astor Radio Landing Ground Campaign whereby Astor receivers were flown into country areas of Victoria, the Riverina district in New South Wales and South Australia and demonstrated by the company Sales Manager to crowds of interested people. In later years, he became a Director of Neutrodyne Pty Ltd, Homecrafts Pty Ltd, Electronic Industries Ltd, National Radio Corporation, Eclipse Radio Pty Ltd as well as Radio Corporation Pty Ltd.

Arthur Warner who was born in England where his father had a radio business, A Warner and Sons, was employed as a Telephone Engineer with Western Electric and Siemens. After service in the First World War, he came to Australia and established his own business in 1922 before amalgamating with Louis Coen Wireless. In later years, when he was joint Managing Director of Radio Corporation Pty Ltd his father's business in England became the Australian Representative of Radio Corporation Pty Ltd in the United Kingdom.

Like Louis Abrahams, Arthur Warner later became Director of Neutrodyne Pty Ltd, Homecrafts Pty Ltd, Electronic Industries Ltd, National Radio Corporation, Eclipse Radio Pty Ltd, as well as Radio Corporation Pty Ltd.

Louis Coen Wireless located in Swanston Street, Melbourne was very successful and was the means of many people obtaining components and becoming interested in the rapidly developing science of radio which saw the establishment of the first broadcasting stations in Melbourne, 3AR and 3LO in 1924 followed by 3UZ in 1925.

The demand for radio components and fully assembled receivers was so great that a chain of stores was established in Melbourne and Adelaide. Company policy was 'Everything in Radio'. By 1927, the company was trading as Louis Coen Wireless Pty Ltd.

The Adelaide branch located in Rundle Street, was established in 1924 and had the largest stock of components and receivers in the State. At the Adelaide Radio and Electrical Exhibition held in 1925, equipment displayed by the firm included a seven valve Pinnacle superheterodyne receiver, a complete kit set for this receiver, and several other imported brands, together with a range of components including All-American, and Ormond variable capacitors; Sferavox speakers; Gordon folding loop aerial; Pinnacle coil holders; Na-Ald sockets and dials; Advance products; and Scientific, Brunet and N and K headphones.

One of the employees in the Adelaide branch was Cliff Moule who later joined the Postmaster General's Department and became associated with studios and transmitters of the National Broadcasting Service. Radio Corporation Pty Ltd was registered in Melbourne on 1 July 1923 and in 1926, three component manufacturers combined and produced Astor receivers under contract to Messrs Louis Coen Wireless. Works Manager was Ernest Austin who left the company in 1928 to form Essanay with Walter Sweeney to produce a range of broadcast receivers.

One of the best known receivers produced was the Astor Five. The company was so convinced that it was the best set on the market that dealers provided a written guarantee that the Astor Five would outperform any other receiver, regardless of price or number of valves. They also guaranteed that it would receive Interstate broadcasting stations at full loudspeaker strength in the city or the country, regardless of the proximity of local stations. It was a money back guarantee if the purchaser was not satisfied. The receiver was produced as a Jacobean console and table models. Other receivers the company produced in 1927, included eight valve console and table receivers with the superheterodyne circuit, console and table batteryless receivers, a self-contained portable model and a morocco bound crystal set.

A basic superheterodyne kit was also produced comprising three intermediate frequency transformers, oscillator coupler, filter and midget oscillator capacitor. The average home constructor did not usually possess facilities for making these critical components for the superheterodyne circuit receivers.

Louis Coen Wireless also imported overseas manufactured receivers. One of the models imported in 1927 was the Crosley Bandbox made in the United States. Crosley receivers and components were very popular in Australia even before 1927. Other importers had brought in the Crosley Harko Jr crystal set and the Crosley Harko Sr one valve receiver as early as 1922 and when the Crosley Pup became available in shops in 1926 it was a hit. There are many still in existence today in vintage wireless collections. It was contained in a four inch square metal box and used a 'book' type tuning capacitor invented by Crosley. It was a regenerative receiver and used a WD12 valve with 22½ volt B battery and 1½ volt dry cell.

An important activity of Radio Corporation was the manufacture of components under the ADVANCE label. The manufacture of ADVANCE products was originally started by Fred Clarke in 1922 and marketed by Clarke and Hagblom. Homecrafts was one of the major distributors. Components included two and three coil mountings with vernier movement fitted to the three coil unit; honeycomb, spider-web and basket-coil plugs; variable capacitors; Supreme audio frequency transformers; valve peep screens; rheostats and potentiometers.

In 1926, the Clarke business was acquired by Radio Corporation of Australia Pty Ltd who immediately expanded the product range. By 1927, the component range included lightning arresters, straight line frequency tuning capacitors, Centralab tuning capacitors, dual and three ganged straight line frequency capacitors, midget capacitors, receiver dials, rheostats including shielded types, potentiometers, porcelain UX sockets, Junior and Senior Neutrodyne kits, Browning-Drake kits, Masterdyne kits, Equamatic kits, shielded audio frequency transformers and many others.

After he sold his business, Fred Clarke joined Tilbury and Lewis Pty Ltd in Richmond becoming a Director of the company and occupying the position of Manager of the Radio Parts Department initially and later, Manager Director of the company. The company manufactured radio receivers under the brand name Van Ruyten and a range of radio components. He remained with the company until 1933 and then left for a visit to USA to study the latest developments in Broadcasting Technology in that country. On his return in 1934, he took up a position as Managing Director of Continental Carbon Co., Pty Ltd manufacturers of electrolytic capacitors, auto radio suppressors and a range of resistors.

Neutrodyne circuits were widely employed with receivers in the early days of broadcasting and in 1928, Radio Corporation acquired an interest in patents owned by the Hazeltine Corporation of America and formed a company known as Neutrodyne Ltd. Many Astor models were manufactured incorporating Neutrodyne features.

Included in their 1928 range of Astor receivers, was the All Electric Five, a five valve set using the Neutrodyne circuit and mounted in a console with in-built Amplion speaker. It was also available as a table version with external speaker. This was the time when receivers powered entirely by the AC mains were about to swamp the market and so eliminate the battery problem that had plagued the listeners ever since the commencement of broadcasting. The in-built power supply system with its rectifying facility was one of the major advances in receiver technology of the period. Another Astor receiver on the market in 1928 was the Astor Porta, employing a Browning-Drake circuit and valve types 199, two A409 and a B406. A French manufactured Sferavox cone loudspeaker and a loop aerial were mounted in the lid. The receiver had been in production prior to 1928 under the brand name Pinnacle Porta.

Other receivers produced about the same time included a table Little Astor model. It was a battery-powered receiver employing regenerative circuit with valve types A425 and two A409.

The company later changed its name to Radio Corporation Ltd, and in 1930 purchased Louis Coen Wireless and its wholesale and components interests.

The wholesale and components interests were subsequently removed from the activities to allow the company to concentrate on the manufacture of receivers. In its factory in South Melbourne, it manufactured every component and part required for assembly of a complete receiver. The company's Radio and Mechanical Laboratories played a major role in development of new models.

The early 1930s saw a wide range of models produced including car radios; the first Astor superheterodyne circuit receiver comprising five valves; the Mickey Mouse model in 1933, originally as a transformerless design but redesigned using a power transformer and full wave rectifier system; and a series of receivers in 1932–33 advertised as Arabian Nights series with exotic names such as Sultan, Kismet, Aladdin, Pasha and others. These receivers had station callsigns printed on the dials, a novel feature at the time.

The Pasha was a nine valve superheterodyne receiver with a number of interesting features including automatic noise suppression when tuning between stations, automatic volume control, automatic tone compensation, dual dynamic differential response loudspeakers and shadowgraph visual tuning. The shadowgraph tuning device produced a rectangular shadow which was narrowest when the station signal was accurately tuned in.

Among the many models available in 1935 were the Models 110 and 170.

Model 110 with Magic Selectivity Control was a deluxe superheterodyne receiver employing multiple function valves providing equivalent of the seven valve performance. The console cabinet design provided an actual baffle area of about 3000 square inches (19500 sq cm) with a large inclined sounding board designed to direct overtones to listener ear level. Features included AVC, tone control, Aero dial with colour light for accurate tuning and a 10 inch (250 mm) Jensen loudspeaker. The veneer cabinet had butt maple panels and contrasting ebony side pilasters.

Model 170 was a seven valve dual wave superheterodyne receiver with short wave tuning being facilitated by a S-L-O-W 70/1 vernier two-speed selector. Features included AVC, tone control and static suppressor. Baffle arrangement was similar to Model 110. The console cabinet was built on curved classical lines featuring rare burl maple, ebony pilasters and figured ribbon maple grille.

The five valve Model 80 one of the first of the 1935 releases incorporated a novel cabinet design marketed as a 'high fidelity cabinet'. Features included artistic openings in the sides designed to improve acoustical properties and eliminate directional effects, an angle mounted baffle installed so that the sound waves were directed at ear level to a listener sitting in a chair, and the provision of a dust-proof cover employing extremely fine silk cloth fitted across the entire back of the cabinet to prevent dust infiltration yet not interfering with normal air circulation or sound exit from the back of the loudspeaker.

By 1937, the company employed a staff of over 400 with the Works floor area being some 4300 square metres. Receivers introduced during the period included such improvements as automatic two-speed tuning, automatic tone compensation and magnified focussed tuning, in addition to a number of refinements in cabinet designs and acoustical properties. The designs included what was called a 'Nerve Box' claimed to be a revolutionary change in chassis design. The entire coil system was built into separate shielded compartments of a compact 'Nerve Box' ensuring complete freedom from interference of other stations on nearby channels. At the time company Chief Engineer was R J Collins an Associate Member of the Institution of Radio Engineers (Australia). Engineers associated with Research and Design activities during the 1930s included John Salvado, G Ogle, D Hardidge and R Burke.

The company had a close liaison with the Hazeltine Electronics Corporation in the USA and local Engineers frequently visited the USA to study the latest developments in receiver technology and manufacturing techniques. In the mid 1930s, a Resident Engineer was maintained in the USA.

In 1938, a wide range of models were available for city and country listeners with consoles being in two formats. The Moderne console was a massively constructed cabinet of upright grand design while the Lowboy console conformed to the most advanced public requirements of the time. In price, a Moderne cabinet receiver was about £4 ($8) cheaper than a Lowboy cabinet receiver.

Receivers at the time included:

- Model 450, a 5 valve AC broadcast band superheterodyne receiver employing metal beam power output valve and focussed light tuning.
- Model 450 DW, a 5 valve receiver similar to Model 450 but incorporating short wave reception capability.
- Model 560 DW, a 6 valve superheterodyne dual wave receiver with seven tuned circuits and metal beam output valve producing 7 watts of audio power.

- Model 560 DW Universal, a 7 valve AC/DC superheterodyne receiver equipped with barretter tube for voltage fluctuation control.
- Model 770 DW, a 5 valve receiver powered from a 6 volt Vesta accumulator with current drain less than 1 ampere.
- Model 77, a five valve mantel receiver powered from a 6 volt Vesta accumulator featuring iron core coupling system and magnified tuning with automatic illumination. It was housed in a bakelite cabinet in black or walnut pattern.
- Mickey Mouse, a 5 valve AC mantel receiver featuring AVC, metal valves, iron core Ferrocart coils and illuminated station logged dial. It was housed in a bakelite cabinet in black or ivory colours or walnut pattern.
- Aladdin, a 5 valve dual wave mantel set featuring AVC, world-wide reception capability, iron core coupling system, special electrodynamic loudspeaker, four level tone selector and magnified tuning dial.
- Model 550, a 5 valve dual wave console made for the low price market featuring walnut veneered cabinet with contrasting chromium bars across the speaker grill, two-speed tuning, tone selector, AVC and iron core coupling.
- Car radios, available in single unit and two unit models suitable for installation in most popular American and English cars.

In 1939, the company became a Division of Electronic Industries Ltd with Arthur Warner as Managing Director and Chairman of EIL. Arthur Warner was knighted in 1956.

The company made a major contribution to the War effort by manufacturing such vital equipment as FM and AM communication receivers, aircraft transmitters and receivers, field transmitters and receivers, Naval communications equipment, radar equipment, raysonde meteorological equipment, piezo-electric crystals and vibrators.

One of the well-known communications receivers produced in large numbers during the War and used at RAAF air operational bases was designated the AR12 and widely employed in conjunction with the AT19 transmitter. A feature of the receiver was that it operated completely from dry cell batteries, the condition of which could be checked by a panel mounted meter. The receiver incorporated a crystal filter and a continuously variable selectivity control. Coverage was 150 kHz to 15 MHz. The receiver was one of the first employed by the RAAF which employed the then new 1.5 volt filament valves. Early advanced operational bases where the receiver was employed included Rabaul, Talagi, Vila and Noumea in 1941.

As part of its piezo-electric crystal manufacturing operations the company developed a quartz mine at Glen Innes in NSW to make Australia independent of overseas radio crystal supply.

Immediately after the War, the company quickly became involved in the manufacture of domestic receivers, car radios, phono-radios and electronic devices of all descriptions.

In 1951, Graham Arthur Warner joined the company staff occupying varying positions including Engineer; Factory Manager; General Manager and Chairman Electronic Industries Ltd, 1966–70. He left in 1970 to become Director South East Telecasters Ltd, South Australia. A graduate of Melbourne University, he obtained early experience as Engineer with Hazeltine Electronic Corporation USA 1948–49 and as Engineer with Pye Ltd England 1949–51. In 1956, he was elected Member of The Institution of Radio and Electronics Engineers, Australia. In 1959, he was Director Neutrodyne Pty Ltd.

By the late 1950s, production included a range of radio receivers, such as portables, radiograms, tablegrams, mantels and car models. However, competition was keen, particularly from Philips, AWA and STC and from the increasing number of imports. With the release of the Astor model BNQ receiver in 1956, the company invested heavily in a special advertising campaign claiming it to be the greatest advertising promotion ever given to a mantel receiver in Australia.

The company employed many technically qualified staff over the years. In the mid 1960s at the time when domestic receiver production was being scaled down, employees who were members of The Institution of Radio and Electronics Engineers Australia included Daniel Krotoszyuski, Ian McInnes and John Salvado.

In the 1960s, Electronic Industries was sold to the UK based Pye group and in the 1970s became part of the Philips organisation.

Prior to the acquisition, business directories listed Radio Corporation Pty Ltd as being Interstate representatives for Electronic Industries Ltd.

During the early 1970s, the manufacture and marketing of car radios was a major part of the company's radio business. Vic Humphrey who had previously been with EMI joined Electronic Industries Ltd as Assistant Manager, Car Radio Division. Vic was responsible for development of car installation kits and associated installation and maintenance literature.

RADIO FREQUENCY SYSTEMS PTY LTD

Radio Frequency Systems Pty Ltd located at Kilsyth, Victoria is a leading designer, manufacturer, supplier and installer for a range of radio frequency sub-systems for the broadcasting industry including aerials, amplifiers, repeaters, baluns, filters, multi-couplers, radio frequency transmission lines and switching and distribution networks.

As a member of the Radio Frequency Systems Group, a highly focused industry group with operations in UK, Italy, France, Germany, USA and Brazil, the Australian company has ongoing access to the latest Technological, Engineering and Systems developments in global communications.

In addition to involvement in broadcasting in Australia the Australian company has been associated with a number of major projects in South East Asia and has service and warehouse facilities in Singapore and Jakarta. In recognition of its contribution to exports RFS has been awarded a variety of Export Awards including AEEMA Australian Exporter of the Year.

RFS was formed by the merger of Antenna Engineering Australia located at Kilsyth with the Commercial Antenna Division of Hills Industries in 1986. AEA was owned by RFS Kabelmetal, manufacturer of Flexwell coaxial cables in Germany and afforded RFS membership of the worldwide RFS Group of companies.

Until March 1998, broadcasting aerials were manufactured at Lonsdale, Adelaide but from that time, the Division was consolidated with the Kilsyth Head Office.

Experience of the company dates back to the 1970s when high power broadcasting aerials were supplied to broadcasters in Australia, New Zealand and Indonesia.

After the completion of major projects associated with the Television Aggregation Program in Australia in 1991, RFS turned its attention to export markets, at the same time developing new products which would appeal to Asian markets. It now exports to virtually all Asian countries.

In 1977, RFS established a Division in USA to supply aerials to the American market. At the 1998 NAB Exhibition in Las Vegas, the company obtained high exposure for its product lines of panel aerials, feeder cables and high power combining systems.

With its team of highly experienced staff, RFS offers complete turnkey project service with specific resources and skills in key areas of installation, field supervision, commissioning, sub-system design, training and project management for all its TV, FM, AM and MMDS broadcasting products.

The following brief details of its FM radio broadcasting products illustrates the broad coverage, typical of products in other specialist areas:

- Band II Panel Arrays 904 Series.
  The panel comprises four dipoles in a square configuration mounted on a reflector screen. In this configuration, RH or LH circular polarisation is possible. The design utilises stainless steel radiators with galvanised screen. Both directional and

omnidirectional patterns are available as well as beam tilt and null fill to customer specification.

- Band II Arrays 903CP Series.
  The panel comprises two crossed dipoles mounted off a reflective screen. In this configuration, circular polarisation is possible. Dipoles are angled towards the screen reducing backlobes and making the panel ideal for three-sided towers or masts.
- FM Sidemount Antennas 828LP Series.
  The series are designed for FM broadcasting applications requiring circular/mixed polarisation and low wind load. It can be arranged up to six levels. The parallel feed system facilities the customisation of null fill and beam tilt to suit customer requirements.
- Low Power FM Yagi Antennas.
  These have been designed for applications requiring circular or elliptical polarisation and low wind load. It can be provided for any number of levels and designed for easy sidemounted installation.
- Sidemount FM Dipoles SL1-818 Series.
  The SL1 series is intended for low power applications up to 500 watt input power. They are constructed of corrosion resistant aluminium while the 818 Series are fabricated from stainless steel and can handle powers up to 20 kW input for multi-element arrays.
- Sidemount FM Antennas Series 760.
  These are horizontally polarised antennas designed for sidemounting to a tower leg or pole. Azimuthal radiation pattern is omnidirectional. Beam tilt and null fill features can be provided on customer request.
- Log-periodic Antennas LDPR FM Series.
  A wideband log-periodic antenna with VSWR of less than 1.3 and without lateral lobes and input power up to 600 watt capability. Can be employed for either horizontal or vertical polarisation mode. Also available as LPD FM Series with higher gain.
- Ground Plane Antennas GPLB FM Series.
  Intended for mounting on top of tower or mast and provides omnidirectional pattern with vertical polarisation.
- Sidemount FM Antenna 6800 Series.
  The Shively 6800 Series features sectionalised construction and can be supplied from single bay up to 16 bay. The 16 bay format provides 9.25 dB gain. Bays are constructed of copper and brass. Model 6814 is rated at 25 kW per bay, Model 6810 at 10 kW per bay and Model 6813 at 3 kW per bay.

A range of balanced FM combiners are available to suit many applications. The balanced or constant impedance bandpass design offers an expandable system built in modular form. A module consists of a balanced pair of bandpass filters, two 3 dB couplers and a balanced load complete with flexible feeder mounts.

Other products include Branch FM Combiners, FM Bandpass Filters, Directional 3 dB Couplers, Power Dividers, Rapid Release U Links, Rigid Line Components, Flexwell Air Dielectric Cables, Automatic Dehydrators, Pressurisation Equipment and Accessories.

In recent years, it has become practice for broadcasters to require FM broadcast aerials to carry more than one service. This is usually a straightforward exercise for a Design Engineer if the services share the same frequency band and have the same radiation pattern requirements.

In 1996, RFS was involved with projects at NTA transmitting station sites at Townsville and Albury for unusual dual-purpose aerial systems. The problems which needed resolution, and the innovative solutions are set out in a company paper of May 1997 by Robin Blair of the Technology Development Group titled 'Dual Purpose Transmitting Antennas'.

Managing Director of RFS is Chris Jaeger and as at mid 1998, Engineers included Robin Blair, Graham Broad, Norm Franke, Tony Magris, Martin O'Donahue, Janis Ozolins and Kevin Thompson.

RADIOKES PTY LTD

Following his discharge from the AIF after the First World War, Robert Keith Stokes became interested in the proposed establishment of broadcasting stations in Australia. In 1923, when the first two stations were being established in Sydney, he established Keith Stokes Pty Ltd, 27 King Street, Sydney with the aim of supplying top quality locally manufactured products to meet the expected high demand for construction of home receivers by manufacturers and the hobbyist. Using the words 'Radio' and 'Stokes' he gave the name 'Radiokes' to the components being manufactured. Later, 'Kit Sets' was added to the label.

By 1925, coils were being manufactured in large numbers for supply to Radio Shops and distributors. A Class stations were in operation in all capital cities, and B Class stations were on air at Sydney, Adelaide, Newcastle, Melbourne, Toowoomba and Bathurst, and there was strong demand from enthusiasts eager to build their own receivers. Coils being produced included honeycomb and duolateral types available as mounted or unmounted formats in sizes ranging from 19 turns to 250 turns. Where low capacity coils were required in the design, the diamond mesh 'Lo-Los' coils in sizes 10 to 75 turns were available. For receivers built for reception of long wave stations 2FC, 3LO and 6WF axial coils were manufactured. They ranged in size from 8 turns of 16 SWG wire to 30 turns of 18 SWG wire.

About that time, it became evident that greater floor space was necessary to accommodate more machinery and staff to expand the product range. The business was formed into The Metropolitan Electric Co., Ltd which later operated from Radiokes House, 120–130 Sussex Street, Sydney.

Shortly after formation of the new company, Keith Stokes entered into an arrangement with Nutron Manufacturing Co., of New Jersey USA for distribution of Nutron and Solodyne components. The centre piece of Nutron products at the time, was the Solodyne valve designed to operate without B batteries. In appearance, the valve resembled the UV201A but it had no terminal for the inner grid-lead. The grid-lead was brought out and connected directly to the valve metal base. To make electrical connection for the circuit, a metal socket was used. The circuit designed to employ the valve was known as the 'Solodyne circuit' with components including a vernier type low loss 23-plate variable capacitor, a 1:10 ratio transformer, a three circuit coupler with tapped secondary and aperiodic primary, and an adjustable grid-leak for regeneration control.

The Nutron TRF kit used in five valve Neutrodyne circuits was also well received by local constructors. The kit comprised three low loss capacitors, three laboratory tested RF transformers assembled ready for panel mounting and two mounted neutralising capacitors.

In 1927, Radiokes announced the availability of a range of Radiokes 'Super Tubes' including a type suitable for filament operation from AC mains supply. The name of the company which manufactured the valves with the Radiokes brand name is not known, but in view of the link with Nutron they may have been made by that company who had a valve manufacturing organisation.

In the same year products available in Radio Shops included a three circuit tuner designed for a reflex circuit and a line of RF chokes intended for use in a range of circuits such as Grimes Inverse Duplex, Solodyne, Browning-Drake, Neutrodyne and Special Circloid designs.

By 1929, the company was one of the leaders in the production of high quality RF components, with the Radiokes Bayer Coil Kit being one of the most popular with local receiver constructors including small manufacturers making receivers for sale. It consisted of an aerial coupler and an RF transformer with a rotor for the application of regeneration to the detector valve. A movable primary coil allowed variation of coupling between primary and secondary coils. The kit was specially suitable for receiver circuits such as the Bayer Four, Champion Bayer Six and the S625 Screen

Grid Four. Another popular kit was the Radiokes Marco Four, one of the Master Series designed for use with the Marcodyne receiver. The kit comprised three units — two of which were mechanically connected together by a bakelite framework. Coils were wound using silk covered wire on polished bakelite formers.

Two Marcodyne receivers were assembled by boys at Sacred Heart College in Adelaide from parts purchased from Newton McLaren Ltd, agents for Radiokes parts, and in an exhibition in Adelaide, the boys took out First and Second prizes in the Schoolboy Section. The College operated its own Amateur station, 5AQ.

Another product of the 1929 period, was the Radiokes Collapsible Cabinet. It was popular with set builders at the time. Advertising literature claimed that the cabinet was:

- Fireproof, because it was made of pressed heavy gauge steel. The chassis, also manufactured from pressed steel, was available drilled to accommodate one of the Radiokes Superheterodyne Kits, or as an undrilled version.
- Shockproof. The outer surface of the steel cabinet was covered with a thick layer of insulating material to prevent electric shock to the operator in the event of the chassis becoming 'live' due to a fault condition. The chassis and cabinet were wired to the set earth terminal by a thick strap.
- Interference proof. The earthed metal case provided effective shielding against unwanted pick-up of electrical interference signals.
- Finish. The cabinet was available in a range of two-tone bronze finishes.

During 1929, the company produced a publication 'Radiokes Booklet' which had much useful information for do-it-yourself set constructors. It was a valuable reference source for component availability and construction techniques.

The company so prided itself with the high quality of its components and kit sets that it offered a 'Perpetual Guarantee' claiming it to be Australia's only and worthwhile guarantee.

When facilities expanded to meet a growing demand for radio components, the company was reformed in 1930 and transferred to new premises at Tracey House, Cnr George and Cleveland Streets. The range of Radiokes was considerable and included RF, IF, oscillator and aerial coils; audio and power transformers; RF and power chokes; resistors; rheostats; potentiometers; voltage dividers; fixed and variable capacitors; vibrators and complete coil and receiver kits. Among its popular coil kit sets available were Reinartz tuner, Binocular, Neutrodyne, Browning-Drake, Circloid and Short Wave kits.

A feature of the factory was the range of complex machinery employed in the manufacture of Radiokes parts and components. Design of machinery, equipment and control of the technical department was the responsibility of Don Gow. Don had served with the Signal Corps of the AIF during the First World War and became associated with the commercial side of the radio industry immediately after discharge from the Service. He built up considerable experience in all branches of the industry including engineering and tool making, radio engineering design, factory layout and management as well as senior administration experience. He left the company during the mid 1930s to take up a position with Airzone as their Metropolitan Representative for Sydney.

The long line of automatic winding machines at Radiokes were designed and constructed on the premises, and handled all types of coils including early honeycomb, spider-web, axial, basket weave and the more recently developed solenoid, binocular, circloid, and others.

In mid 1930, staff working in the factory averaged 75.

In 1934, Radiokes marketed the Model 12.35A Dual Wave AC Kit and the Model 12.35B Dual Wave Battery Kit. They were complete receiver kits and included all components and parts including valves and a comprehensive wiring and assembly chart providing a wire-by-wire description for the assembly and wiring procedure.

The company Directors in 1934 were R K and G M Stokes and the business had distributors or agents in all capital cities for marketing radio accessories under the brand names Radiokes and Kit Sets. Sales Manager was Allan Parcell who had just joined the company.

Later in the year, the company introduced four specialised All-Wave Kit Sets. They were De Luxe International Super type 12/89; type 12/42; type 12/44; and type 12/44B, the latter being a battery-powered design.

The 12/89 featured an Hartley oscillator; two stages of IF amplification, AVC, diode detection and Class A push-pull output stage. Valves were either 6 volt or 2 volt series. Four wave bands covered the range 15 to 550 metres.

With the type 12/42 the Radiokes All-Wave Tuning Tank type 5/42 was followed by valve types 56, 57, 58 (two), 55 and 2A5 output plus 80 rectifier. There were eight tuned stages in all. Diode detection was obtained from the 55 type valve.

The type 12/44 used Radiokes 5/44 All-Wave Tuning Tank. It was basically a 4/5 superheterodyne design using valve types 2A7, 58, 2A6 and 2A5 output plus rectifier.

So great was the demand for the company products, particularly coil kit sets, that a branch was opened in Melbourne at 294 Little Collins Street. In 1929, the branch reported high demand, particularly for 'The Little Aristrocrat', a compact three circuit tuner; Standard and Master Browning-Drake Kit; and the Radiokes Peridyne Shielded Kit.

By 1934, Interstate distributors included A J Veal Pty Ltd and RE Trickey and Co., Melbourne; Newton McLaren Ltd, Adelaide; Carlyle and Co., Ltd, Perth; W and G Genders Pty Ltd, Hobart and Launceston; and E V Hudson Pty Ltd and Trackson Bros., Brisbane. There was also a representative in Wellington, New Zealand.

In the same year, the Metropolitan Electric Co., began Australian manufacture under licence of radio components of the major USA manufacturer Hammarlund Mfg Co.

By this time the company kit sets had become big business and sold in large quantities. The most popular were:

- The 1934 Standard Battery Superhet, 7 valve.
- The 1934 Standard AC Superhet, 8 valve.
- The International All-Wave Superhet, 7 valve.
- The Battery All-Wave Superhet, 6 valve.
- The Band-Pass 5 valve.
- The Moneysaver Superhet, 5 valve.
- The Moneysaver Battery Superhet, 5 valve.
- The Short Wave Converter, 4 valve.
- The Pentagrid Four Battery Superhet, 4 valve.
- The Radiokes Battery Receiver, 3 valve.
- The International All-Wave De Luxe Superhet, 9 valve.

The kit sets were supplied complete in every detail with the chassis being predrilled for mounting of components and included Royalty Licence Plates where appropriate.

About 1936, Radiokes Ltd took over the role of handling Radiokes label products.

Among the many employees at this time were Arthur Spring, Harold O'Shea, Max Laurey and Colin Sanderson. Harold O'Shea and Arthur Spring later left to work for Crown Radio who produced similar products.

By 1938, the Radiokes product range was extensive and included audio transformers, coil boxes, coils, coil kits, midget variable capacitors, dials, foundation kits, IF transformers, receiver kit sets, padder and trimmer capacitors, power chokes, power transformers, RF chokes, resistors, transposition blocks for aerial feeders, transposed aerial coupling transformers, vibrators, volume controls, voltage dividers, lightning arresters and others.

At least seven designs of AF transformers were available with application as A class single coupling transformer, A Class push-pull transformer, high impedance audio choke, B Class input transformer, Class AB transformer, A Class high fidelity transformer for AC receivers and B Class high fidelity for AC and Battery receivers.

The range of IF transformers was also extensive, and included T, ST Square, QS Square, QIC Iron Core, MIC Iron Core Midget, SIF Sirufer Core, AD Laboratory Intermediates and APV Variable Selectivity Air Dielectric types. The T, ST and QS types were available for 175 kHz IF working as well as 465 kHz, while all the others were available only for 465 kHz working. All the transformers were subjected to Q Meter tests and a guaranteed tolerance given on both capacity and inductance, and all were treated with a special impregnating process. The AD Laboratory Intermediates were a new release developed in the company laboratory. The coils were Litz wound on tubing, provided with iron cores and tuned with specially designed air dielectric capacitors. They provided very good selectivity and sensitivity, and held performance accurately through a wide range of temperature and humidity. They sold in large numbers to receiver manufacturers who did not make their own coil units.

In 1938, Keith Stokes purchased the sole selling rights of Radiokes products from Radiokes Pty Ltd with the company being controlled by Radio Supplies Pty Ltd, Wingello House, Angel Place, Sydney. Keith Stokes was Managing Director of the company.

About this time, RCS Radio Pty Ltd, another components manufacturer acquired the manufacturing plant and facilities of Radiokes and by arrangement, RCS manufactured Radiokes components for Keith Stokes on an OEM (Original Equipment Manufacturer) business basis.

RAYCOPHONE LTD

Raycophone Ltd, a major supplier of theatre sound systems and radio receivers was founded by Raymond Cottom Allsop, in Sydney in November 1929. The name Raycophone was derived partly from his names Raymond Cottom.

Ray Allsop had been involved in wireless experimental work as early as 1911, when only 13 years of age. At the time, there were only 26 licensed experimenters active in Australia. On 1913, he took up an Apprenticeship with the Maritime Wireless Company Ltd, Randwick, which manufactured equipment for the network of Coast Radio Stations installed around the Australian coastline. It was the only wireless manufacturing organisation in Australia where youths, with an interest in wireless, could obtain an Apprenticeship in the technology. Prior to the outbreak of the First World War, he operated wireless telegraphy experimental station with callsign XCA at his parents home in Baker Street, Randwick, not far from his place of employment.

During the War, he spent time as a Ship's Wireless Operator on a number of merchant marine ships, and also, in the Royal Australian Navy. After the War, he returned to the factory, but by this time, it had been taken over by the Navy. He continued working there as a Laboratory Assistant until the Navy ceased operations there and transferred the facility to the Department of Repatriation for training purposes.

Ray subsequently joined New System Telephones Pty Ltd which later produced NST and Hollingsworth broadcast receivers.

Following Government approval for the establishment of broadcasting stations in Australia, he became involved in the construction of 2SB (later 2BL) when it became the first station to go to air when transmissions commenced officially on 23 November 1923 following a period of test transmissions. He remained with the station until July 1929 being a key member in upgrading the transmitting and studio facilities over six years. At that stage, the Postmaster General's Department took control of the station as part of the Government's plan to establish the National Broadcasting Service. Although given the opportunity to transfer to the Department to continue working at the station, Ray chose to leave.

About this time, Ray was Associate Technical Editor of 'Wireless Weekly'. One of his well-known contributions was a series of articles on construction of short wave receivers and modifications to commercially available MF types to receive the short wave bands.

After leaving 2BL he set up the business Raycophone Ltd in a factory in Trafalgar Street, Annandale in June 1929.

It was an opportune time to start the business, as cinemas were in the process of converting from silent film technology to sound technology. Also, high tariff imposed by the Government on imported broadcast receivers made local manufacture an attractive proposition.

The fact that radio equipment in the form of electric phonograph pick-ups, photoelectric cells, powerful audio frequency amplifiers and large loudspeaker systems were employed for the theatre equipment, meant that the production of theatre sound systems and radio receivers was an easily co-ordinated factory operation. It also meant that a drop-off in one area of activity could keep factory operations going without reducing staff.

Within 15 months of setting up business, more than 100 theatres had been equipped with Raycophone sound systems. This was encouraging for future operations considering the large number of other firms active in promoting sound equipment produced in the USA. By early 1934, the number of installations passed the 200 mark, and by the end of 1937, more than 375 theatres in Australia and New Zealand had been equipped with Raycophone equipment.

Included among the first receivers produced by Raycophone was the AC5, an AC powered five valve receiver employed three Philips screen grid penthode valves and fitted with a Magnavox dynamic loudspeaker designed with a new X core. The set was available in highly polished veneer console. Distribution was in the hands of Harringtons Ltd, Radio, Cine and Photo Merchants who had been established for over 40 years. The first Raycophone receiver was released during July 1930.

Model 41E, a 4/5 valve table receiver was well received by the public. It sold in large numbers when released. It employed three screen valves type UY224, power amplifier UX245 and rectifier UX280.

In early 1932, the company released the Model 62E, a six valve receiver with Radiotron valves in a Beale designed and manufactured highly polished veneer wooden cabinet made of five-ply maple panels. It featured exclusive stereoscopic tone and screen grid power detector designed to operate with low distortion at high signal level. A battery-powered version Model 62B, was produced shortly after the 62E.

Models 42E and 52E were also part of the range of receivers available at the time. The 42E, a four valve set included a single RF stage utilising a variable mu screen grid valve and a screen grid linear power type detector allowing reaction to be obtained without any extra controls. Output valve was a Super Penthode Power type matched to a Magnavox dynamic loudspeaker. The 52E was a five valve receiver employing two RF stages.

The 1933 releases included:

- Model 263AE, a six valve superheterodyne receiver with visual tuning; bandpass stage; dual loudspeakers; illuminated drum dial calibrated in metres; pick-up facility; matched Radiotron valves comprising detector-oscillator 57; two stages of amplification with two 58's; diode detector, AVC and audio amplifier 55; penthode output 59, plus rectifier 280.
- Model 253AE, an AC powered five valve superheterodyne set in console and table cabinets, fitted with dual loudspeakers and valve types 57, 58, 57, 59 in line plus 280 rectifier.
- Model 243AE, an AC powered four valve superheterodyne receiver in console and mantel cabinets of veneer wood with piano finish.

Battery-powered versions were also available.

Later in the same year, Model 263AE was revamped and released as Model 63AE. It was claimed to be the first Australian made receiver to employ the latest American pentagrid converter. Valve types used were 2A7, pentagrid converter; 2B7, diode detector with audio amplifier; 2A5, indirectly heated output pentode; two 58 RF pentodes; and 280 rectifier. The circuit was basically RF stage ahead of the autodyne, a 175 kHz IF amplifier; a diode detector-audio amplifier resistance coupled to a pentode output valve.

The mantel Pee-Wee, a four valve superheterodyne set was released to the trade about September 1933 and proved very popular, particularly with listeners in metropolitan areas. Valve types were two 57's, 2A5 output and 280 full wave rectifier. It provided 3 watts into a 4 inch (100 mm) Rola electromagnetic loudspeaker.

The Raycophone Reflex5 Model 254PE produced just before the Christmas 1933 marketing season was claimed to be the first design of its type in Australia to be available to the public. Other manufacturers were also developing similar designs at the time. Valve types were 2A7, pentagrid converter; 58, 465 kHz IF amplifier; 2B7, duplex-diode-pentode, 2nd IF amplifier, diode detector, pentode audio amplifier; 2A5, power output pentode; and 280 rectifier. The design was available as consolette and table models.

During 1933, Noel Smith joined Raycophone and worked in the Laboratory on product development. After completing High School education at Maitland, Noel took up an appointment as Cadet Engineer in 1923 in the Locomotive Branch Testing Laboratory of the NSW Railways. Following granting of a Scholarship, he took leave from the Railways to attend University full-time and graduated in 1931 with Honours. On resuming with the Railways he was appointed Assistant Engineer. Noel left the Railways in 1933 to join Raycophone. He later moved to Breville Radio where he was Chief Engineer.

Among the many models released during 1934, were a large eight valve console with push-pull pentodes in the output stage, and two large dynamic loudspeakers; a Universal AC/DC powered model and table Model 154PE with reflex superheterodyne circuit. During this period, Design Engineer was Clarrie Healey.

In early 1935, Harringtons Ltd announced that it intended to cease business, so Raycophone formed Raycophone Sales Company at 62 Booth Street, Annandale to market its receivers initially throughout New South Wales. A large range of receivers was available powered from AC, AC/DC, batteries or generator sources. Sales Manager was Val Mackinney.

At the end of the year, the company decided to scale down receiver production but to continue with the talking picture equipment installation work.

The 1935 models being sold in Radio Shops included:

- Model 61GB, a six valve receiver powered by 6 volt battery or generator employing valve types 6D6, 6A7, 6D6, 75, 75 and 41 in line.
- Model 61AWB, a triple band console, powered by A, B, and C batteries.
- Model 57E, a five valve AC powered mantel receiver with valve types 6A7, 6D6, 6C6, 42 and 80. Features included 6 inch (150 mm) dynamic loudspeaker, pick-up socket; illuminated double calibrated Efco Aero dial; tone control; and static suppressor. The console was veneer wood with a piano finish.
- Model 61AW, a triple band set with coverage 15 to 600 metres and housed in mantel or console cabinets.
- Model 66E, a six valve receiver with valve types 6D6, 6A7, 6D6, 75 and 80 in line; Weston Visual Tuning Meter; two-speed illuminated Efco Aero dial; tone control and static suppressor.

A model which sold well in many Radio Shops during the 1935 Christmas period was Model 51DEZ, a five valve dual wave superheterodyne receiver employing valve types 6A7, 6D6, 75, 42 and 80 rectifier. Features included Aero dial; AVC; tone control; pick-up socket; and loudspeaker mounted at the top of the cabinet rather than in the usual bottom position. This was one of the last models produced before ceasing the manufacture of receivers.

During 1938 when the World Radio Convention was organised in Sydney by the Institute of Radio Engineers (Australia), Ray Allsop using Raycophone equipment gave a demonstration of stereoscopic sound in the Sydney Plaza Theatre. Almost 2000 delegates and guests heard for the first time in Australia, the electrical reproduction of an orchestra possessing effects in the aural field similar to stereoscopy in optics. The orchestra providing the program material was located at the Regent Theatre with the program begin fed over specially balanced Post Office cable circuits.

Included among staff who worked for the company are Kevin Borthwick, Keith Davison, Clarrie Healey, Fred Smith, C Youngsen, John Harrington, T R Bushby and others.

During the Second World War, Ray Allsop served in the Royal Australian Navy as a Commissioned Officer, and played a leading role in the development of Radar and Asdic equipment for employment by the Navy.

After the War, he campaigned for many years for the introduction of FM broadcasting in Australia but did not live to see it introduced. In 1971, he received the Order of the British Empire (OBE) for pioneering work and services to radio. Ray died in 1972.

RCS RADIO

Ronald Albert (Ron) Bell, founder of RCS Radio, Sydney, and a licensed Electrician began involvement in radio in 1919 when he joined United Distributors. He then moved through other organisations obtaining experience with the Stromberg-Carlson Laboratory and Airzone Receiver Testing Department.

In July 1932, he founded RCS Radio and began production of a range of high quality components at 12 City Road, Sydney. The letters RCS were derived from Radio Components, Sydney. Items included RCS sealed coil sets, Superheterodyne and TRF kits, short wave kits, RF chokes, voltage dividers, resistors, line filters, and components for short wave receivers. The company had distributors in all States to handle its products.

In order to meet demand for extra manufacturing and warehouse space, the business transferred to 21 Ivy Street, Darlington. By 1934, they produced 40 different coil designs.

A further change was made when the company relocated to temporary premises at 50 Glebe Road, Glebe after the Darlington factory was burnt to the ground during July 1938.

In 1939, the company introduced a range of coils and capacitors employing Trolitul insulation which had been developed in Germany for low loss radio frequency applications. The insulation was extensively used for coil formers, capacitor mounts, beads in coaxial cables and other parts were low loss was required. It was a hydro-carbon compound which melted at a fairly low temperature and could be easily moulded to any desired shape by the application of heat and pressure.

RCS coils and capacitors which employed Trolitul included:

- Tuning coils wound on, and supported by, a combined former and base producing coils of high efficiency.
- Broadcast coils comprising air core aerial coils, 460 kHz; air core RF coils, 460 kHz; air core oscillator coils; iron core aerial coils, 460 kHz; iron core RF coils, 460 kHz; iron core oscillator coils, 460 kHz; permeability tuned aerial coils, 460 kHz; permeability tuned oscillator coils, 460 kHz.
- Intermediate transformers comprising air core 1st, 460 kHz; air core 2nd, 460 kHz; iron core 1st, 460 kHz; iron core 2nd, 460 kHz.
- Beat frequency oscillator coil for 2JU Super Six receiver.
- Midget variable tuning capacitors in Star and MC midget range with 2 to 14 plate models.

In early 1942, the wide range of products still available for civilian use included RCS dials, audio transformers, and coil units. Dials comprised DA1 and DA2 single glass dual wave types, with the DA2 being designed for use with a Five Band Communications Coil Kit and H type capacitor. Type DA1 was a standard dual wave dial for use with RCS coils and F type capacitor. The DA5 dial was designed for use on the 1600 to 550 kHz and 13.7 to 40 metre bands with H type capacitor. All these series were edgelit and wedge driven. The audio transformers included TA1 audio choke in bakelite case, TM1 modulation transformer; TB4 single input A class in bakelite case; TB5 push-pull A Class in bakelite case; TB6 input B Class in bakelite case; TB36 B Class input high fidelity in steel case; and TB37 AB Class in bakelite case.

After the War, by which time the company had been established at 174 Canterbury Road, Canterbury, and was trading as RCS Radio Pty Ltd, production facilities were geared up to meet the peacetime needs of radio enthusiasts and industry.

By 1946, popular components included the DA7 dial; permeability tuned 460 and 175 kHz transformers with Trolitul base and special capacitor pockets; panel strips; Star and MC variable capacitors with Trolitul end plates, and filter chokes and audio transformers with Trolitul bobbins. The widespread employment of Trolitul by the company was a carryover from its wartime experience with this high class insulating material. They had specialised in providing Trolitul mouldings for components used with equipment for the Services. Installation of the injection moulding equipment had started during 1939.

Highlights of the product range during 1947 included the RCS Loop Aerial kit which was prematched and tracked as a unit at the factory using laboratory Q meters. The kit comprised a loop aerial coil, two premature intermediate frequency coils, one oscillator coil and a padder with Trolitul base.

By 1948, the factory was producing a great range of components including standard intermediate transformers, Magnasonic broadcast coils, standard superhet coils, TRF coils, loop aerial coils, short wave coils, RF chokes, dual wave kits, coil formers, dials, audio transforms, filter chokes, power transformers, speaker transformers, resistors, voltage dividers, potentiometers, rheostats, line and aerial filters, variable capacitors, Magnetite iron cores and many others.

During 1951, the company transferred operations to 651 Forest Road, Bexley and with the introduction of the transistor on the radio scene, began the production of components to meet the requirements of the new technology. The establishment of television also brought about the production of new components and kit sets. Typical of new components in the early 1950s included kit sets for a range of Transporta transistor portables, transistor coils and IF transformers, a range of printed circuit boards and TV receiver coil kits. RCS was the first commercial PCB company in Australia and in 1992 was the only organisation which had all the project PCB's described in popular technical magazines and would produce to any design on request.

A recent product of the company was the Super Ducky RF Preamplifier which provided typically, over 20 dB gain up to about 1000 MHz and at least 9 dB gain up to 2000 MHz. The preamplifier was designed on two PC boards to provide flexibility. Two boards could be fitted in a single case with aerial attached to the top and cables connected to the receiver and a 12 volt DC power supply or alternatively, the preamp section could be separated and fitted into a masthead box.

In 1994, RCS Radio Pty Ltd and its associated company RCS Design were still operational at the Forest Road address under Managing Director Bob Barnes. RCS Design provided a CAD service and PCB production.

SLADE'S RADIO PTY LTD

Slade's Radio Pty Ltd was founded by Charles William Slade at 61a Lang Street, Croydon, a Sydney suburb.

Charles Slade was born in England on 22 May 1893 and began his career in wireless in February 1909 when he joined the Royal Navy as a Wireless Boy. He served on various ships throughout the First World War and remained in the Navy until September 1922. At the time, he held the rank of Petty Officer Telegraphist. Part of his Naval service included a period in Australian waters on HMA Submarine J7.

He returned to Australia in 1924 in possession of an English PMG First Class Certificate in Wireless Telegraphy with plans to eventually start up business on his own account. With this in mind, he registered Slade's Radio on 20 May 1925, although there is some evidence that when he eventually commenced business he traded as Croydon Radio.

In 1925, he joined Wireless Newspapers Ltd as Technical Editor of 'Wireless Weekly' where he worked until 1928 and then transferred to become Radio and Technical Editor of the 'Daily Telegraph Radio Supplement'. In 1929, he left journalism and worked with Keogh Radio until 1930.

After the short period with Keogh Radio, he commenced his own business at his residential address during 1931, specialising in superheterodyne receivers and precision test equipment under the brand name Calstan. Company advertisements in the 1930s, indicated that the name was derived from CALibrated to STANdard.

In a 1934 issue of 'Australian Radio News', an advertisement announced the availability of a range of Slade-Paton test equipment, manufactured by Slade-Paton Radio and Test Equipment Manufacturers, Lang Street, Croydon. Instruments available included AC/DC Analyser and Valve Tester.

Paton Electrical Instrument Co., in Ashfield was another test instrument manufacturer in Sydney and it is understood that Slade and Paton entered into a partnership agreement. However, the venture lasted for less than two years after which the two organisations separated and again became competitors in the test instrument market.

In 1935, the company produced a new DC powered valve tester Model DC203 designed for testing all metal valve types available at the time. The unit operated from a 6 volt accumulator supply.

About the same time, a range of Slade Junior (Midget Series) Test Equipment was produced. The instruments were designed and manufactured in a compact and portable form for the Radio Serviceman. Each instrument was housed in a small leatherette covered carrying case. The range included Model AD101, AC/DC Multimeter; Model AD102, AC/DC Multimeter; Model D101, DC Multimeter; Model D102, DC Multimeter; Model A103, Output Meter; Model C601, Analyser Unit; Model B903, Ohm-meter and others.

During 1936–37, Charles Slade was a member of the Technical Committee of the Australian Radio Manufacturers Patents Association Ltd. The organisation was a co-operative association formed to protect members against patent attacks. Others on the Committee included Charles Norville (Chairman), Chief Engineer, Breville; W A Syme, Managing Director, WA Syme and Co.; N H Buchanan, Chief Engineer, Sterling Radio; John Briton, Chief Engineer, Briton Electrical and Radio Pty Ltd; H A Warby; and Allen Scott, Chief Engineer, Stromberg-Carlson (A/Asia) Ltd. President was Leslie Bean, Managing Director, Stromberg-Carlson (A/Asia) Ltd.

By 1937, the range of test equipment included set analysers, multimeters, signal generators, oscillators, output meters, volt-ohm meters, valve checkers, moving coil meters and others. The Set Analyser No. 385 was very popular with Radio Servicemen as it enabled point-to-point analysis of receivers without removing the chassis from the cabinet.

The company designer kept a close watch on overseas developments in test instrument technology and during overseas visits important data was collected to enable improvements to be made to locally produced models.

The company apparently supplied Calstan test equipment to distributors who rebadged them with their own brand names. As example, the Vealls Radio Catalogue 1938 advertised a range of test equipment bearing the names, Velco-Calstan Model 222 AC Valve Checker, Velco Model 222 Portable Valve Checker, Velco Model 222B Battery-Operated Valve Checker, Model AC223 Combined Tube Checker and Multimeter, Velco Model S133 DC Multimeter, Velco AD135 AC-DC Multimeter, Velco AD136 AC-DC Multimeter, Velco-Calstan All Wave Oscillator, Velco Model 305A Combined Oscillator and Output Meter and Velco-Calstan Set Analyser Models S431, 485 and 445.

In 1938, the company produced the Model 223 Multitester, a combined valve tester and multimeter which incorporated all the good features of earlier models such as the Model 203, plus new technology. It proved to be popular with small radio businesses and many can be seen today in private vintage radio collections. It could test every type of valve being used with Australian built radio receivers at the time and could measure a range of AC and DC voltages and currents, and resistances up to 5 megohms. A companion instrument designated Model 223A, was a dual operation design capable of working with either AC mains or a 6 volt accumulator. It was available with internal or external vibrator.

An upgraded oscillator was also added to the range of instruments. It was the Model 306 which replaced the Model 305 and was available in AC or DC powered versions. The 223 Multitester together with the 306 Oscillator provided a portable testing laboratory for the Radio Serviceman.

At the time of the outbreak of the Second World War in 1939, the company had a fair share of the test equipment market and was holding its own with sales of receivers it manufactured. In addition to receivers produced under the Calstan brand it produced unbranded models for sale by others. At one stage, it brought in chassis from some other manufacturers and rebadged them with its own brand name. Well-known distributors in all States and in New Zealand handled the company products.

Company Chief Radio Engineer was Arthur Ferguson and Chief Electrical Engineer was C Jones. Chief Electrical Engineer before Mr Jones was A Alldridge.

About 1933, Slade entered the domestic receiver manufacturing business with one of the first releases being assembly of a chassis to a 1933 Wireless Weekly circuit Standard Super-Het and fitted into a veneer wooden console cabinet. Distribution was arranged through some 17 Sydney Dealers.

By 1934, three popular models included:

- Model 24, a five valve battery-powered console receiver provided with heavy duty Eveready batteries, and employing valve types two 32s; 1A6; Mullard PM2DX; and Mullard PM22A. Loudspeaker was Amplion permag type.
- Model 25, a six valve battery-powered console receiver employing valve types two 32s; 1A6; Mullard PM2DX; Mullard PM2B's in push-pull output. A battery supply comprised 100 Ahr, 6 volt accumulator; and B battery comprised Eveready Superdyne type.
- Model 27, a seven valve receiver with push-pull output and provided with AVC.
- Model 71, an AC powered seven valve console receiver employing valve types 57; 58 (three); 2A6; 2A5 and 80 rectifier. Features included Slade All-Wave Kit; AVC; Efco Aero type dial; Yaxley wave change switch; 9:1 dial ratio; short wave trimmer; wave band coverage 13–35, 35–90, 90–200 and 200–500 metres.

The Slade All-Wave Kit was also sold to the public. It consisted of three air dielectric 465 kHz Intermediate's, wave change switches and coils all enclosed in an aluminium box supplied completely wired ready for use. A circuit diagram was provided with the kit.

By Christmas 1935, the range of receivers produced by Slade's Radio was labelled Calstan with the following being available:

- Model D5AV Special, a 4/5 dual wave superheterodyne receiver employing IF of 465 kHz and equipped with valve types AK2, frequency converter; AF3, IF amplifier; ABC1, demodulator, AVC rectifier and AF amplifier; AL2, output penthode and 1561 rectifier.
- Model D6B, a six valve superheterodyne set.
- Model D6A, a six valve AC powered dual wave receiver.
- Model D6S, same as D6A but fitted with auto noise suppression facility.

Battery-powered versions were also available in the range.

In mid 1938, the Calstan AT4 was released and promoted as a home 'second set'. It incorporated push-button station selection, AVC, reflex circuit and was housed in a compact mantel type cabinet.

The set had no tuning dial. Eight push-buttons were provided to enable the listener to instantaneously select any one of eight 'pre-tuned' stations. The pre-tuned circuits were of the capacitor trimmer types with air dielectric trimmers being used for adjustment of oscillator circuits and mica trimmers for aerial tuning circuits.

Valve types comprised 6A8G, frequency converter; 6D6, 458 kHz IF amplifier; EBL1 combined duo diode-output pentode which acted as detector, AVC rectifier and high gain output stage; and 80 rectifier. Loudspeaker was a 6 inch (300 mm) unit with field coil resistance of 2500 ohms.

In early 1940, the company announced that it had begun the production of two newly designed receivers under a Calstan national distribution scheme. Both receivers were in piano finished veneer wooden cabinets, with one being a table model and the other a console.

The console, designated Model 46, was a five valve AC powered dual wave receiver with a number of interesting features including, tuning by means of a fly wheel type medium-ratio control; a straight line dial of the curved top-front-edge type; band coverage 550–1600 kHz and 13.5 to 42 on short wave; independent scales for the two ranges, with illumination being controlled by the wave change switch; pick-up terminals for gramophone reproduction; negative feedback network; comprehensive power supply filter and decoupling system. Valve types employed were 6J8G, triode-heptode frequency converter; 6U7G, IF amplifier; 6B6G, detector, AVC rectifier and AF amplifier; 6V6G, beam output tetrode; and 5Y3G rectifier.

Calstan portable receivers available at the time included, Model B54P, a five valve MF band set; Model D54P, a five valve dual wave receiver; and B44P, a four valve MF band set.

Each portable was provided with tuned loop aerial and provision for external aerial; one PR8 and two PR45 batteries; Rola elliptical loudspeaker; and RF stage.

Charles Slade enlisted in the Royal Australian Navy during the Second World War and was stationed at Signal Hill, Garden Island, Sydney. The station was one of the earliest Naval Wireless Stations, having been provided with equipment manufactured by AWA as early as August 1914.

Charles returned to business after the War, and following a commercial arrangement, Zenith Radio Co., Pty Ltd marketed Calstan brand receivers. One of the earliest marketed under the new arrangement was Model 513P, a five valve AC powered dual wave set housed in a walnut veneer wooden console cabinet. It had a large flood-lit dial and was fitted with a Rola permag loudspeaker. It was released just before Christmas 1946.

In 1949, the Calstan Model 529 was a popular receiver with dual loudspeakers, 12 inch and 5 inch (30 cm and 15 cm); provision for record player; large flood-lit dial; and a streamlined veneer wooden console cabinet.

When experimental FM transmissions were being conducted by the PMG's Department in Sydney during 1947–61, the company produced receivers capable of FM reception. A notice at the factory in 1949 invited the public to witness demonstrations of frequency modulation reception and also microgroove recordings, using the company's newly developed equipment.

Model 106 was a combination nine valve receiver designed for both FM and AM dual wave reception. It was fitted with record changer facility. The set was housed in a highly polished veneer wooden cabinet and was claimed to be the first FM, AM Radiogram produced in Australia. A special dipole aerial was available for listeners who wished to take advantage of the experimental FM transmissions. Model 105 was a six valve FM tuner in a mantel bakelite cabinet. It was provided for those listeners who already possessed an AM band receiver but who wished to listen to FM broadcasting.

In 1953, a dual car/home radio was a popular model. It operated from 6 or 12 volts DC or 240 volt AC supplies. Sales literature claimed it could be changed from car to home use in less than 30 seconds.

In the same year, Model C50 radiogram was available through Zenith outlets. It was an eight valve receiver with dual wave reception capability; three-speed automatic record changer; 12 inch (30 cm) loudspeaker; push-pull output stage; in-built record compartment and piano finish veneer wooden cabinet.

Charles Slade died in early 1962, and the company ceased operation about that time.

STANDARD TELEPHONES AND CABLES (A/ASIA) LTD

Standard Telephones and Cables (A/Asia) Ltd, had its origins with the USA firm of Western Electric. Western Electric was a large firm manufacturing telecommunications equipment and was purchased by the American Bell Telephone Company in 1882.

In 1883, the company opened an office in Great Britain and when the British Broadcasting Company was established, Western Electric was in a strong position to provide broadcasting equipment including transmitters, studio equipment and home receivers, initially made in USA.

It later began manufacturing operations in England with one of its early products being a 500 watt transmitter built in its London laboratories in October 1922. The transmitter used with station 2WP was also equipped with a studio and included the WE double button microphone, the first microphone developed specifically for broadcasting purposes.

One of the WE employees who worked on the transmitter when it was transferred to Birmingham and later taken over by the BBC was F C McLean (later Sir Francis McLean), who came to Australia in 1974 to conduct an independent inquiry into FM broadcasting.

Western Electric also established offices in other countries including Australia, with an office being opened at Vickery's Chambers, Pitt Street, Sydney in 1895 in order to promote WE telephone apparatus to the Australian Colonies who were all developing telegraph and telephone services at the time. Mr S Kingsbury was in charge of the office. In 1903, Richard Hungerford arrived from London to take charge of the office.

In 1912, the branch became Western Electric Company (Australia) Ltd with Richard Hungerford as Managing Director.

By that stage, the company had moved business to Hoffnung's Chambers in Pitt Street, but with staff growth to 11 people, the premises became too small and operations were transferred to Hardt Building, Carrington Street.

During the years of the First World War, the company moved to Harvard House, Castlereagh Street where accommodation included a showroom on the ground floor where a range of electrical equipment was displayed. It included a 32 volt home lighting system, many of which were sold to country people.

In 1923, Harry Pearce who later became Publicity Manager of STC, organised a Radio Department leading to the importation of a range of Western Electric broadcasting equipment including program input equipment, valves, the WE microphone, home receivers and various components and radio accessories. Sales Manager was Mr L Clarke.

Richard Hungerford represented Western Electric at the Conference convened in Melbourne on 24 May 1923 by Postmaster General Gibson to discuss the establishment of a broadcasting service in Australia.

The first WE receivers sold in Australia when broadcasting commenced in 1923 were manufactured in England, and were the 'Sealed Set' types, in accordance with Government requirements at the time. These receivers employed the company developed WECO valve, a small peanut type which required only 0.85 to 1.1 volt for the filament and could operate with a single dry cell. The filament consisted of a ribbon of platinum alloy heavily coated with oxides to give high electron emission at low temperatures. It was available, following selection at the factory, in three categories of HF amplifier, LF amplifier and detector.

In a full page advertisement in a wireless magazine of the period, headed 'Wireless Days and Nights' with an artists painting showing a family sitting in a lounge room listening to a table model receiver with horn loudspeaker, the text stated 'Radio waves at lightning speed are passing over your home. You can call a halt to these invisible waves and listen to the messages they bear. Grand Opera, a Lecture, a Speech or the latest Market and Weather Report — all these and much more, if you have a Radio Set. To obtain the utmost in Radio Entertainment you need Western Electric Radio-phone. Full information and advice on the selection of equipment gladly given at a personal call or by post.' The address was given as 192–194 Castlereagh Street, Sydney and telephones as City 336, 356.

At the 1925 Royal Agricultural Society Easter Show in Sydney, Western Electric mounted one of the best displays of radio equipment in the new Hordern pavilion.

Items on display included:

- The 2001 Crystal Set built in a polished cedar case with space for a pair of headphones. The set was complemented with a separate two stage amplifier which allowed it to operate with a loudspeaker. Power for the valves was provided by two No 6 Columbia dry cells and a 45 volt Columbia high tension battery.
- The Weconomy Crystal and Two Valve Receiver, an integrated model employing honeycomb coils inductively coupled, with tuning being effected by means of two variable capacitors. The set was built in a neat polished mahogany case and provided loudspeaker strength for stations within 30 km. Like the 2001 with the separate crystal set and amplifier, the valves were powered by Columbia dry cells.
- The type S150 Two Valve Receiver with one radio frequency stage followed by detector. Two Weco valves were used with WE transformer and WE headphones. The receiver was built in a polished mahogany case and had an estimated reception range of 400 km.
- The Type S155 Four Valve Receiver with one radio frequency stage, a detector and two audio frequency stages designed for loudspeaker operation within 350 km of the transmitting station. It was equipped with Weco valves and a separate battery case for the dry cell batteries.
- The Five Valve Weconomy Loudspeaking Assembly, a more powerful version of the S155.
- The Type A131 Loudspeaker Assembly, another five valve receiver designed for low distortion operation with broadcasting stations within 500 km. Output power was sufficient to provide high quality reception for listeners in a small hall or large room.
- The Type A141, a four valve model, and the Type A142, a three valve set designed for listeners located in a city where a transmitter was located.
- To meet the needs of customers who preferred receivers in cabinets, a range of horizontal and vertical style cabinets were on display. The cabinets were of highly polished hardwoods and had a space for accommodation of batteries and in some cases, for a loudspeaker.
- The display included WE water cooled transmitting valves shown publicly for the first time in Australia. The valves were the WE220B, an amplifier with capacity of 10 kW continuous anode dissipation, and the WE222A, a water cooled diode designed for a rectifier system providing for 12 kV direct current. Other valves on display included types 211D rated output 50W, 205D rated output 5W and the 211D or peanut receiving valve.
- Other items displayed were WE audio transformers, lightning arresters, National Carbon Co., 'B' batteries fitted with Fahnestock clips, WE headphones, WE loudspeakers from the WE Baby to the big concert balanced armature model designed by WE to produce minimum distortion.

In 1925, the Western Electric Company in USA sold its International holdings. The outcome was that the British Western

Electric Co., became Standard Telephones and Cables Ltd. A similar change in identity occurred with the Australian and New Zealand branches. They became Standard Telephones and Cables (A/Asia) Ltd.

In December 1925, Standard Telephones and Cables (Australasia) Limited placed an advertisement in 'Wireless Weekly' under the heading 'CHANGE OF NAME'. It announced that the name Western Electric Company (Australia) Ltd had been changed to Standard Telephones and Cables (Australasia) Limited with business at 192–194 Castlereagh Street, Sydney. The statement stated:

> 'The address and telephone numbers remain unaltered. Standard Telephones and Cables (Australasia) Limited, will continue to act as Sole Australasian distributors for Western Electric products, including radio materials, domestic electrical appliances, telephones, wires, cables, and electrical accessories generally.
>
> The products offered, and the service rendered, will be of the same high standard as heretofore, and a continuance of the generous public support extended in the past to Western Electric (Australia) Ltd is confidently anticipated.'

Although the transmitters for the early A Class stations were provided by AWA, much of the program input equipment and studio facilities were provided by STC. It was manufactured in the USA by the Western Electric Company.

The local company received its first orders for transmitters in 1926. They were manufactured in the company London works and installed in New Zealand the following year.

In 1926, Stuart (Sandy) McPhee an Engineer of worldwide experience in telecommunications came to Sydney to expand the local manufacturing facilities. Although he had worked as a telecommunications expert in many countries of the world, he was born and educated in Melbourne. Sandy acquired factory space in Myrtle House, Chippendale and equipped it with all necessary facilities for manufacture of telephones to satisfy a contract with the PMG's Department. He later became a company Director and Works Manager.

With the establishment of the National Broadcasting Service in 1929 and the desire of the Australian Government to expand broadcasting to major country centres, STC played a major role in providing the equipment.

Station 2NC Newcastle was the first station commissioned employing STC equipment. It went to air in 1930 followed by a similar 2 kW station at 4RK Rockhampton in 1931. In 1931, 2CO Corowa began transmission with a 7 kW transmitter followed by 5CK Crystal Brook, also a 7 kW transmitter.

Other stations equipped with STC transmitters included 7NT, 2NR, 4QN, 3GI in the mid 1930s; and 6GF, 6WF, 3WV, 2CR, 2FC, 3LO, 3AR and 4QS in the late 1930s. These were transmitters with 10 kW output capability, and during the same period, the company provided transmitters of lower output power to a number of Commercial stations.

In 1924, WE had a staff of only about a dozen but by 1926 when the company became STC, additional staff were employed to fulfil Contract orders for telephone equipment for the PMG's Department and in order to build up a skilled workforce for later planned manufacture of broadcast transmitters and radio receivers. By 1927, staff had trebled and it became necessary to appoint an experienced Engineer to handle production activities. Mr R S Beckwith of the London office was appointed Chief Engineer and took up duty in June 1927.

Following a decision made to begin local manufacture of domestic radio receivers, in 1929 the company began design of production line facilities to cater for fully Australian designed and constructed models.

At the 1930 Radio and Electrical Exhibition in Sydney in March of that year, the company exhibited a range of STC brand receivers together with a display of automatic telephones and high power audio amplifier equipment. During 1930–31 the range of receivers included:

- Supersonic Nine, based on a UK WE design produced in 1926. It was a battery-powered superheterodyne model with an IF of 45 kHz and provided with a 24 inch WE Electric Kone loudspeaker. It was designed for the country listener and featured miniature valves known as 'peanuts'. The valve had been designed by the USA Western Electric company just after the First World War with production commencing there with the advent of broadcasting in the early 1920s. The valve was designed for operation from a single dry cell and used an oxide coated filament requiring a power of 1.0 volt at 0.25 ampere. In the USA the valve was designated type 215A but those manufactured in England by the company were designated as 4215A. For many years it was the smallest valve used for broadcasting purposes and was still available into the late 1930s.
- Electric Three, designed for local station reception employing three valves plus rectifier for AC powered models. It was designed with neutralised RF stage; Mullard power detector; output penthode feeding a built-in Australian made Magnavox loudspeaker; illuminated single dial control; and aerial trimmer. It was available in mantel or consolette cabinets.
- Model 400, a four valve mantel receiver featuring screen grid power detector; penthode output; pick-up facility; dynamic loudspeaker; and built-in power pack.
- Model 402, a four valve receiver in console cabinet with lift-up lid and finished in two tone walnut veneer. Features included screen grid power detection; penthode output; built-in power pack; pick-up facility and dynamic loudspeaker.

AC powered receivers employed electrodynamic moving coil loudspeakers but battery-powered models were equipped with balanced armature loudspeakers.

When 4RK Rockhampton was commissioned in July 1931 using an STC designed and supplied transmitter, the Postmaster General's Department which carried out the installation, ordered two STC Triple-Triple Electric Four receivers for use as program monitoring sets for the station. They were supplied by Queensland distributors for STC receivers, Edgar V Hudson, Brisbane. The receiver consisted of three screen grid valves and three tuned RF stages and a super pentode as power output stage. The console was panelled in beautifully figured burr walnut and finished in high gloss duco. It had a lift-up lid fitted with an automatic stop mechanism. The same cabinet design was used to house the Model 302 receiver which was a three valve version of the Triple-Triple Electric Four or Model 402 as it was catalogued.

At the 1932 Sydney Show, STC exhibited a selection of receivers including models incorporating variable mu and pentode valves; electrolytic capacitors; power pack with transformers wound with double cotton covered copper wire; silent tuning system; and deluxe cabinets. The double cotton covered wire used in the power transformers was an attempt to overcome the problem of high failure rate in AC powered receivers where the transformer was a major problem. The unique silent tuning system created a lot of interest with Show visitors. By simply pressing a button, the dial pointer could be swung past a powerful local station without any loudspeaker blast. In effect it acted like an automatic level control.

Just before Christmas 1932, Model 636DS was released. It was a seven valve receiver employing dual loudspeakers providing high fidelity reproduction. Early in the New Year, models released included: a five valve superheterodyne; a seven valve superheterodyne; an eight valve superheterodyne; a bandpass four and others. Cabinet types included types No. 7 and No. 8. The No. 7 was panelled in highly figured veneers with a cedar inset panel affording a pleasing contrast and finished in full piano lustre. It was used in housing the bandpass four, five valve and seven valve superheterodyne receivers. The No. 8 cabinet featured figured and selected walnut and maple veneers. Five and seven valve receivers were used with this cabinet.

All the 1933 superheterodyne receivers were equipped with Raytheon 6 pin valves.

In December 1935, a new design employing Raytheon all-metal valves was released. It was a six valve receiver with features including dual wave capability; AVC; variable sensitivity control; short wave band covered 15–80 metres; simplified system of short wave tuning; spotline tuning; cabinet design incorporated a sloping panel.

Because of increasing demands on the manufacturing and assembly areas, mainly as a result of the production of transmitters for the rapidly expanding National Broadcasting Service, work started in 1936 on the construction of a large factory at 258 Botany Road, Alexandria. The number of Commercial stations was also rapidly rising, and so was the demand for domestic receivers. By mid 1936, there were nearly 90 broadcasting stations on air.

A feature of the new factory which became operational in November 1936, was the well-equipped machinery areas. Equipment included metal cutting equipment; machines for drilling, tapping, broaching and gear cutting; automatic lathes; power presses; and coil winding machines.

Senior company staff at the time comprised Managing Director, Harold Trenman; Director and Commercial Manager, J Clarke; Technical Director, R A Beckwith; Director and Telephone Manager, A H Cameron; Director and Transmission Manager, Tim Bore; Director and Works Manager, Stuart McPhee; Manager, Radio Receiver Division, Jasper Coote; Radio Receiver Designs Engineer, Tom Court; Advertising Manager, Harry Pearce.

The range of about 20 receivers available during 1936 included Model 514, a five valve mantel receiver employing glass envelope valves; Model 511, a five valve console receiver employing glass envelope valves; Model 580, a five valve console set equipped with metal valves; Model 530, a five valve dual wave receiver equipped with metal valves; Model 613, a six valve console receiver with metal valves; Model 623, a six valve dual wave console set with metal valves; Model 510B, a five valve battery console receiver; Model 520B a five valve dual wave battery-powered receiver; Model 677B, a six valve battery-powered model; and Model 780B, a seven valve battery-powered dual wave set. Models 613, 680B and 686B were fitted with Westector copper oxide rectifier as detector and AVC rectifier.

At least 33 models were available in the 1937 range and included:

- Model 5017B, a five valve MF band mantel receiver with 6 inch (150 mm) STC dynamic loudspeaker. Chromium bands were fixed across the loudspeaker grill.
- Model 5018F, a six valve World Range console receiver with 8 inch (200 mm) STC loudspeaker. A five valve MF band version, Model 5019F was also available. Model 5018G incorporated a dual loudspeaker system.
- Model 5017A, a five valve MF band set with 6 inch (150 mm) STC loudspeaker placed in the corner of the mantel type cabinet.
- Model 5028H, a five valve lowboy model with 6 inch (150 mm) STC loudspeaker.
- Model 5026D, an eight valve World Range receiver in lowboy type cabinet. Features included Magic Tunagraph and station relocator; dial calibrated with three wave bands; two 6A3 valves in push-pull providing 12 watts undistorted output; high fidelity AF amplifier circuit covering range 35–10000 Hz; AVC; metal dust core coils; 12 inch (30 cm) STC loudspeaker and full lustre piano finish cabinet.

With the availability of the 2 volt Eveready Air-Cell in 1937, six models were produced for operation with Air-Cells. They were Model 5020C, a five valve table receiver; model 5020E, a five valve console cabinet receiver; Model 5020F, a five valve console cabinet receiver; Model 5023C, a five valve dual wave table receiver; Model 5023E, a five valve dual wave console cabinet receiver and Model 5023F, a five valve dual wave console cabinet receiver.

By 1937, the floor space had expanded considerably, and by mid 1938, the company employed 700 people, the majority of whom were engaged in receiver production. At the time. some 35 models were leaving the production line, ranging from four to ten valve models and including mantel, console, combination and portable types. One of the consoles employed an eight button automatic station selector. Two 10 valve models were produced, with one being housed in a standard console and the other in a combination cabinet. Both employed 6A3 valves in push-pull in the output stage feeding a 12 inch (30 cm) loudspeaker. Two of the designs employed an IF of 175 kHz while all the others employed 450 kHz.

A feature of STC cabinets was the beautiful veneer patterns with a brilliant gloss piano finish. Many can be seen in vintage radio collections today. The company had a program of continual technical development and many designs were noted for high class performance, advanced design features and high reliability. British made Brimar valves were widely employed, but in 1939 STC commenced the manufacture of valves, initially for Post Office equipment, but later for broadcast receivers.

Two of the 1939 models, AT505 and AT529 incorporated eight station preselected push button tuning system. During the year, the standard IF was changed from 450 kHz to 455 kHz.

Two popular STC receivers sold in Radio Shops in 1940, were the portable model 511P, a five valve MF band receiver employing 1–PR8 and 2–PR45 batteries providing an operating time of 170 hours, and the AC broadcast mantel model 413X. The 413X was released just before Christmas 1940 and sold well. One Radio Shop in Adelaide sold seven during the week preceding Christmas Day. The receiver was a four valve type enclosed in a highly polished veneered wooden cabinet. Valve types included 6A8G, frequency converter; 6G8G, 455 kHz IF amplifier and detector; 6AG6G, steep slope output pentode and 5Z4G indirectly heated full wave rectifier. It included an RF type volume control and no AVC was employed. A 6.5 inch (162 mm) loudspeaker was employed.

During 1941, a wide range of models was released. Included were:

- Model H consolette available with chassis 413H, a four valve MF band receiver and chassis 512H, a five valve MF band receiver.
- Model G mantel available with chassis 554G, a five valve dual wave deluxe receiver.
- Model X mantel available with chassis 413X, a four valve MF band receiver; chassis 512X, a five valve MF band receiver; and chassis 548X, a five valve dual wave band receiver.
- Model 555F, a deluxe five valve console dual wave band receiver incorporating bandpass tuning, negative feedback, electron-ray tuning indicator and 12 inch (30 cm) loudspeaker.
- Model 513, a five valve AC powered MF band receiver; model 549, a five valve AC dual wave receiver and model 551, a five battery-operated dual wave receiver.
  All three models were housed in a new STC designed lowboy cabinet. Manufacture of all cabinets to cater for STC receivers was carried out on the premises by skilled staff under control of Oliver Hobson.
- Model 550P, employing five 1.4 volt filament valves. It was designed to provide dual wave coverage and featured a large vertical straight line dial with station calibrations. The cabinet was covered with 'hogskin' material.
- Model 557D, a five valve receiver covering the MF band and 13.5 to 125 metre short wave band. Valve types were 6J8G, 6G8G, 6J7G, 6V6G and 5Y3G. Features included split spectrum tuning dial; twin pointer dial system; bandspread tuning; tetraphonic amplification, a new system of audio reproduction; electronic eye tuning; visual indicators for volume control and wave changing; permeability IF tuning; beam power output; 12 inch (30 cm) electrodynamic loudspeaker.

The company planned to release a range of receiver models and by early 1942 seven models were on the market. In the production of the new range, certain materials such as bakelite and brass were not employed because of the urgent need of these materials for Defence purposes. The new models included:

- Model 410, a four valve mantel MF band receiver employing valve types 6A8G, 6G8G, 6V6G and 5Y3G. Receivers were housed in fabric covered cabinets.

- Model 430A, a four valve receiver with similar valve line up to Model 410 but fitted with a quasi-edgelit straight line multicoloured dial. It was housed in a figured walnut veneer cabinet with a piano finish.
- Model 558A, a five valve dual wave receiver fitted with valve types 6J8G, 6U6G, 6B8G and 5Y3G. The receiver used the Accentor tone control giving four tone positions of treble, normal, bass and extra bass.
- Model 515Y and 536Y, both five valve AC powered receivers housed in the same Y type console cabinet. The 515Y was capable of MF band reception while the 536Y was designed for dual wave reception. Both models featured high Q iron core aerial coil, permeability IF tuning, straight line tuning dial and 12 inch (30 cm) loudspeaker.

The dual wave model provided coverage of bands 13.5 to 43 metres as well as the MF band. It provided 3 watts output and featured the Accentor tone control which provided a method of controlling feedback with high and low frequency boost. Valve types were 6J8G, 6U6G, 6B8G, 6V6G and 5Y3G.

Production of STC receivers was resumed after the War with about 34 models being released in 1946. They included Models 557 and 557C, AC powered five valve triple wave band receiver in console cabinet.

Popular models which later followed included:

- Models 105T and 205T, popularly known as 'Model T', a five valve mantel receiver in plastic cabinet with walnut finish.
- Model Emperor, a five valve dual wave table set fitted with elliptical loudspeaker and pick-up facility. It was housed in a plastic cabinet.
- Model Bantam, a five valve receiver designed for country listeners and available in plastic cabinets of colours, walnut, ivory, green or pink. The moulded cabinets were produced on the premises.

The Bantam was later upgraded and released with a newly designed cabinet in colours of all white, all cream, grey and white and Chinese red and white.

In 1958, two popular STC radiograms employing Brimar valves were being sold in Radio Shops. They were:

- STC Surrey, an eight valve full fidelity dual wave radiogram. It included a 12 inch (30 cm) loudspeaker and three-speed record changer.
  The cabinet featured walnut veneer and contrasting blonde interior. A drop shelf door was a convenient shelf for stacking records.
- STC Model A6461, marketed as 'Windsor', a six valve four band AC operated console radiogram released in 1956. It featured automatic gain control; three-speed high fidelity mixer record changer; inverse feedback across two circuits; separate bass and treble tone controls; power switch in treble tone control; extended short wave scale divided into three bands; twin permag loudspeakers 12 inch (30 cm) for low frequencies and 5 inch (125 mm) for high frequencies. Valves comprised 6BA6, RF amplifier; 12AH8, converter; 6N8, IF amplifier, detector and AGC; 12AX7, audio amplifier and tone control; 6L6GA, power output beam tetrode; and 5Z4G, rectifier.
  The HF section covered a total frequency ratio nearly four to one with only one set of tuning coils but with fixed capacitors switched in series and/or parallel with each of the three sections of the variable tuning capacitor. Splitting the HF band into three separate sections facilitated tuning of the receiver. This tuning system was an STC Patent taken out in the name of Winston Muscio who was in charge of STC receiver design activities during the 1950s. In line with company policy, the cabinet for this radiogram was made on the premises by local staff. The cabinet was finished in Persian walnut veneer exterior and blonde interior.

With the introduction of the transistor, STC was amongst the early Australian companies to produce all solid state portable receivers. Many of the transistors were made in-house by the Components Division.

Manufacture of domestic receivers ceased in 1961 when STC decided to withdraw from the consumer products field.

One of the company staff who played a major role in STC receivers was Tom Court, Radio Receiver Design Engineer. Prior to joining STC in 1925, he had been involved in wireless experiments as early as 1910 and during the First World War served as a Ship's Wireless Operator in the Royal Australian Navy. In 1923, when the Government called a Conference in order to determine conditions for the introduction of broadcasting in Australia, he was a delegate at the Conference representing the Wireless Institute of Australia. During 1923–24, he was associated with the design of stations 3AR and 3UZ in Melbourne.

He joined STC in 1925, and when the company became involved with the manufacture of broadcast receivers, he was appointed to take charge of design aspects. He still occupied the position of Radio Receiver Design Engineer when the company diverted its activities to the manufacture of Service equipment at the outbreak of the Second World War.

At the World Radio Convention held in Sydney in 1938 under the auspices of the Institution of Radio Engineers (Australia), Tom presented a Paper on 'Precision Measurement of Small Inductances in Quantity Production' in which he pointed out that production of broadcast receivers in Australia was largely seasonal, involving manufacture at high pressure over limited periods requiring smoothness of production if demands are to be met when they occur. One of the critical aspects of receiver production was to produce components to close electrical and mechanical tolerances. The measurement of mechanical tolerances was straightforward, and could be easily carried out by unskilled staff. However, measurement of electrical tolerances in the production line was not an easy exercise. To overcome the problem of measuring small inductance tolerances with coils using unskilled labour at STC, a Comparative Inductance Bridge was developed. It employed Standard coils covering the full range of tuning coils to be measured. Tom Court's involvement in receiver design extended over more than 22 years and during this period he was assisted by many Engineers and Technicians. Some of these included Eddie Black (1929–33); Bill Joiner, Winston Muscio and Walter Forward (1934–40); Bill Joiner, Karl Auert (1941–49) and Cliff Jones (1950–51).

Tom was one of the early members of The Institution of Radio Engineers (Australia) being elected member of the IRE Council for 1934–35. During 1950–51, he served as President of The Institution.

When Tom retired, Winston Muscio became responsible for receiver design activities and during the period 1952–59 he was assisted by Engineers Bill Eason and Ian Stuart and Technicians Sid Maguire, Alan Richardson and others. The company ceased manufacture of Consumer Products in 1960.

During the War years, STC manufactured a wide range of transmitters and receivers for the Services. At the end of the War, employees numbered 2200 and factory floor space was at least 23000 square metres.

One of the major projects undertaken during the War years was a joint venture with AWA for the supply of high power Radio Australia transmitters for installation at Shepparton. Post War broadcast transmitters of the company have been detailed elsewhere.

The company had a record of producing reliable transmitters over a long period of time. From the mid 1930s, six generations of MF transmitters ranging in output powers from 50 watts to 55 kW were designed and manufactured in the Sydney works.

It was estimated that during the late 1950s, about 80% of the total power radiated by broadcasting transmitters in Australia came from STC manufactured transmitters.

The company also produced broadcast studio equipment in the form of control desks, amplifiers, metering panels, jackfields, high grade off-air monitoring receivers and racks and cabinets. Production of studio equipment ceased in the 1950s.

In addition to supplying broadcast transmitters to the Australian market, the company exported many MF and HF transmitters overseas. As part of Australia's Aid Program under the 1950 Colombo Plan, 2.5, 5.0 and 10.0 kW MF transmitters were exported to many countries including Thailand, Vietnam, Hong Kong, the Philippines, Borneo and others.

The 1960–70s was a busy period for the Radio Transmission Division at Liverpool. Exports included 50 kW and 100 kW transmitters to India, Spain and Mozambique and all solid state village broadcast transmitters to Pakistan. The company also supplied and installed 55 kW MF transmitters, aerial systems and power generating plants to Thailand and Vietnam. Company Engineer for the Vietnam project in 1965–66 was Rex Giles. The Thailand project also included the provision of studios at two centres.

Many of the company Engineers have left their mark in the advancement of Broadcast Engineering technology. One of the earliest in the transmitter field was Cecil (also known as Claude) McQuillan. He was an Honours graduate in Engineering Science from London University and also held a Diploma from the Imperial College, London. He joined Standard Telephones and Cables Ltd, London in 1923 and for five years was associated with research into Transatlantic radio telephony tests, the design and development of the 200 kW transmitter made by STC for the British Post Office Rugby station, and development of broadcast transmitters up to 50 kW output. From 1928 to 1930, he was Chief Engineer of the African Broadcasting Co., and installed and operated stations throughout South Africa.

He rejoined STC London and came to Australia to oversight a contract for the supply and installation of National stations 2NC Newcastle, 4RK Rockhampton, 2CO Corowa and 5CK Crystal Brook. The major components of the first transmitter were imported from the parent company in London, but all other equipment was manufactured locally in the Sydney works of the company. In 1933, he undertook an overseas tour including England and the Continent to study the latest developments in Broadcasting Technology and returned to Australia to oversight another contract for new Regional stations at 7NT Kelso, 4QN Townsville, 2NR Grafton, 3GI Sale, 6GF Kalgoorlie, 2CR Cumnock, 6WA Wagin and 3WV Horsham over the period 1935–37. At the time, he was STC's Chief Systems Radio Engineer.

During the period 1929–35, Claude was assisted in field installations by Jim Mallinson.

Over the years a great number of STC staff were associated with the expansion of the broadcasting industry. A complete listing would be difficult to compile but any listing would include:

David Abercrombie, Karl Auert, Brian Baber, Eddie Black, Tom Basnett, R S Beckwith, Arthur Bishop, Clive Bishop, Tony Brettingham-Moore, Ken Brown, Robert Brown, Gordon Cameron, Bill Carfax-Foster, Yee Chen, Stanley Conning, Jasper Coote, Tom Court, Brian Cox, Bill Eason, Walter Forward, J T R Freeman, Johannes Fieguth, Rex Giles, Dr Rudolph Guertler, Bill Kirby, David Hutchinson, Phil Humphries, Fred Hynes, Bill Joiner, Cliff Jones, Cecil Kearney, Alec Kennedy, Bob Long, Jim Mallinson, Bob MacCulloch, Sid Maguire, John Matthews, Don McPhail, Stuart McPhee, Claude McQuillan, Winston Muscio, Clive Pickup, Tom Prentice, Alec Ralph, Alan Richardson, Bill Roberts, Bill Robinson, E R Ruddell, Gordon Shaw, Ian Stuart, Lawrie Thomas, Keith Thow, Jack Tremlett, Jack Trivett, G Weeks, J Whelan, Wally Whitely, Bert Wood, P S Wooley and many others.

STC Engineers have played a major role in the operation of learned societies in Australia for many years, particularly from the Golden Years of Radio commencing in the 1930s when the company was a major participant in the broadcasting industry with the design and manufacture of domestic receivers and broadcast transmitters.

At the World Radio Convention in Sydney in 1938 sponsored by The Institution of Radio Engineers (Australia) during Australia's 150th Centenary celebrations, Tom Court was a Councillor of The Institution and Chairman of the Sydney Division. He delivered a paper at the Convention and Bert Wood read a paper on behalf of a distinguished French Engineer.

Over a period of some 30 years from 1937, it has been estimated that more than 50 STC Engineers presented technical papers at a meeting of The Institution of Radio and Electronics Engineers, Australia. Engineers have also served on Technical Committees of The Institution of Radio and Electronic Engineers (Australia) and The Institution of Engineers, Australia.

Senior company Engineers who served as President of The Institution of Radio Engineers (Australia) and its present body The Institution of Radio and Electronics Engineers, Australia include T P (Tom) Court (1950-51); H B (Bert) Wood, (1952–53); K S (Ken) Brown (1957–58); D J (David) Abercrombie (1958–59) and D J (David) Hutchinson (1972–73).

From the beginning, the company had a long tradition of appointing Chief Officers with an Engineering background. From the establishment of Western Electric Company (Australia) Ltd in 1912 Managing Directors comprised:

- 1912–32, R B (Richard) Hungerford.
- 1933–45, H C (Harold) Trenman.
- 1946–49, D (Daniel) McVey.
- 1949–61, T M (Tim) Bore.
- 1961–69, S O (Sam) Jones.
- 1969–85, A T (Allen) Deegan.
- 1985–94, G (Bill) Page-Hanify.
- 1995– R J (Ron) Spithill.

Tim Bore, Allen Deegan, Bill Page-Hanify and Ron Spithill were Australian company employees with an Engineering, Manufacturing, Marketing or General Management experience.

Harold Trenman had a distinguished career in England before coming to Australia in 1933 to take up the position of managing Director. He was educated at Manchester Technical College and qualified as Engineer through City and Guilds London. Harold worked with the British Post Office until 1906 and then transferred to Western Electric Co., Ltd where he was Superintendent Installations. When WE became Standard Telephones and Cables Ltd he remained with the organisation becoming Deputy Manager 1928–32 and was later appointed a Director.

Daniel McVey who succeeded Harold Trenman in 1946, was a former senior Commonwealth Public Servant. He qualified for entry to the PMG's Department Queensland as Cadet Engineer shortly after the start of the First World War but enlisted in the Army serving during 1915 to 1919. On discharge, he began his training as Cadet Engineer. After graduation, he advanced through various levels in the Department including positions as Metropolitan Lines Engineer, Brisbane; and Superintendent Mails, Sydney.

He left the Department to take up a position with the Public Service Board Canberra, later transferring to Supply and Development as Permanent Head.

In 1939, he succeeded Sir Harry Brown as Director General of Posts and Telegraphs. He left the Department in 1946 to accept the position of Managing Director with STC.

Tim Bore was a long-time employee having joined the company in 1923, the year that radio broadcasting began in Sydney. He played a major role in producing the large numbers of transmitters during the 1930s, including the joint AWA/STC project for the provision of two 100 kW transmitters for Radio Australia during the War years. At the time, he was a Director and Transmission Manager. When he retired in 1961, Tim Bore had given 38 years service to the company.

During the 1960s, the company's great program of expansion was being guided by Sam (later Sir Sam) Jones, one of the nation's foremost Telecommunications Engineers. He became Managing Director in 1969 on the retirement of Tim Bore.

Following graduation from the University of Melbourne, Sam began work with the PMG's Department Engineering Branch in 1927 working on many major projects in the transmission area. He was the Author of a series of articles on Transmission Practice published in the Telecommunications Journal of Australia including one article on radiation and reception of radio waves.

When the STC manufactured 2000 watt transmitter was being installed by STC Engineer Bert Wood at 6GF Kalgoorlie in 1936, Sam Jones was the Department's Acceptance Officer for the project.

At the outbreak of the War in 1939, he joined the Army as Lieutenant Colonel Commanding Divisional Signal Unit with the AIF Abroad until 1941 when he became Deputy Signal Officer-in-Chief Australian Home Forces until 1942 when he took up the position of Director, Radio and Signals Supplies, Ministry of Munitions until 1945.

After the War, he became Technical Manager, Philips Electric Industries Pty Ltd, occupying the position from 1945 until 1950, when he was appointed Technical Director. During the period 1956 to 1961, he was Chairman of the Telecommunications Co., of Australia Pty Ltd.

In 1961, he became Managing Director, Standard Telephones and Cables Pty Ltd a position he held until 1969. In 1968, he was appointed Chairman of STC and occupied this position until 1976.

Samuel Jones was knighted in 1966, and was a member of many important bodies and companies. He was a member of the Government's Electronics and Telecommunications Industry Advisory Committee, Australian Telecommunications Development Association, Australian Radio Technical Services and Patents Co., Pty Ltd and many others.

Sir Samuel was a Fellow of The Institution of Radio and Electronics Engineers, Australia and was given the honour of officially opening the IREE National Radio and Electronics Engineering Convention held in Sydney in 1976.

Allen Deegan AM succeeded Sir Samuel Jones who retired in 1969. At the time, the company had a workforce of over 3800. Allen joined the company in 1942 but took leave to serve with the RAAF during the Second World War.

When Allen took over as Managing Director, the company had reached an important milestone in its history. It celebrated its 75th Anniversary.

Because of the implementation of new policies by the Government of the day, particularly in the form of tariff cuts and revaluation of the Australian dollar, the company like many others in Australia went through a difficult period. Rationalisation of company structure and activities was necessary. The Components Division, Export Division and Radio Transmission Division were all closed. Nevertheless, the company overcame difficult problems by entering into new technological developments associated with telephone equipment. A new printed circuit board and assembly factory was opened in 1973 in Bowden Street, Alexandria with state-of-the-art manufacturing facilities. It became the centre for the manufacture of a range of new products.

Allen also involved the company in the established coaxial submarine cable technology requiring extensive changes to buildings at Liverpool.

In 1985, he relinquished his position of Managing Director to concentrate on his role as ITT senior officer for Australia and New Zealand and Chairman of the company.

Bill Page-Hanify who became Managing Director in 1985, had joined the company in 1960. Prior to joining the company, Bill worked with the PMG's Department Queensland as Engineer where he participated in the installation of the first ARF Crossbar Telephone Exchange in Australia at Toowoomba.

On joining STC, he initiated the Crossbar Engineering Group and during the mid 1960s, was engaged on the development of electronic switching systems. He was General Manager 1975–78, and Marketing Director 1977–85 before appointment as Managing Director. Bill retired on 31 December 1994 but remained as non-executive Chairman.

Ron Spithill became Managing Director in January 1995.

In January 1987, STC became part of Alcatel N V and changed its name to Alcatel-STC. Alcatel is an international corporation formed as a result of a joint venture between CGE of France and ITT of USA.

In May 1991, the company name was changed to Alcatel Australia Ltd.

In 1995, the company authorised the publication of a book to commemorate its centenary. Preparatory work for the book began in 1991 with an Editorial Group comprising Ray Howells, Donald McPhail, Winston Muscio and David Wilson. Author of the book which was titled 'CALLING THE WORLD — The First 100 Years of Alcatel Australia 1895–1995' was James Murray.

STROMBERG-CARLSON (AUSTRALASIA) PTY LTD

The company derived its name partly from the large USA company Stromberg-Carlson Telephone Manufacturing Co., located in Rochester, New York which had been involved in the manufacture of telephone equipment and apparatus prior to the turn of the century. The USA company entered the broadcasting field in 1923 with the manufacture of a five valve battery-operated receiver employing a Neutrodyne circuit and by 1930 was one of the major receiver manufacturers in the USA. The company had been established by Alfred Stromberg and Androv Carlson.

The Australian company Stromberg-Carlson (A/Asia) Pty Ltd was formed in 1927 with Leslie Percival Reed Bean as the Chief Officer, supported by a small staff.

Mr Bean commenced work with the Postmaster General's Department as an Engineer in 1904, and held various appointments in Melbourne, Perth and Sydney, rising to the position of Acting Deputy State Engineer in New South Wales in 1919. In the same year, he left the Department, and following a visit to Stromberg-Carlson in the USA, he founded L P R Bean and Co., Ltd representing Stromberg-Carlson in Australia.

There was a great demand by the Australian Post Office for supply of telephone equipment as the network was in need of considerable upgrading and expansion to meet post War demand for telephone facilities.

To meet the specific needs of the APO, Bean established a factory in 1923 in William Street, Sydney to produce equipment not available from Stromberg-Carlson in the USA.

About the same time, he joined a group of local radio equipment dealers and distributors to form a company for the purpose of constructing and operating a broadcasting station. A licence with callsign 2SB (later 2BL) was granted to establish the station. It was hoped that the venture would lead to increased sales of broadcast receivers and components marketed by the partners involved. He was Chairman of Directors of the company until the station was taken over in 1929 by the Government when it established the National Broadcasting Service.

The telephone equipment manufacturing operation was a successful part of the business and following a second visit to Stromberg-Carlson in USA by Leslie Bean, the original company L P R Bean and Co., Ltd was incorporated into a new company, Stromberg-Carlson (Australasia) Pty Ltd in 1927 in which the American company was a partner. Mr Bean was Chairman and Managing Director of the new company which employed a staff of about 50. The USA company subsequently relinquished its controlling interest in the Australian company but continued to provide technical back up and access to the large number of company telephone and radio patents.

When demand for radio receivers became great, following the establishment of broadcasting in Australia, the company began the design and manufacture of receivers to meet the demands of Australian listeners. The radio side of the business soon became the major part of the company operations. Factories were located at 76 William Street and 86 Crown Street, Sydney.

Initially, receivers were imported from the USA, but they were expensive and not popular with local buyers. The locally designed and produced models began to roll off the production line in 1928 using the brand name Treasure Chest. About 300 people were involved in the production of the receivers and manufacture of components including capacitors, transformers, power packs, chassis and later, loudspeakers.

The Treasure Chest receivers were one dial models housed in metal boxes and finished with two tone brown with gold highlights. Escutcheon plates were plated with an antique gold finish. Metal box receivers were being produced in great numbers at the time by a number of firms in USA due to reduced costs in producing metal box type cabinets compared with wooden types.

The Treasure Chest range included three valve regenerative battery-powered set; six valve battery-powered receiver with neutrodyne circuit; four valve AC powered receiver; and a seven valve AC powered set with a neutrodyne circuit. A four valve battery-powered portable was also available. The company marketed a beautiful wooden console cabinet with doors to accommodate any of the metal cased model chassis.

The company also produced the SC6 kit set based on the factory assembled six valve battery-powered model. The assembled kit set comprised three stages of tuned and neutralised RF amplification, a detector and two stages of transformer coupled AF amplification. All four tuning capacitors were ganged with a compensating device to ensure no loss in efficiency of the input stage for different aerial systems. Philips valves were employed and comprised A425 (three RF amplifiers); A415, detector; A415, AF amplifier; and A409, power output stage. Battery requirements were three 45 volt heavy duty B batteries, 4 volt accumulator A battery and three 4.5 volt C batteries.

The AC mains powered Treasure Chest models were fitted with Socket Power Units as standard units and following a demand for these units, the company decided to sell them to the public. The power equipment comprised three separate units designated No. 2906 'A' Socket Power Unit, No. 402 'B' Socket Power Unit and No. 301 Power Switching Relay. The 'A' Socket Power Unit was a Gould Unipower Unit constructed to Stromberg-Carlson specification to provide a reliable source of filament current from house lighting AC mains. The Stromberg-Carlson No. 402 'B' Socket Power Unit was used to replace the B batteries used for valve high tension. It provided outputs of 45, 90 and 135 volts using an RCA Rectron rectifier. The Stromberg-Carlson No. 301 Power Switching Relay was a bridging relay to provide a single switch control when socket power units were being used.

A wide range of receivers were produced during 1930–31 and included:

- Model 22X, a three valve AC powered regenerative receiver.
- Model 34, available as table, console and phono-radio combination.
- Model A44, available as table, console and phono-radio combination.
- Model A62X, available as table, console and phono-radio combination.
- Model A63, a six valve battery-powered receiver.

Features included special ripple filter unit; improved volume control; shielded transformers; 224 type valves in circuitry employing screen grid valves; Magnavox loudspeakers; high grade ripple finish both internally and externally.

By late 1931, a new range of TRF receivers were produced as the Classic Series with the majority being designed for AC operation. The company also produced Model 731, their first superheterodyne circuit receiver. It was one of the first on the market from a commercial manufacturer at the time. The following year, the TRF circuit was not produced. All models employed superheterodyne circuits.

The 1932 superheterodynes included Spenser 532, a five valve AC powered set; Spenser 632, a six valve AC powered receiver; Convertible 532; Convertible 632, a six valve AC powered set; Phono-radio combinations; Audiola 592, a five valve console receiver; and Audiola 492, a four valve mantel receiver. The Audiola 492 was one of the first receivers on the market employing a four valve superheterodyne circuit.

Stromberg-Carlson receivers were very popular with the buying public. Sales were 250% above the 1931 level. Many new technical features were incorporated in the receivers as a result of extensive development work in the well-equipped Laboratories. These included automatic volume control; production of automobile receivers; visual and silent tuning, and introduction of the muting system. The visual and silent tuning system enabled a station to be tuned-in without high noise level being produced between station carriers. When a visual tuning needle rose to maximum height position, the station carrier was correctly tuned-in. The muting system highly attenuated all background noise when tuning between receivable carriers.

The following year, 1933, also saw the release of many models with improved technical facilities. Models included:

- Audiola Model 693, a six valve superheterodyne set with AVC, visual and silent tuning, muting between stations, 8 inch (200 mm) dynamic loudspeaker.
- Model 633, a six valve AC powered superheterodyne receiver with newly designed drum dial, visual and silent tuning, muting system, and 8 inch (200 mm) dynamic loudspeaker.
- Model 403, a four valve battery-powered console receiver equipped with four 6.3 volt filament valves. A battery was an Exide 3XH7 accumulator.
- Model 734, a seven valve AC powered set featuring AVC, visual tuning, push-pull output stage, and 'focussed' reproduction. Valve types were 6A7 pentagrid converter; 78 (two) IF amplifiers; 85 demodulator and AVC feeding two 42 type valves transformer coupled in push-pull.
- Model 554, a five valve AC powered all wave receiver with valve types 6A7, pentagrid converter; 6F7, 1st IF amplifier and 1st audio amplifier; 6B7, 2nd IF amplifier, diode detector and AVC; 42 pentode output plus 80 rectifier. Although double purpose valves were employed, each set of elements performed a single function providing a set equivalent to a typical seven valve receiver.

By 1934, the company had a large network of distributors throughout Australia. They included Noyes Bros. (Sydney) Ltd, in Sydney, Newcastle and Lismore; Wagga Wireless Distributors, Wagga; M Brash and Co., Melbourne and Geelong; A L Veall and Co., Pty Ltd, Melbourne; Noyes Bros. (Sydney) Ltd, Brisbane; Lawrence and Hanson Electrical Co., Ltd, Brisbane; Findlays Pty Ltd, Hobart and Launceston; Wills and Co., Launceston; Findlay and Wills Pty Ltd, Devonport; Radio Wholesalers Ltd, Adelaide; Savery's Pianos Ltd, Adelaide and Musgroves Ltd, Perth.

Bill Smith who owned a Radio and Electrical business in Wallaroo in South Australia had the following receiver models in stock during 1933–34; Model 703, a seven valve battery-operated set; Model 504, a five valve battery-operated set; Model 734, a six valve plus rectifier all electric set; Model 54, a universal AC/DC four valve plus rectifier set; Model 534, an all electric four valve plus rectifier set, and Model 554, an all electric dual wave four valve plus rectifier set.

In 1935, his stock was supplemented with model 836, a great drawcard for country listeners remote from a transmitter. It was an AC/DC dual wave set with seven valves plus rectifier. Valves were all Philips types and included a current limited barretter. Mr Smith also stocked the Model 572 Roamer, one of the first car radios to be fitted to a car in his district.

In 1936, the company transferred activities to a new factory in Bourke Street, Alexandria. It was opened by Prime Minister Rt Hon. A Lyons in the presence of about 160 guests, most of whom were from the radio industry. In addition to receivers, an expanded range of components were manufactured with the installation of new machinery. The components were employed in company manufactured receivers and also sold to the public and other radio businesses.

One receiver produced in the new premises was the Model 737, one of the early receivers to employ an acoustical labyrinth loudspeaker system. The system was developed by Stromberg-Carlson, USA.

At the outbreak of the War in 1939, there were 20 models in production. They included the model 737 and models incorporating electrical 'flash tuning' and mechanical 'flash tuning'.

A range of about 17 models were produced during 1940–41 and included AC powered dual wave band mantel and console cabinet receivers, battery-powered receivers in mantel and console cabinets, a seven valve radiogram and a portable receiver.

During the War years the company produced a range of equipment and components for the Services including telephone switchboards, telephone equipment, Radar equipment, Fullerphones, Aldos lamps, and receivers. The receivers were of the 'amenities' type and were widely used throughout Australia and the Pacific war zones. The receiver covered two wave bands and had provision for connection of a pick-up and extension loudspeaker.

To cater for pressure in meeting the production requirements of the Services, the factory floor area was expanded and an igloo type structure added nearby.

The factory contained large workshop facilities and was basically self-contained. Facilities included a well-equipped tool shop, lathe shop, press shop, coil winding machines, plating baths, painting and lacquering booths and large assembly and test areas.

Although radio receiver production resumed after the War, competition was keen and the company like many others found it difficult to make a worthwhile profit. Production of radiograms and plastic mantel receivers were a major part of the production line work but other items were added to keep staff employed. These included electric motors, fans, radiators and radio components.

Radios produced during the 1950s included:

- Model 37A11, Music Clock three valve mantel receiver.
- Model 44B11, Vagabond portable, four valve receiver with valve types 1R5, 1T4, 1S5 and 3V4.
- Model 48A11, Baby Grand mantel four valve AC powered set with valve types 6BE6, 6BA6, 6BM8 and 6X4.
- Model 54A11, Air Queen Mark2, five valve mantel receiver with valve types 6BE6, 6BA6, 6AV6, 6AQ5 and 6X4.
- Model 54A12, Maestro, Melody Maker and Party goer five valve AC powered receiver with 5 inch (125 mm) permag loudspeaker for the Maestro Gram 8 inch (200 mm) loudspeaker for other models.
- Model 54A21, Sussex dual wave radiogram with five valves types 6AN7, 6N8, 6BD7, 6M5 and 6V4 rectifier.
- Model 55A11, Duophone five valve AC powered mantel set with valve types 6BE6, 6BA6, 6AV6, 6M5 and 6X4. Loudspeaker was Rola 5C model.
- Model 55A12, Clock Radio five valve AC powered mantel set.
- Model 55P11, Wayfarer portable five valve receiver employing battery pack type 753 and Magnavox 525 loudspeaker.
- Model 56A11, Brentwood, Modernaire five valve AC powered receiver with valve types 6BE6, 6BA6, 6AV6, 6M5 and 6X4 rectifier.
- Model 56A22, Imperial, Sussex Mark4 radiogram dual wave receiver with valve types 6BE6, 6BA6, 6AV6, 6M5 and 6X4 rectifier.
- Model 58A11, five valve TV radiogram New Yorker with valve types 6BE6, 6BA6, 6AV6, 6M5 and 6X4 rectifier.
- Model 64A31, Savory radiogram, six valve dual wave receiver with valve types 6AE8, 6N8, 12AX7, 6M5 and 5V4G rectifier.
- Model 65A21, Cadenza, six valve dual wave receiver with RF stage, push-pull output and employing valve types 6BA6, 6AN7, 6N8, 6BD7, 6M5 and 6V4 rectifier.
- Model 65A22, Hi Fi radiogram of six valves with valve types 6BA6, 6AN7, 6N8, 6BD7, 6M5 and 6V4 rectifier.
- Model 67A11, Sussex Mark5, six valve receiver with Rola 8M loudspeaker and valve types 6BE6, 6N8, 12AX7, 6AQ5 (push-pull) and 6V4 rectifier.
- Model 68A21, Cadenza, six valve receiver with push-pull output stage and dual loudspeakers provided as either 8M and 5FX or a pair of 6M types.
- Model 68A22, Hi Fi dual wave radiogram of six valve and push-pull output stage.
- Model 39S01/39S11, Chorale Radio-Stereogram of six valves comprising 6BE6, 6BA6, 12AU7, 6BM8 (two) and 6V4 rectifier.
- Model 19S01/39S01, Toorak TV Stereogram with valve types 6BE6, 6BA6, 6AV6 and 6X4 for Radio Tuner; 12AU7 for Stereo Control Unit and 6BM8 (two) and 6V4 for Stereo Amplifier.
- Model 39S01/39S11, Avalon Stereogram of six valves.
- Model 21S11/31S01, Maestro Stereo, Marlborough, Cheltenham 3 in 1, comprising valve types 6AN7, mixer; 6N8, IF, demodulator and AVC in Radio Stereo Control Unit and a pair of 6BM8 in Stereo Amplifier plus 6V4 rectifier.

A boost to activities came with the introduction of television but it did not last long. Sales fell rapidly, and the company had difficulty in keeping up with the rapidly changing technology in radio and TV receiver design and manufacture, and also in meeting its financial commitments.

After making a diversion into the manufacture of fully assembled electronic organs and kit sets, it ceased operation during 1961.

Radio receivers produced by Stromberg-Carlson (A/Asia) Pty Ltd over the years included Audiola, Stromberg-Carlson and Roamer brand names and a large number of unbranded models produced under contract for distribution by other businesses as well as badge names including Paling Victor and Crosley.

Many Engineers, Technicians and Administrators worked for the company at various stages of their careers. Up to the outbreak of the War, they included Eric Moore, Chief Engineer 1932–34; followed by Allen Scott, Chief Engineer from 1934; Norm Gilmour; Jack Smith; Fred Thom; John Paton; Benjamin Olney; R Barron; Arthur Bates; Arthur De Courcy-Browne; George Eglon; Allan Freedman; Arthur Everitt, Chief Tester; John Bond, Sales Engineer; H M Tyler; Fred Whitehouse; G Jenkins; Fred Hawkins; Doug Thwaites; Don Lindsay, Design Engineer, and others.

Eric Moore, who was company Chief Engineer 1932 to 1934, had a long association with Radio Engineering extending back to the pre-War wireless telegraphy era.

Following completion of education at Armidale College and Sydney High School, he began work with the Telefunken Company, who had the contract for construction of the first two Australian Coast Radio Stations. Eric worked on the construction of the Sydney station AAA from 1910 to 1911 and then transferred to the Postmaster General's Department, where he worked on the expanding telegraph and telephone networks until 1914.

Having become proficient in Morse Code, he went to sea in a merchant ship as Ship's Wireless Operator until 1916, making best use of free time for further studies in Electrical Engineering.

He undertook a Royal Naval Examination and, being successful, was appointed Lieutenant in Electrical Engineering in the Royal Naval Air Service.

With the establishment of broadcasting in Sydney in 1923, he took up a position of Manager of Radio Department of Farmer and Co., Ltd, who had the licence for operation of 2FC.

He worked with 2FC until 1926, and then went overseas to gain experience in the mass production of broadcast receivers. He took up a position in the USA with the Stromberg-Carlson organisation and remained there until 1932. Eric then returned to Australia to become Chief Engineer of Stromberg-Carlson (A/Asia) Ltd, where he remained until 1934. During this period he was also Chairman of the Standards Committee of the Institution of Radio Engineers (Australia), and Vice-President of the Society of Radio Technicians, Australia.

Eric Moore left the company in 1934 to set up practice as a Consulting Radio Engineer and in 1936 accepted a position with the Philips organisation as Chief Design Engineer.

A long-serving member of the staff was Herbert Murray Tyler, who joined Stromberg-Carlson in 1934. He was a graduate of the Sydney Technical College and had previously worked with O'Donnell Griffin, BGE and Anthony Hordern and Sons where he had for five years been in charge of the Radio Department's technical and service activities. On joining Stromberg-Carlson he was initially concerned with training, but later became Sales Engineer. At the time when he left the company in 1948, he occupied the position of Factory Manager. He then moved to EMI as Supply Manager for a period of 23 years before he retired.

George Eglon who was Factory Manager in 1939 when the company was preparing to change over from domestic receiver production to Services work, was educated at Leicester Technical School in England and joined L P R Bean and Co., in 1924. He was appointed Factory Manager of Stromberg-Carlson (A/Asia) Pty Ltd in 1931 and became a Director in 1935.

One of the company's prominent Sales Engineers in the mid 1930s was Arthur De Courcy-Browne who was member of the Sydney Division of The Institution of Radio Engineers (Australia) in 1937–38. He joined the radio industry in 1935 as Sales Engineer for Noyes Bros. (Sydney), Ltd who marketed Seyon brand receivers and a large range of components.

In 1937, he took up a position as Factory Representative and Sales Engineer for Stromberg-Carlson (A/Asia) Pty Ltd in Newcastle. In 1966–67, he was President of The Institution of Radio and Electronics Engineers, Australia at the time that Her Majesty the Queen granted the IREE a Royal Charter.

After the War years when the company became involved in the production of TV receivers, George Dale who had earlier worked with AWA was one of the senior Engineering staff associated with planning and assembly of facilities for mass production of receivers.

In the late 1950s, as the company was winding down its manufacturing operations, which were mainly in the radiogram and television receiver fields, it was managed by Allan Freedman who had joined Stromberg-Carlson as Sales Manager in 1929. He was a B Sc. graduate from Yale University in the USA. He had worked with the Pilot Radio and Tube Manufacturing Co., in the USA for five years before coming to Australia. The company was very active as a manufacturer of receivers from the early 1920s, and produced a series with the unusual brand names Universal Wasp, Super Wasp, Air Scout, Air Hound and others. Some of these were imported into Australia by Radio Shops including the Adelaide Radio Company in South Australia.

Chief Engineer of Stromberg-Carlson (A/Asia) Pty Ltd at the time was Allen Scott who had occupied the position since 1934. He later became Works Manager/Chief Engineer. He was a graduate of the Sydney Technical College where he obtained a Diploma in Electrical Engineering. Allen was a Member of The Institution of Radio Engineers (Australia) and a member of that organisation's Examinations Board in 1939–40. Another member of the Board at the time, was Eric Moore who had preceded Allen Scott as Chief Engineer at Stromberg-Carlson (A/Asia) Pty Ltd.

Doug Thwaites was one of the Sales Engineers employed by the company in the late 1950s. He had come to Australia in 1956 from England and having worked for periods on TV servicing and teaching at RMIT he joined Stromberg-Carlson in 1958, transferring to Adelaide where he provided technical assistance to distributors in South Australia and also Western Australia.

Fred Hawkins who had earlier trained as a Musician, began work with Stromberg-Carlson as a Process Worker gaining experience in a wide range of activities including assembly of receiver chassis, assembly of receivers into cabinets, testing and alignment of receivers, and workshop practices including welding, painting, lathe work, winding coils and transformers, assembly of loudspeakers and variable capacitors. He was subsequently promoted to the position of Line Supervisor, a position he held until mid 1955 when he left Stromberg-Carlson to take up a position with Admiral of Australia Pty Ltd, manufacturers of radio and TV receivers.

Don Lindsay a graduate of the Sydney University worked for Stromberg-Carlson as Design Engineer until 1933 when he left to become Design Engineer with AWA.

THE GRAMOPHONE CO., LTD

The Gramophone Company Ltd was associated with the production of home entertainment equipment in the form of gramophones under the brand name His Masters Voice, many years before the establishment of broadcasting.

The Head Office in England began manufacturing broadcast receivers in 1930 when the Gramophone Company took control of the Marconiphone Company but it was considered by their Australian representatives that the receivers were not suitable for the Australian conditions. The first model produced was the HMV Little Nipper a three valve TRF set covering the medium and long wave bands. Several were sent to Australia for assessment purposes.

In early 1930, the Australian company imported receivers from the USA and marketed them as His Masters Voice Radio-Gramophone receivers. They were sold at the premises at 163 Pitt Street, Sydney and sold for £125, a high price for a radio set in those days. The receiver was fitted with 10 Radiotron valves and featured microsynchronous tuning, Victor loudspeaker and record player.

The receiver had been manufactured as Model R32 by Victor Radio since June 1929 with the well-known HMV dog logo. For its time, it was an advanced design. The Victor Super Automatic Station Selector was a unique dial. A knob was moved horizontally across a dial to tune in a station. The record playing facility was an Electrola unit designed to play and reproduce Victor records electrically, with automatic record brake facility. The cabinet was made of the finest walnut veneers and included front doors.

When decision was made to design and manufacture receivers in Australia, the Company decided to commence full-scale production from the start, rather than producing a low number of sets and building up numbers over an extended period.

A new floor was added to the gramophone production area at Homebush in the mid 1930s, and equipped with the latest equipment and facilities for producing high quality broadcast receivers under the guidance of Engineers brought out from England.

Initially, four chassis were manufactured using the HMV label and a large stock was assembled before commencing a sales campaign. The models released in 1936 included:

- Model 720, a six valve all wave radiogram with AVC and magic eye tuning.
- Model 719, a receive only version of Model 720.
- Model 121, a six valve MF band console receiver with AVC.
- Model 718, a six valve all wave set in table type cabinet.

The Model 719 was an all-wave set with 6E5 tuning indicator, an RF stage ahead of the pentagrid converter and a single 42 type output pentode feeding a 6.5 inch (162 mm) loudspeaker.

Bands covered were 16.5-55, 55-175 and 175-560 metres.

The dial was 180 degree movement type with circular face and double ended pointer. The bandspread indicator rotated through a full 360 degrees over a subsidiary scale calibration in the centre of the main scale.

Controls comprised four position tone, three position noise suppression, three position wave change, volume, and tuning with dual ratio drive and bandspread indicator on the dial.

The project was an immediate success, and plans were put in hand immediately to increase production and the range of receivers. An important lesson learned was that Australians preferred the large console models in preference to table models, so popular in England.

The company built up a reputation of high quality with its receivers, and good back-up service by careful selection of dealers. No sales were made to the public direct from the factory, and unauthorised dealers received no discounts.

By 1937, the company had nine models in production including three all wave and three dual wave band types. Eight of the models were consoles and three were designed for battery-operation. Within two days, the number of models produced had reached 28 and included three models employing eight valves.

One of the 1937 releases was Model 346, a battery-powered six valve dual wave receiver. It was designed for operation from either dry cell batteries or vibrator/accumulator for the high tension supply. Valves were 2 volt filament types wired series-parallel to permit operation from a six volt accumulator. Valve types were

1C4, RF amplifier; 1C6, frequency converter; 1C4, IF amplifier; 1K6, detector, AVC rectifier and AF amplifier; 30, audio driver; and 19 as Class B output. Intermediate frequency was 460 kHz with the IF transformers being permeability tuned. Loudspeaker was an 8 inch (200 mm) permag type. Power supply was provided by Vesta R6V15 six volt accumulator. A synchronous type vibrator was employed to provide high tension with a battery/vibrator system.

In late 1938, the company released a new six valve Universal dual wave set in time for the Christmas sales market. It was Model 619, designed to operate from 160 to 280 volt sources without adjustment. Valves included beam output type and triode-heptode converter. A barretter in the valve filament circuit ensured constant filament current and protection against mains voltage fluctuations. Features included short wave coverage 13.9-47 metres; overload protection in dial lamp circuit; electrolytic capacitors mounted on the loudspeaker to protect them when loudspeaker was disconnected; insulated jacks provided for extension loudspeaker; separate volume control for extension loudspeaker; continuous action two way tone control, and 10 inch (250 mm) heavy duty loudspeaker.

Senior people associated with the company during the period include W A Donner, General Manager; John Briton, Factory Manager; W G Simpson; J R Whitaker; G H Choules; Fred Canning, Senior Radio Design Engineer, and others. Subsequent technical staff included James Elder, Percy Le Marchant and Harry Owen.

During the War, the production facilities were devoted almost exclusively to radar equipment. The Company produced over 5000 units of radar equipment and test equipment and included complete transportable stations widely employed in the South West Pacific region.

Nevertheless, the company was able to provide resources to produce a range of 1939 designed Columbia domestic receivers, all with 460 kHz IF.

Models available in Radio Shops in 1940 included:

- Model 600, a four valve MF band portable battery-powered receiver.
- Model 444, a four valve AC powered MF band mantel receiver in veneer wooden cabinet.
- Model 880, a five valve AC powered dual wave mantel receiver in veneer wooden cabinet.
- Model 110, a five valve AC powered dual wave table Grand Radiogram in veneer wooden cabinet.
- Model 540, a five valve AC powered dual wave radiogram in veneer wooden console cabinet.
- Model 420, a six valve AC powered dual wave radiogram in veneer console cabinet.
- Model 509, an eight valve AC powered dual wave radiogram in veneer wooden console cabinet.
- Model 519, a deluxe radiogram with automatic record changer.
- Model 660, a five valve dual wave receiver in veneer wooden console cabinet.

Others available at the same time included:

- Five valve receivers. Models 550, AC, MF band; 250, AC/DC, dual wave; 320, vibrator/battery, dual wave.
- Four valve receivers. Models 145, 1.4 volt filament valves, battery-powered, dual wave; 151, MF band, battery-powered; 161, MF band, vibrator/battery-powered.
- Dual wave receivers. Models 410, six valve AC powered; 470, eight valve, AC powered; and 300, seven valve vibrator/battery-powered.
- Four valve bakelite mantel receivers. Models 440, MF band AC powered; Model 41, 1.4 volt filament valves, MF band, battery-powered; Model 51, MF band, battery-powered; Model 52, dual wave, battery-powered; Model 61, MF band, vibrator/battery-powered; and Model 62, dual wave, vibrator/battery-powered.

The Model 410 was one of the most popular receivers with a number of interesting features. They included automatic expanding selector; HMV semi-octagon edgelit dial; range coverage 187 to 545 m, and 13.9 to 47 m; independent dial scale illumination controlled by the wave change switch; two-speed tuner with gear driven vernier; magic eye tuner; negative feedback in audio channel; five position Tone Monitor with settings of Wide range, Normal, Bass, Speech and Overseas; HMV Tone Diffuser designed to provide even distribution of the high note output of the loudspeaker; loudspeaker mounting of the main electrolytic capacitors in power supply unit; extension loudspeaker jacks; switch for silencing the receiver loudspeaker; pick-up jacks which automatically silenced the radio section of the receiver; mounting of tuning indicator in such a manner that it was viewed through the tuning dial scale; 12 inch (30 cm) loudspeaker with 1200 ohm field coil; floating deck construction to isolate RF and mixer sections to reduce microphony problems; temperature stabilised permeability tuned IF transformers; double action radio and audio AVC; low volume tone compensation provided by the tapped volume control and tone monitor system; and tropic impregnation of components and insulation.

Valve types employed in the Model 410 were 6K7GT, RF amplifier; 6J8G, frequency converter; 6K7GT, 457.5 kHz IF amplifier and automatic expanding selector; 6B8G, detector, AVC rectifier and AF amplifier; 6L6G beam type output tetrode; and 5V4G indirectly heated rectifier. Tuning indicator was 6U5/6G5.

Two popular consoles produced during 1941 were the Model 661, a five valve dual wave AC powered console receiver, and Model 551, a five valve MF band AC powered console receiver.

After the War, the company resumed the manufacture of domestic receivers and other equipment at its Homebush plant.

Among the early receivers produced, was Model 46W, a four valve MF band mantel receiver in a cabinet of walnut and mahogany veneers. Another receiver was Model 847, a four valve dual wave table radio powered by vibrator/battery system and covering bands 1600 to 545 kHz and 16.5 to 52 metres short wave. Features included AVC; tone monitor combined with on/off switch; tropic proof impregnation; 0.7 ampere battery drain; housed in polished veneer wooden cabinet.

By mid 1948, models available included 888, a five valve dual wave AC powered receiver in veneer wooden cabinet; 46B, a four valve MF band, AC powered receiver; 547, a five valve MF band, AC powered receiver. Models 46B and 547 were housed in bakelite mantel cabinets in colours of walnut or walnut and ivory.

About this time, Dick Huey joined the company as Chief Engineer and Product Engineer after working as Technical Superintendent with AWA Consumer Products and Special Products Divisions.

In 1949, Dick went to the UK where he was attached to EMI Engineering Development Ltd where he worked on a number of major projects until 1950 when he returned to Australia to take up a position with the NSW University of Technology as Senior Lecturer in the School of Electrical Engineering. He later became Associate Professor.

Dick had been interested in radio from his University years as a Science student and joined The Institution of Radio Engineers (Australia) as a Junior Member in 1932, the year the Institution was founded. In 1967–68, he served as President of The Institution which at that time was known as The Institution of Radio and Electronics Engineers (Australia). He also served on a number of Committees and Boards. Included amongst honours received from The Institution were the Award of Honour 1981, and the A G Pither Award 1982.

In mid 1949, EMI released its miniature mantel five valve Little Nipper receiver in colours of cream, walnut, green, pink or blue. It was fitted with an elliptical loudspeaker. The receiver was later available as a dual wave set in a new cabinet style with colours of cream, brown, green or burgundy.

In 1949, EMI Sales and Service Pty Ltd was established. It took over the manufacturing operations of The Gramophone Co., Ltd and became responsible for distribution activities previously carried out by others which in NSW included Block and Gerber Ltd for radios, and Hoffmans for records.

In 1951, the Radio Centre, Kings Cross, Sydney operated by Eastern Suburbs Electrical Co., Ltd stocked a complete range of His Masters Voice radios as well as latest HMV records. Receiver models in demand at the time included:

- Model E43D, a five valve AC powered dual wave auto-radiogram for homes where consideration of space demanded a radiogram of moderate physical dimensions. It also provided an in built storage compartment for records.
- Model S23A, a six valve dual wave receiver of high sensitivity which performed well on overseas broadcasts providing good output at low distortion level.
- Model E23, a portable electric record player with facility for attaching to a standard radio receiver.
- Model D33A, a table radiogram in attractive veneer walnut cabinet providing good local and overseas reception.

In 1953, with the increasing demand for car radios, the company appointed Vic Humphrey as Field Engineer responsible for car radio products. He was later promoted to the position of Manager Car Radio Division and in 1957, became National Sales Manager of EMI's Car Radio Division. He remained in that position until 1967.

About 1956, the company became EMI (Australia) Ltd and continued to manufacture domestic and car radio receivers, radiograms and TV receivers until the mid 1970s when the production line was closed down.

Included among its technically qualified Engineering staff who were member of The Institution of Radio and Electronics Engineers, Australia were Allan Harley, Percy Le Marchant and James Elder.

In the early 1970s, the company advertised itself as Sound Recording Specialists for radio, TV and films. It had three large studios, 8-track 3M machines, 4-track Scullys and Ampex 2-track machines (compatible stereo) and a fast disc processing service in mono or stereo.

The company later became a music organisation known as EMI Records Australia Pty Ltd. It ceased producing records about three years ago but in 1993 was manufacturing CD's and cassettes at its Silverwater factory with recording functions being carried out at EMI Studio 301 in Castlereagh Street, Sydney.

THOM AND SMITH PTY LTD

The firm was founded by Frederick William Parkes Thom and John (Jack) Edwin Smith on 17 December 1929. Just prior to establishing the company, the partners were employed by Stromberg-Carlson (A/Asia) Ltd.

Fred Thom commenced his career in radio as an office boy with Amalgamated Wireless (A/Asia) Ltd in 1919, but was eager to learn the technical side of the business and on 27 January 1920 became an Apprentice Electrical Fitter in the company's upstairs factory at 97 Clarence Street, Sydney, known as Australectric. The factory manufactured telecommunications equipment, marine wireless apparatus and handled the marine activities of AWA.

Fred passed through various sections including manufacturing screws using turret lathes, the coil winding section, the Patent Department and the Valve Manufacturing Department where the Expanse B valve was being made and used in the P1 marine regenerative receiver. He completed his Apprenticeship on 25 March 1925 and left AWA to become Foreman in charge of production with L P R Bean and Co., who had premises at 86 Crown Street and Newstead House, Castlereagh Street. The company manufactured Telecommunications Equipment and was Australian agent for Stromberg-Carlson, a giant USA firm. In 1927, the company changed its name to Stromberg-Carlson (A/Asia) Ltd.

In 1929, Fred left the company to start up a partnership business. He became a foundation member of The Institution of Radio Engineers (Australia) when the organisation was formed in 1932, and in 1940, was made a Fellow of The Institution.

Jack Smith commenced work with Western Electric in London as an Apprentice Electrical Instrument Maker in 1912. From 1916 until 1923, he was Foreman in the toolroom of Siemens Brothers, London.

In 1924, he came to Australia where he obtained a position with Stromberg-Carlson (A/Asia) Ltd where he remained until 1929 when he and Fred Thom set up their own business.

The business was established at 11 Nicholson Street, Woolloomooloo with a factory of floor area about 92 square metres for the manufacture of Tasma brand broadcast receivers. Initially, two models were produced, each comprising two valves plus rectifier. There was a staff of six producing and testing the receivers with output being 20 receivers a week. Their first employee was George Woodward a toolmaker who left Stromberg-Carlson at the same time that Messrs Thom and Smith left.

Sales increased rapidly and by 1931, it became evident that the company had to expand to meet the demand for their receivers.

In October 1931, a new factory was established in Dowling Street, East Sydney, incorporating modern production and manufacturing techniques. They also began to place the brand name Tasma on the receiver cabinets whereas earlier, they had produced unbranded chassis. At the same time, a dealer organisation was established and a publicity sales campaign implemented.

The new facilities included a well equipped Laboratory, with several items of test equipment being imported.

In order to establish a high level of expertise in receiver design, they employed a Dutch Engineer, Y B F J Groeneveld as Chief Engineer-in-Charge of Technical Research and Development. He commenced duty in August 1932.

Mr Groeneveld had joined Philips in Eindhoven, Holland, in 1925 and as Chief Engineer of the company's Radio Laboratories was in charge of Scientific Radio Research. He was associated with the design of the famous Philips short wave transmitter at Eindhoven. Mr Groeneveld was responsible for the production of the first Tasma superheterodyne circuit receiver which became available in 1933. There were eight models in the new range including a seven valve deluxe model and an AC mantel set, model 180. The company also adopted a policy of marking station callsigns on the dial rather than numbers as had been the practice by other manufacturers up to that time.

In order to overcome a selectivity problem with some receivers in service during the early 1930s, the company produced the Tasma Wave Trap in 1932. It became very popular and sold in considerable quantities, particularly in capital cities. The device was fitted near the receiver and inserted in series with the aerial lead-in wire. A variable capacitor in the wave trap enabled the interfering station to be tuned out.

In 1935, Tasma introduced its bandspread receivers. Consoles produced during the year included Model 290, a five valve mains powered superheterodyne with AVC and Band Spread dial and fitted with new octode valves; Model 190, a battery-powered receiver; Model 265, a six valve receiver and Model 185, their top of the range receiver which was an All-Wave superheterodyne circuit of seven valves with AVC and a Carlyle piano finished cabinet. The Band Spread dial employed an auxiliary pointer which 'spread' stations through a much larger arc than covered by the normal dial enabling greater accuracy in station logging.

Thom and Smith was one of the first to tackle the problem of the failure of broadcast receivers in the tropical areas of Queensland. Fred Thom personally toured the area, repairing their Tasma receivers at no cost and gathering data on the cause of the failures. As a result, they installed a comprehensive system in the factory for impregnation, to hermetically seal all coils and other components which were likely to be affected by high humidity conditions.

A great range of models was produced during the 1936–37 period. They included Model 315, a 6 volt auto set in 1936 and Model 420, a 6/12 volt auto set in 1937. Model 465 released in 1937 was a six valve dual wave band console cabinet set designed to operate from a 32 volt home lighting system. Two seven valve models were available. Model 415 was a battery-powered dual-wave set and Model 440 was an AC powered dual wave receiver. Both were available in 1937. More than 30 new models were released over the period.

By 1938, the company was well-established in a new 2200 square metre factory in Botany Road, Mascot where they were producing 9000 receivers, comprising 18 different models a year with a staff of 300. In addition to their Tasma brand, the company produced Genalex brand receivers for the British General Electric Company and some Philips Radioplayer models. The firm had about 600 dealers throughout Australia and New Zealand. In addition to domestic receivers, they manufactured car radios including the Tasma-Ford brand.

The company also expanded into the manufacture of telecommunciations equipment components, producing 3000 type relays for the Post Office telephone exchanges and switchboards. At least 60 employees were engaged on this work.

Chief Engineer was Eric Fanker who had previously been Radio Engineer with Darelle Products. In the 1950s, he left Thom and Smith to become General Manager, Admiral of Australia Pty Ltd.

With the start of the Second World War in 1939, the company was well set up to divert effort to producing radio and other equipment for the Services. They were soon producing a range of communications transmitters for the RAAF including AT14, AT14A, AT15A and AT17 models. The company's early investigations into tropic proofing radio equipment components was a major factor in the high reliability of these transmitters in the Pacific and other tropical regions.

Although resources were diverted to manufacture of equipment for the Services, the company was able to continue to produce domestic receivers in the early years of the War.

The 1940 range comprised 23 models including two auto and one portable models. The company recognised the demand for receivers with short wave capability accentuated by the War and the rapidly changing overseas situation. Out of the 20 home models, 15 were dual wave types.

Excluding auto and portable receivers, the entire range of 20 models was housed in four cabinet styles.

The Tasma Baby model was provided with a small moulded plastic cabinet 300 mm wide, 150 mm deep and 200 mm high. The cabinet type housed four models of receivers.

Two console type cabinets known as Sonya and Sandra were employed. In the Sonya cabinet, the dial was located on the top of the cabinet in a continuation of the rolled front panel. The cabinet was used to house a five valve broadcast AC receiver; a standard five valve dual wave AC model; a special five valve dual wave AC model with an RF stage; a four valve dual wave battery set; and a four valve vibrator/battery set.

The Sandra cabinet housed a five valve and a six valve dual-wave set, both with an RF amplifier stage; a five valve dual wave set for battery-operation; and a five valve vibrator powered unit.

Radiograms, known as Tasmagram were housed in cabinets known as Sally. Models included a five valve AC broadcast set; a five valve AC dual wave set; and a six valve AC dual wave receiver with an RF amplifier.

Models released during 1941 included:

- Model 806, a five valve broadcast AC powered set with beam power output and inverse feedback. Valve types were 6J8G, 6U7G, 6G8G, 6V6G and 5Y3G.
- Model 881, a four valve battery-powered broadcast receiver employing two volt filament valves of types 1C7G, frequency converter; 1M5G, IF amplifier; 1K7G, detector, AVC, AF amplifier; and 1L5G, output pentode. Batteries comprised 2 volt A battery and three 45 volt B batteries. It was also available as vibrator operated model powered by a 6 volt battery.

All these models were housed in the Tasma Popular console.

- Model 801W, a four valve broadcast band AC powered receiver employing valve types 6J8G, EBF2, EL3NG and 5Y3G.
- Model 875W, a four valve broadcast band battery-powered set using 2 volt filament valves. Batteries were 2 volt A and three 45 volt B types. Valve types were 1C7G, 1N5G, 1K5G and 1L5G.
- Model 876W, a four valve set employing a five valve circuit and powered by a 6 volt vibrator system. Valve types were 1N5GT, 1A7GT, 1P5GT and 1D8GT.

These models were all mantel types housed in Tasma Baby veneer wooden cabinet.

Other console cabinets available were Tasma DeLuxe and Tasma Gumnut. The DeLuxe housed models 830, a six valve dual wave AC set; 886, a five valve dual wave battery-operated set; and 886, a five valve dual wave vibrator powered receiver. The Gumnut housed model 801G, a four valve AC set; model 810G, a five valve dual wave AC receiver; model 875G, a four valve broadcast band battery-powered receiver with 2 volt filament valves; model 876G, a four valve broadcast set powered by a 6 volt vibrator system and model 880G, a four valve dual wave receiver battery-powered and employing 1.4 volt filament valves.

When manufacture of domestic receivers began again after the War, the standard Tasma Baby and the Tasma Export Model 1010 were popular models available at Radio Shops. The Model 1010 was a five valve AC powered triple wave receiver covering the bands 13 to 42 metres, 30 to 100 metres and the standard MF broadcast band. It was housed in a streamlined moulded cabinet.

By early 1947, Tasma Baby models available in Radio Shops included Model 1001, a four valve AC operated receiver; Model 1075, a four valve battery-powered set utilising 2 volt filament valves; and Model 1005, a five valve AC operated broadcast band receiver.

Tasma DeLuxe console models included model 1031, a five valve AC operated dual wave set and Model 1086, a five valve vibrator powered dual wave set utilising 2 volt filament valves and powered by a vibrator unit using a 6 volt accumulator.

In early 1948, a new version of Tasma Baby, model 1105 was produced with a patented roller tuning system. It was AC powered and was followed by AC/DC and battery-powered models.

During 1952, Tasma receivers available included:

- Triplet, an AC/DC mantel set that could be used as a portable, bedside or car radio.
- Tonemaster, a table model with Plastacoustic sound fret; world-wide reception capability; pick-up terminal; combination on/off switch and volume control.
- Twin, a mantel receiver available as four and five valve models with dual wave reception and featuring roller tuning.
- Radiogram, featuring worldwide reception capability; high fidelity reproduction; automatic three-speed record changer; record compartment; self-supporting lid; and housed in cabinet finished with Italian veneers.

Following merger with President Consolidated, receivers were marketed as President-Tasma. In 1954, one model was the popular Radiogram Model 51, a five valve world range receiver. Features included pianocraft cabinet with walnut or rosewood finish; automatic three-speed slideout record changer; tilt down tuning panel with four controls; two large record storage compartments; and warning light in bottom rail.

Among the transmitters produced during the War years for the Services, were eight Model BC200 transmitters designed for broadcasting purposes for entertainment of troops in the war zones. The transmitter produced 200 watt output employing a pair of 813 valves in the power amplifier and a pair of similar types in the modulator. One of these transmitters was installed by Bill Morrison at a site at Jaquinot Bay, New Britain in 1946 on return of Allied Forces to the area. Prior to joining the Army, Bill had worked at 7HO Hobart commencing in 1937 as a Control Booth Operator and becoming a Technician in 1938. After discharge, he resumed duty with the station becoming Chief Engineer in 1951. In 1959, he was appointed Chief Engineer of television station TVT6 and made an overseas trip to study the latest in Broadcasting Technology on behalf of 7HO and TVT6. In the 1970s, Bill was Manager for Planning and Development.

After the War, a number of the Tasma BC200 transmitters were modified for use with National Broadcasting Service stations pending supply of factory produced post War models. Stations 5DR (later 8DR) Darwin and 4QL Longreach were among stations where Tasma transmitters were installed for a period. Besides Messrs Thom, Smith and Y B F J Groeneveld, staff associated with the company prior to the War included Arthur Bates; Eric Fanker who replaced Mr Groeneveld as Chief Engineer in 1935; R J C Bryce; William J O'Brien; R H J Jennings; S T Lindsay; John Paton; Stephen Tazewell; Norm Buchanan; George Woodward; Basil Brown; Wally Barrs and others.

At peak of production, Tasma was amongst the largest receiver manufacturers in Australia. Although it resumed receiver production after the War, building up staff to about 800, the company ran into financial difficulties during 1952 and early 1953.

Thom and Smith merged with Electronics Division President Consolidated Ltd, a refrigerator manufacturer. However, President itself also ran into financial difficulties and Thom and Smith was later sold to the Pope group.

Fred Thom left and built a small factory opposite the Thom and Smith factory in Botany Road.

The business known as Thom Electronics employed some former Tasma employees and later when James N Kirby bought into Thom Electronics, Crosley TV receivers were produced. General Electric bought out the Kirby interest but eventually the operations ceased.

Although the Tasma brand was a household name for well over 20 years with radio receivers the brand never appeared on TV receivers.

UNITED DISTRIBUTORS LTD

The company began operations as Uniting Distributing Companies Ltd, in 28 Clarence Street, Sydney, some time before the first broadcasting stations 2BL and 2FC were commissioned in 1923. It manufactured receivers with the Radiovox and Udisco labels with the first Radiovox models including:

- Model E, a one valve receiver in small table cabinet and supplied complete with valve, headphones, batteries and accessories for a simple outside aerial.
- Model A, a five valve receiver in console cabinet and built-in wooden horn loudspeaker in a patented resonant sound chamber. It featured a lift-up lid for easy access to the valves.

The Udisco United Three was a three valve set with regenerative circuit and was popular with many local listeners at the time.

As the company were wholesale merchants only, receivers had to be purchased through Radio Shops.

By April 1924, factory output had been expanded with a range of chassis being fitted to two different console cabinet designs. One design housed two and three valve receivers while the other housed four to seven valve receivers.

In mid 1924, the company became United Distributors Ltd and within a short time had branch offices in Melbourne, Brisbane, Adelaide, Hobart, Perth and also in Wellington, New Zealand.

In Sydney, the main office was located at 28 Clarence Street, but because of the huge turnover of stock, the company acquired a four-storey building at 72 Clarence Street. They moved into the new headquarters about September 1924, just in time to take delivery of £40000 of imported radio parts and accessories, with another £60000 on the way from USA and England to meet the expected demand of the Christmas rush.

Stations 2BL and 2FC had been broadcasting for nearly 12 months and there was an enormous public demand for radio receivers and components, not only in Sydney, but also in the other capital cities where stations were either already on air, or in the course of construction. The company supplied Radio Shops throughout Australia, with most of their business being wholesale. There were at least 300 wholesale customers on their books at one stage.

The ground floor of the new building contained the Sales Department and included rooms for demonstrating the range of receivers the company sold. The second floor was devoted entirely to stockholding, while the third floor was equipped to manufacture Radiovox and Udisco receivers and Signal home assembly kits. By the end of 1924, kit sets were being produced at the rate of nearly 300 sets per week. Loudspeakers recommended for use with the kit sets included Music Master de Luxe, Atlas, Signal and Brandes models, all of which could be purchased at the shop.

The Signal Kit was so popular with 'do-it-yourself-constructors' that in 1924 five models were available. They comprised Model P, a one valve receiver; Model Q, a two valve receiver; Model R, a three valve receiver with AF stage; Model S, a three valve receiver with RF stage and Model T, a four valve receiver.

Among the early receivers was the United Three, a three valve regenerative receiver popular as early as 1923.

At the 1925 Royal Agricultural Society's Easter Show in Sydney, United Distributors mounted one of the best radio displays at the Show. Included were two large superheterodyne receivers with glass covers to allow the public to inspect the inside of a typical superheterodyne receiver. They also displayed a range of Umakit home assembly kit sets and a magnificent Beard De Luxe receiver, designed by the company Chief Engineer, Ernest Beard.

Among the most popular receivers produced by the company were the Udisco models produced in three, five, six and eight valve models, the UDL produced in four and five valve models and the Beard De Luxe receiver.

At the first Radio Trade Exhibition held in Adelaide in 1926, orders were received from visitors to the Exhibition for 32 receivers during the five days of the display. The Udisco receivers employed the Capacidyne circuit claimed to be an Australian invention which gave high selectivity, low distortion, high tonal performance and easy operation of the controls. Tuning dials were synchronised, with wavelength changes being performed by a switch instead of the usual coil change methods. The receivers were designed to cover the long wave, medium wave and short wave bands. Coverage was 20 to 2000 metres and it was claimed that most models could receive all Australian stations and overseas short wave stations. The top of the range receiver was the Super-Neut Udisco Eight with the receiver being placed on top of a highly-polished cabinet containing a Clyde United Wet accumulator and Ray-O-Vac B batteries. A Quam horn type loudspeaker sat on top of the receiver. July 1926 price for this receiver complete was 110 guineas. The 4, 5, 6 and 8 valve models produced at the time, employed Philips A609 valves. The valve, a triode amplifier, was released by Philips in 1926.

In 1928, the company trading as UDISCO, opened a new factory at Primrose Avenue, Rosebery, a Sydney suburb. It was designed to accommodate a workforce of 50 Engineers, Mechanics and Testers and to produce up to 450 receivers a week. The Chief Engineer was Mr E Gordon, and the majority of staff were former Navy trained ship's wireless operators with an average experience of 12 years on radio equipment maintenance, wiring and testing.

Shortly after moving into the new premises, the company produced the Udisco Electric Super-Neut range of all-electric receivers. Any station could be easily tuned in by manipulation of a single dial knob. An ABC Eliminator pack was employed to power the set from the mains. The range included 6, 7, 9 and 10 valve models. The receivers included an in-built facility to enable the receiver audio stage to be used for playing gramophones. A feature of the receiver was the beautifully hand polished full console cabinets.

About May 1929, the retail outlet point was transferred to 151 Castlereagh Street with the company Head Office being located at 69 York Street in the city.

The subsequent fate of the company is not clear, but in March 1930, the Electric Corporation of Australia Ltd (ECA) announced that UDISCO receivers had been superseded by ECA with the new models being manufactured at the former UDISCO Works at Primrose Avenue, Rosebery.

The range of ECA receivers included:

- ECA All Electric Three; Four and Six valve models. Battery-powered versions were also available. Cabinets were table types with a USA made Rola loudspeaker being mounted on top of the cabinet.
- ECA Combination Concert Model in AC or battery-powered forms. Features included single dial control; power detection; screen grid valves in RF and AF stages; variable tone corrector; in-built gramophone facilities; choice of Escarola dynamic or magnetic loudspeaker; beautifully designed console cabinet with lift-up lid and front doors with selected maple timbers being employed in the construction. The cabinet was provided with a high gloss finish.

Chief Engineer of the company over the period 1924 to 1929 was Ernest Beard. When he left the company he founded Ace Amplifiers Ltd in 1931 to manufacture specialised radio equipment. He used UDISCO as his new company's telegraphic code.

Ernest Beard began his career in wireless in 1912 as an experimenter in wireless telegraphy in England, building a spark transmitter and several receivers including coherer, electrolytic and crystal types. In 1913, he joined the Royal Navy as Wireless Operator gaining experience with valve equipment being employed by the Navy towards the end of the War.

Ernest came to Australia in 1920 setting up business to specialise in radio frequency amplifier designs. In addition to his role as Chief Engineer with UDISCO he was responsible for the design and construction of the original 2GB and 2KY broadcasting transmitters.

By the mid 1930s, his company had become involved in many electronic projects and in 1937, Ace Amplifiers Ltd was granted patents in signalling apparatus and in automatic gain control.

Another senior employee of United Distributors was Henry Long who held the position of Retail Branch Manager for some time. He had been associated with commercial radio since 1926, later becoming Manager of Latimers Wireless Supplies Ltd before moving to United Distributors Ltd. When United Distributors Ltd began to scale down its activities due to fall in sales during the Depression he left the company and founded United Radio Distributors Ltd in September 1932 at 14 York Street, Sydney as a wholesaler in various brands of radio receivers and components. He later moved to 73 York Street to provide more space for the expanding business. The company was joint distributor in New South Wales for Electricity Speciality Manufacturing Co., Ltd of a range of ESM receivers, and also for Radiokes products manufactured by Metropolitan Electric Company.

In 1938, United Radio Distributors Pty Ltd, then located at 183 Pitt Street, Sydney marketed three receivers under the President label. They were all AC powered dual wave set in console cabinets. During 1941–42 some 13 models were available with two vibrator/accumulator powered models with dual wave capability employing the unusual IF of 212.5 kHz. Technical Manager at the time was W J Mawer.

The company closed down operations about 1942 but recommenced activities about 1947.

WALKER H C & CO., ASSOCIATED FACTORIES

Harry Walker was one of a number of entrepreneurs in the mid 1930s who established or acquired businesses associated with the radio and motion picture industries.

He established H C Walker and Co., Associated Factories with headquarters at 73–75 George Street, Redfern and became Managing Director of the group of companies comprising Peerless Manufacturing Co., Ltd; Duffy Radio Co., Ltd; Motion Picture Supplies Ltd; Cinema Supplies and Cummings Bros, Ltd.

Walker was a qualified Accountant and entered the radio industry with Harringtons Ltd as General Manager in the early days of broadcasting. In 1927, he was Chairman of Radio Industries Ltd, a registered company established to advance the interests of people and businesses involved in the radio-electrical industry. Directors of the company comprised principals of major organisations associated with the industry. He was one of the radio business leaders who gave evidence to the 1927 Royal Commission on Wireless.

In 1929, he left Australia to study the broadcasting industry in USA, particularly in retailing and manufacturing. He also made a detailed study of the motion picture industry. On his return in 1930 he was appointed Managing Director, Harringtons Ltd and Raycophone Ltd. Harringtons had an arrangement with Raycophone to handle the distribution of Raycophone receivers, parts and cinema equipment.

He resigned in 1932 to form H C Walker & Co., Associated Factories. Peerless Manufacturing Co., registered in October 1932 produced moulded radio parts including valve sockets, speaker plugs, various models of coil formers and products to other company specifications.

The Duffy Radio Company Ltd acquired by Walker was founded by John Duffy who began his career in radio in June 1920 several years before the establishment of broadcasting stations. He later became Manager of Radio Service with Home Recreations where he remained for four years before moving to Harringtons Ltd as Wholesale Radio Manager. He left Harringtons to form his own company on 9 February 1933 to produce Duffy brand receivers and components, specialising in short wave designs. Early receivers produced included the Duffy All-World Set designed for medium wave and short wave reception in 1933. The following year he produced the 8 valve Comet. He also manufactured an All Wave Two receiver in kit form and the Duffy Transposer designed to enable medium wave receivers to receive short wave stations. Components included RF chokes, aerial couplers, calibrated coil kits, coils formers and low loss variable tuning capacitors.

The Duffy short wave chokes were popular with builders of short wave receiver. They were made as Type D for screened grid valves and as Type C for low impedance circuits. The winding pattern employed, kept distributed capacity to a very low level. Units were hermetically sealed and capable of handling a current of up too 100 milliamperes continuously, so enabling them to be used in the output of power packs.

The Duffy Comet Short Wave receiver was one of the best receivers on the market at the time for reception of overseas short wave stations. Development work was undertaken in the well-equipped Short Wave and Television Laboratories to ensure the design met the most stringent specifications. Receivers were set up in the Laboratories at 73–75 George Street, Redfern and the public was invited to demonstrations during afternoon periods when the BBC programs were being broadcast to Australia.

An important feature of the design was the dual channel tuning system incorporating a straight short wave and straight MF band receiver. National Union and Ken-Rad valves were employed. Types included:

- Broadcast band, 77, autodyne; 78, intermediate frequency amplifier; 78, second detector; followed by a special Transposer.
- Short wave band operated as a TRF receiver using 77, first RF amplifier; 78, matched detector; followed by special Transposer.
- Audio amplifier employed 77, driver; and 89, output.

Controls comprised tuning, station finder, trimmer and audio volume control on short wave channel land tuning, volume control on MF band channel. A short wave/broadcast switch provided for mode selection giving 5.6 valve superheterodyne MF band receiver in one position and 4.5 TRF short wave receiver in the other. An 8 inch (200 mm) Amplion permag loudspeaker was employed.

The model was available with eight valves including rectifier for AC operation and seven valves for battery operation. The battery-powered version operated with 6 volts A battery with a drain of 2 amperes while the B battery comprising three 60 volt Diamond batteries provided for a drain of 20–24 milliamperes.

The console cabinets were veneer wood with lustre finish.

As part of his efforts to promote interest in short wave listening he produced 'Duffy Short Wave News' a very popular publication with short wave fans.

Other companies in the H C Walker group, Motion Picture Supplies Ltd, Cinema Supplies and Cummings Bros, Ltd were talkie and cinema manufacturers and distributors.

WETLESS ELECTRIC MANUFACTURING CO.

The Wetless Electric Manufacturing Company was founded by A P J Wetless at St Peters, Sydney in 1923. He was a qualified Electrical Engineer and when he set up the business he specialised in the manufacture of capacitors which were required in large numbers to meet the demand following the introduction of broadcasting in Australia in 1923. He expected a high demand for capacitors from manufacturers of domestic radio receivers and Radio Shops to supply the need of enthusiasts who built their own receivers.

Within a few years, he saw a need to expand his manufacturing resources into other radio component areas and developed facilities to enable the manufacture of high quality inductors. By 1929, products were being distributed through outlets in all States and included RF chokes, Neutrodyne Kit comprising three low loss coils and two neutralising capacitors, Reinartz tuner, single rotor tuner, Browning-Drake Kit with neutralising capacitor, double rotor tuner, and range of nine midget variable capacitors ranging from 3 plates to 19 plates.

A new range of mica capacitors was also introduced about this period. Two types were manufactured — the first quality, type B and a lower quality, type A. The capacitor unit was composed of thin sheet copper, rather than the usual foil, and separated by high grade Indian ruby mica. The unit was clamped rigidly between two Continental bakelite outside plates, which were held in compression by nickelled brass bands secured by eyelets. Tinned soldering lugs were provided with the grid capacitor being fitted with suitable clips for holding the grid-leak as well as extra long mounting lugs. With the type A, the metal clamping bands were dispensed with, the outside bakelite plates being held in compression only by eyelets. Otherwise, the construction was similar to the type B. Type A was marketed in capacitances ranging from 0.0001 MFD to 0.002 MFD while the higher grade type B was available in capacitances as high as 0.02 MFD. The type B grid capacitor could be attached directly to the grid terminal of a valve socket without the need for any wiring.

In early 1932, the company produced a range of Wetless F tubular type capacitors to meet the demand of a rapidly expanding radio receiver manufacturing industry. They were designed to facilitate rapid assembly of the chassis. The capacitors were manufactured to meet equipment working voltage needs up to 250 volts DC or 500 volts DC. The 250 volt working types comprised capacitors of 0.25, 0.3 and 0.5 MFD while the 500 volt working types were manufactured in capacitances of 0.01, 0.02, 0.03, 0.04, 0.05 and 0.1 MFD.

About the same period the company manufactured a range of shielded capacitors with metal cases and designed for base fixing to the chassis by means of metal screws. The capacitors were widely employed in filter circuits and had a working voltage capability of 500 volts DC. They were available in capacitances of 0.01, 0.02, 0.03, 0.04, 0.05, 0.1, 0.25, 0.5, 1.0, 2.0, 4.0, 2X0.5, 3X0.5 and 4X0.5 MFD.

At the time of production of these new lines of coils and capacitors, business was being conducted at 28 King Street, Rockdale.

Research and development was an ongoing activity and new types and designs were being continually added. Noise suppression units and high voltage oil-filled units were introduced and by the early 1930s, Wetless were major suppliers to transmitter manufacturers and station staff building their own transmitters and aerial coupling units.

Included in the range of high voltage capacitors were:

- Type CW600T, a two terminal model for use where both terminals carried high voltage. Each terminal was provided with a silver-plated corona disc.
- Type CW600C, a one terminal model where the earthed metal case formed the second terminal. The high voltage terminal was provided with a corona disc.
- Type P51-400, a cylindrical design with terminals at both ends of the cylinder. The cylinder was normally mounted horizontally with the body attached to a pair of ribbed porcelain insulators.

When the 5CL Adelaide, 5 kW transmitter, which had been rebuilt in 1936 by local staff was dismantled and sold for scrap in the 1960s, the majority of oil-filled capacitors were Wetless types.

The company appears to have ceased business about the time of the outbreak of the Second World War in 1939.

ZENITH RADIO CO., LTD

The company was established by H Coles at Paddington, Sydney for the design and manufacture of Zenith brand receivers. The 1934 range included four console cabinet and three table cabinet models.

One of the table models was the Zenith Eaglet, a five valve superheterodyne receiver with clock type dial and chassis finished in an iridescent apple green colour. The cabinet featured matched figured veneers and high lustre finish. Loudspeaker was a 6 inch (300 mm) Magnavox dynamic loudspeaker fixed to the inside top of the cabinet with a grill cut into the top woodwork.

Model 63 a six valve battery-powered superheterodyne receiver with Aero dial in console cabinet employed Philips and Ken Rad valve types 34, RF amplifier; 15, autodyne; 34, IF amplifier; two B217, and a B240 output valve. The B Class audio output stage fed an Amplion permag loudspeaker.

Zenith battery-powered receivers were popular with country listeners and company designers spent considerable effort in updating the six valve design. Following six months work, a new model was released in mid 1932. It employed Philips two volt filament valves including KBC1 and B240. Battery requirements were 2 volt accumulator A battery, three 45 volt B batteries in series and 4.5 volt C battery. An Amplion permag loudspeaker was installed in the console cabinet.

One of these receivers was purchased from an Adelaide Radio Shop by Bill Burt, a grazier, about 30 km east of Hawker, a few months after 5CK Crystal Brook, the first ABC regional station in South Australia was commissioned. The owner had a 32 volt home lighting system on the property and arranged for the Radio Shop to build up a power unit so the receiver could operate from that system. He constructed an aerial system using a single 10 metre high galvanised water pipe guyed in three directions. A wire was erected with one end tied to the pole and the other end tied to the windmill tower. The lead-in wire came from one end providing an L type aerial. He reported excellent reception, not only from 5CK but also from 5PI which came on air about the same time, 5KA, 5CL and 5DN. In 1974, the receiver was stored in a shed on the property and acquired by a travelling antique dealer.

During 1937, the company produced a large range of receivers with names such as Explorer, Adventurer, Traveller, Ranger, Roamer, Magic Star and a deluxe version of the Adventurer. In late 1937, receivers were available under the Ambassador label.

With the availability of the 2 volt Eveready Air-Cell A battery source from mid 1937, three models were released by Zenith to take advantage of the new power source. They were:

- Model C4B, a four valve MF band console cabinet receiver.
- Model C4BD, a four valve dual wave band console cabinet receiver.

- Model C5BD, a five valve dual wave band console cabinet receiver.

At the outbreak of the Second World War, production of domestic receivers was scaled down and the company resources diverted to the manufacture of radio accessories and VHF transmitters for the Services.

Production of domestic receivers apparently did not resume after the War. In 1947, the company was marketing Calstan models following an agreement with Slade's Radio Pty Ltd. In 1953, a Calstan eight valve radiogram combination with push-pull output and 12 inch (30 cm) loudspeaker was marketed by Zenith.

Technical staff who had worked with Zenith at various times included Norm Buchanan, Chief Engineer; G Brownlee, Receiver Designer; M Edwards, Factory Manager and F T Newman, Factory Manager.

Other Organisations

Although amongst the largest manufacturing organisations in Australia at the time, those companies previously listed, comprised only a fraction of the number actively involved, either directly or indirectly in supporting the broadcasting industry. The technical press of 1938, indicated that in that year at least 70 factories and businesses of various sizes with staff levels ranging from a few, to thousands, were associated with the manufacture, assembly, development, design, construction, retailing, distributing or servicing of broadcasting equipment, components or accessories.

In order to meet the need to expand, many of the larger firms changed their addresses several times to move to larger premises and also, as a result of amalgamations and policy changes, some also changed their business names.

In addition to those already described, other organisations selected as representatives of large distributors and retailers, small manufacturers, and service organisations throughout Australia who were active prior to, and at the outbreak of the Second World War when the decade of the 1930s was coming to a close, followed by the immediate post War period, together with the names of some of the senior staff where known include:

* **Acme Radio Laboratories Pty Ltd, Melbourne**
(C J Whight)

* **Amplion (A/Asia) Ltd, Sydney**
(Patrick Manley, Lance Graham)
The company was registered on 19 September 1930 and produced the well-known brand of Amplion loudspeaker.

* **Andersen and Frantzen, Sydney**
Radio cabinets.
(Hans Christian Andersen and Victor Frantzen)
The business was registered in April 1916.

* **Aristone Radio Co. (Aust.), Pty Ltd, Prahan**
Aristone receivers.

* **Australian General Electric, Sydney**
Australian General Electric (AGE) was a branch of the giant USA firm General Electric Company and was established in Australia in 1897 the year after Marconi was granted his patent for the invention of a practical system of wireless telegraphy.
AGE became involved in the radio industry when it imported RCA Radiola receivers manufactured in the USA in 1929 and marketing them simply as RCA models. AWA was using the word Radiola for its receivers at the time.
Models marketed in early 1930 by AGE included:

- RCA Radiola Model 44, a four valve table model using three screen grid Radiotron type UY224 valves and a Radiotron UX245 power valve. The receiver was equipped with Model 103 loudspeaker.
- RCA Radiola Model 60, an eight valve superheterodyne battery-powered receiver in table cabinet and fitted with Model 103 loudspeaker.
- RCA Radiola 21, a five valve receiver with two screen grid UX222 valves. Features included metal shielded chassis; walnut veneered cabinet; stencil-cut illuminated selector dial; and Model 103 loudspeaker.
- RCA Radiola Model 22, a battery-powered receiver with chassis similar to Model 21 but housed in deluxe Queen Anne style cabinet in several selected veneers. Batteries and loudspeaker were housed within the cabinet.

Following restriction on imported receivers by the Australian Government, AGE contracted with AWA in 1930 to provide its receiver requirements, and marketed them under the AGE label. Just before Christmas 1930, the AGE2 was released. It employed Radiotron valves, BTH loudspeaker; gramophone pick-up jack; and was housed in a table cabinet made in Australia by Beard Watson, well-known cabinet-makers.

About 1933, the company changed its name to Associated General Electric Industries Ltd and marketed its AWA manufactured receivers under the Hotpoint Band-Master label. Models released by AGEI during 1934 included:

- Mercury, a seven valve AC powered console cabinet receiver featuring AVC, noise suppression circuit, tone adjuster, and GE Aeroplane type dial.
- Talisman, a six valve AC powered set using Radiotron valves and employing AVC, safety fuses, GE Aeroplane dial, and enclosed in veneer cabinet with high lustre finish.
- Duette, a five valve superheterodyne reflex circuit receiver with AVC, local/distance switch;, rubber-floated tuning capacitor, GE Aeroplane dial with square clock face and enclosed in a table type cabinet.
- Jupiter, a five valve superheterodyne reflex circuit with vernier volume control, moulded cone dynamic loudspeaker GE Aeroplane dial, and housed in a veneer console cabinet.
- Pandora, a five valve AC powered superheterodyne reflex circuit with valve types 6D6, RF amplifier; 6A7, detector-oscillator; 6B7, IF amplifier, detector, AVC and AF amplifier; 42, power pentode output; and 80, full wave rectifier. The set was housed in a veneer console cabinet with piano finish.

Pandora was also produced as a battery-powered model designated Model 354B using valve types 34, RF amplifier; 1A6, detector-oscillator; 34, IF amplifier; 6B7, 2nd detector; and 38, output. IF was 175 kHz. A battery was 6 volt accumulator and B battery four 45 volt dry cell batteries in series with drain of 20 milliamperes.

In 1936, the company became Australian General Electric Ltd and released 16 Band-Master models housed in five different cabinet designs. Features included illuminated slide rule type dial with vernier control; three models equipped with metal envelope valves; one model fitted with magic eye tuning; and battery-powered models fitted with low consumption valves.

Model M656E, a five valve superheterodyne reflex circuit set was housed in a distinctive table cabinet of Canadian quilted maple of sand colour and provided with a rubbed satin finish.

By mid 1937, the range of Band-Master sets included 21 models ranging from five to eleven valve types powered by AC, DC, vibrator/accumulator or 32 volt home lighting systems. Phono-radio models with BTH motor and pick-up were also available.

In December 1937, receivers were being advertised as Hotpoint Band-Master with new features including high gain input circuit employing aerial coil with magnetite shell and core; Isometric tuning with stations evenly spaced on a straight line; air trimmer capacitors; and oscillator and IF coils fitted with magnetite cores.

The 1939 releases contained a number of new features including a giant console model with keyboard tuning; new G type Radiotron valves; moulded table cabinets; new phono-radio combinations; BTH pick-up and self-starting automatic stop motor; tandem volume/sensitivity switches; 12 inch (30 cm) projection welded loudspeaker with seamless moulded cone, dustproof and with high stiffness to mass ratio.

In 1940, AGE Ltd became a Proprietary Company. About this time staff who left the company to join the Services included J Watson and N Woodmore.

During the Second World War period, the company were suppliers to the Services of electrical equipment, insulating varnish for tropic proofing radio components, and thermostatically controlled crystal ovens for radio transmitters.

Marketing of Hotpoint Band-Master receivers resumed after the War with a range of mantel sets released about mid 1947. They included Model K55DE, a five valve AC powered dual wave receiver with 5 inch (125 mm) electromagnetic loudspeaker; Model K55DB, a battery-powered receiver with 5 inch (125 mm) permag loudspeaker; Model K55DV, an accumulator/vibrator powered set with 5 inch (125 mm) permag loudspeaker; Model K55DA, a mantel set employing 1.4 volt filament valves. All models had 'Hi-lo' tone control and were housed in wood veneer cabinets with high lustre finish.

About 1950, two new models were marketed:

- Model M7 Hotpoint Activator, a portable receiver in plastic case with handle and in-built power pack. By plugging the set into an AC power point and operating an 'Activate' switch, the batteries were said to be 'revitalised' and so prolonging battery life.
- Model P6, a four valve AC powered receiver fitted with an Australian made 6BV7 valve. The set was equipped with a continuously variable tone control and a new AVC circuit design. It was housed in shatterproof plastic case in colours of lustrous brown, burgundy, grey or ivory.

In 1955, AGE Pty Ltd changed its name to Australian Electrical Industries Pty Ltd (AEI) and from about that time the label Hotpoint Band-Master was changed to just Band-Master until marketing of radio receivers ceased during the 1960s.

* **AUSTRALIAN ENGINEERING EQUIPMENT CO., PTY LTD, MELBOURNE**

Components, including TCC capacitors since about 1931.

* **BATY C S AND CO., PERTH**

Batyphone receivers. First produced late 1920s.

* **BEALE AND CO., LTD, SYDNEY**

Manufacturers of high quality radio cabinets and marketers of Beale and Panchromatic label receivers, 1934–37. Managing Director was Ron Beale.

Beale models released during 1935 included Mistral, Armoire, Special Exhibition and De Luxe Radio-phono combination, receivers. Models marketed in 1937 included a range of five valve MF band and dual wave series powered from AC, AC/DC or accumulator/vibrator sources.

* **BLOCK AND GERBER LTD, YORK STREET, SYDNEY**

The Block and Gerber Ltd company was registered on 1 April 1926. It was associated with Weldon Electric Supply Co., Ltd which in 1927 was sole distributor in Australia of the Royal Cruiser, five valve receiver manufactured by the American Bosch Magneto Corporation. The receiver was encased in a solid walnut table cabinet with unified control which provided single dial simplicity of operation with two dial advantage.

Among the early Weldon brand receivers released by Block and Gerber Ltd were Models E1 and 101 which were both available during the 1930 Christmas period. The Model E1 was a four valve set with a screen grid valve and a 245 power valve; record replay facility; and Magnavox loudspeaker. The Model 101 was a three valve set.

The 1931 releases included:

- Model 300, a table cabinet receiver.
- Model W310, a three valve AC powered receiver with Magnavox dynamic loudspeaker.
- Model W315, a three valve AC powered receiver.
- Model BG35, a deluxe six valve receiver featuring direct coupling; electrolytic capacitors; electrostatic shielding; single dial control; four variable mu valves; type 247 pentode; type 280 rectifier; and pick-up terminals and switch.
- Model BG34, a three valve direct coupled console with variable mu screen grid valve; type 247 pentode output; and 280 rectifier.

Console models W310 and W315 were housed in cabinets of richly patterned Queensland walnut veneer, enriched by carved mouldings and carvings.

The first Weldon superheterodynes were constructed in late 1932, with Model BG55, a six valve receiver with six and seven pin valves, being made complete with cabinet for sale to the public through Radio Shops or as a chassis only, version as a Badge Engineering product for sale by others in their own cabinets.

In mid 1933, the company produced Model BG65, and AC powered six valve superheterodyne set with 465 kHz IF. Circuit was an autodyne superheterodyne with two IF stages and type 57 valve resistance coupled to a type 59 pentode. Components employed in assembling the receiver were standard commercially available types which could be purchased from most Radio Shops. This enabled do-it-yourself constructors to purchase components and built their own sets to the company design. Several of these sets can be seen in vintage radio collections, with some being of assembly standard at least equal to that of the factory assembled units.

In 1934, the company stocked a range of other company brands for sale through its outlets. They included AWA Fisk Series Models initially but later included Airzone, Stromberg-Carlson, Emmco, Astor and Mullard brands. During the year, E C Covell, late of Noyes Bros, became Manager of the Radio Parts and Accessories Department.

A new range of Weldon models were released in 1935 and included:

- Model Mid-1935, a five valve AC powered superheterodyne set in Aerotron Jubilee console cabinet.
- Model 8/35, a five valve AC powered superheterodyne receiver in Shelley console cabinet and provided with full vision clock face dial.
- Model 7/35B, a seven valve battery-powered superheterodyne receiver in Shelley console cabinet and provided with AVC and clock face dial.
- Model 10/35, a six valve dual wave superheterodyne receiver in Milton console cabinet.
- Model 11/35, a seven valve dual wave AC powered receiver with push-pull output and housed in Milton console cabinet.

* **BORTHWICK, EVERITT AND CO., SYDNEY**

The company were manufacturers of Beco brand receivers 1936–39. The brand name was derived from the initials of the founders plus 'co'.

The company, founded by Kevin Borthwick and Arthur Everitt about 1935, manufactured Beco label receivers, chassis and radio parts.

Kevin worked as an Engineer with Raycophone Co., for five years and with AWA for six years before joining with Arthur Everitt to form the company.

Arthur received his technical education from Sydney Technical College and commenced work with AWA in 1923 as an Apprentice. Following completion of the Apprenticeship he left AWA to join Stromberg-Carlson as Chief Tester. After a period with New System Telephones Aust Ltd as Assistant Engineer, he joined Lekmek Radio Laboratories as Manager Service Department before joining up with Kevin Borthwick to set up the business. Arthur was an Associate of the Institution of Radio Engineers (Australia).

In 1936, the company released eight models with one being a five valve dual wave battery-powered receiver in a console cabinet. The others were AC powered models. All models were superheterodyne types employing an IF of 465 kHz but Model 870 released in 1939 employed an IF of 460 kHz. It was a five valve dual wave receiver in console cabinet.

Included among the 1936 releases was the Mystic, a Universal powered MF band five valve mantel set featuring combined reading lamp and midget radio receiver. The lamp was a standard 240 volt 75 watt single coil filament lamp and acted as series voltage dropping resistor for the receiver valve heaters. The receiver employed an IF of 460 kHz.

During the 1937–39 period, more than 40 models with brand names Wonder, Weldonette, Mystic and others were released. They included to combined clock/radio arrangements with five valves. Model 2/39D was an AC powered dual wave band receiver; Model 6/39D, a six valve console cabinet dual wave band receiver incorporating tele-tune dial system of pre-tuned circuit type. Models 2/39DG, 2/38A and 2/39G were five valve Grandfather type radio/clock models. The 2/39G had dual wave capability.

During 1940–41 about seven models including four dual wave models were marketed but no further models were released during the rest of the War years.

Weldonette receivers became available again in 1946, with several new designs being released in 1948.

In 1949, the company produced the York four valve MF band AC powered kit set complete with bakelite cabinet and all components including valve types 6J8G, 6G8G, 6V6G and 6X56GT. As an alternative, the York Foundation Kit was available, aimed at the small manufacturing market.

* **BRASH M AND CO., PTY LTD, MELBOURNE**

Distributors of Stromberg-Carlson and Radiola receivers from 1927 and manufacturers of Linconola receivers and radiograms.

* **BRITISH AUSTRALIAN RADIO CO., PTY LTD, MELBOURNE**

BAR Universal radio receivers.

* **BRITISH GENERAL ELECTRIC CO., LTD, MELBOURNE**

The company began its involvement in the radio industry in Australia by importing Gecophone brand receivers and radio components manufactured by General Electric Co., Ltd, England.

The Adelaide Branch of BGE located in Gilbert Place had a wide range of receivers and components in stock in 1925 including Junior and No 1 crystal sets; Model 2, a two valve receiver, and four valve table receiver with plug-in coils. Components included variable and fixed capacitors, crystal detectors, crystals, headphones, coils, coil holders, loudspeakers, rheostats, switches, AF transformers, variometers, plugs, sockets, lightning arresters, Osram valve types DE2, R, DE8, DE6, DE5, DER and DE3. The type R was a bright emitter while others were dull emitter types.

A number of Gecophone receivers were imported over the years, even though many included long wave capability not of any use to Australian listeners after 3LO, 2FC and 6WF converted to medium wavelengths. Models seen in vintage radio collections include Victor 3 battery set; Model BC3130, AC powered four valve TRF set; and Model BC3240, an AC powered TRF set with screen grid valves.

When receiver import restrictions were imposed by the Australian Government, the company decided to market receivers under the brand Genalex, manufactured under contract for BGE by Thom and Smith Ltd, manufacturers of the Tasma brand of receivers.

In April 1932, the company announced the release of a range of 'Empire made' AC powered Genalex receivers built in Australia, but employing English manufactured Osram valves.

The range included:

- Model A4, a four valve receiver with screen grid valve detector; a variable mu valve; pentode power valve; and rectifier valve. It featured tone control, volume control, single dial tuning, gramophone pick-up jack, and dynamic loudspeaker.
- Model A5, a five valve receiver with screen grid detector; variable mu first audio; screen grid second audio; pentode power valve and rectifier.
- Model A6 Standard, a six valve receiver housed in high quality walnut veneer cabinet. It featured screen grid detector; first and second variable mu audio; two pentode valves in push-pull output; and rectifier.
- Model A6 De Luxe, similar chassis to A6 but housed in deluxe piano finished veneer cabinet.
- Superheterodyne Six Standard housed in console cabinet and fitted with first and second screen grid detectors; variable mu intermediate; oscillator; power pentode; and rectifier.
- Superheterodyne Six De Luxe, similar chassis to Standard, but housed in deluxe console cabinet.
- Model A6, Phono-radio combination of Model A6 chassis with record replay facility, including turntable, motor and pick-up.
- Superheterodyne Six Phono-Radio combination of the Superheterodyne Six Standard chassis and record replay facility, including turntable, motor and pick-up in console cabinet.

All models were AC powered and equipped with Osram valves. To take advantage of the increased Christmas period sales, the company released an eight valve AC powered superheterodyne set in high quality cabinet featuring parallel pentode output valves feeding dual loudspeakers.

At the 1933 Sydney Radio Exhibition, BGE displayed a range of receivers including the Dapper Five and the Bureaudio (Bu-Radio), a five valve superheterodyne combined radio/writing desk in a cabinet of Queen Anne design. They also displayed five and eight valve battery-powered models. All models were equipped with Osram catkin all-metal valves. Components on display included GEC Home Broadcaster microphone, and the Electric Record-Changer capable of automatically playing through eight records.

Two popular Genalex battery-powered receivers of the mid 1934 period were Models 190 and 150:

- Model 190, a superheterodyne receiver with 460 kHz IF and including Osram valve types 77, autodyne; VS24; 75; and two B21. Features included Class B output with push-pull driver feeding an Amplion type 01 loudspeaker; AVC; and noise suppression circuit. Batteries included 6 volt 80 Ahr A battery, and three Ever-Ready 45 volt heavy duty B batteries in series. Cabinet was a highly-figured Queensland maple type with semi gloss polished finished.
- Model 150 employed 175 kHz using separate oscillator circuit and self bias. Valve types were three S23 and five L210 Osram valves. Loudspeaker was an Amplion type L1 permag type. Batteries were 2 volt accumulator type A battery and four Ever-Ready 45 volt heavy duty B batteries in series. Cabinet was a Senior model of highly-figured Queensland maple veneer with satin finish.

In 1936, BGE marketed a range of Genalex Dual Wave Fives. They included Model BC365, an AC powered set in Lachlan table cabinet; Model BC365, same chassis in Glenelg console cabinet; Model BC350, an AC/DC powered receiver in Lachlan table cabinet; Model BC350, same chassis in Glenelg console cabinet; and Model BC310, a battery-powered set in Glenelg console cabinet. Features included AVC; Sirufer IF transformers and air trimmers; counterbalanced tuning control; full vision clock face dial, and high quality cabinet designs.

With the availability of the 2 volt Eveready Air-Cell as an A battery supply in mid 1937, Genalex models were designed to take advantage of this power source. They included:

- Model BC470, Peel, a four valve MF band table receiver.
- Model BC470, Nepean, a four valve MF band console cabinet receiver.

* Model BC480, Peel, a five valve MF band table receiver.
* Model BC480, Mitchell, a five valve dual wave console cabinet receiver.

In mid 1939, the company released one of its most comprehensive ranges including some 50 different models. The range featured AC, AC/DC and battery-powered models. The AC powered range included MF band receivers for local reception, and five and six valve dual wave models housed in mantel or console cabinets; push-button tuning; and radiogram models.

Battery-powered models were available to suit operation from 2 volt and 6 volt accumulator filament supplies, accumulator/vibrator for HT supplies, home lighting power systems and all dry cell batteries.

In early 1941, BGE released the Overseas Ten receiver manufactured in England by the General Electric Co., Ltd (GEC). The receiver covered the bands 11–550 meters and 900-2100 metres by continuous switching. The 10 valve superheterodyne receiver employed an independent HF unit, two IF stages, chromoscopic dial and dual dynamic loudspeakers. It was housed in a table model cabinet of walnut veneers with a high lustre finish.

From about 1953, Genalex brand receivers were replaced by BGE brand which sold into the 1960s.

Included among the large staff employed by BGE over many years were D E Webster, A F Ward, M R Wood, E Higginbotham, T Whitcomb, H M Tyler, Clem King, R H T Jennings and John Tait. John Tait who worked for BGE for about 14 years was appointed Manager, Radio and Telephone Department in 1931. He left the company to form Sterling Radio Ltd with N H Buchanan.

* **BURNDEPT (A/ASIA) LTD, SYDNEY**

Ethophone receivers, crystal detectors, Ethovox loudspeakers, Super Vernier dial.

* **BURGIN ELECTRIC CO., LTD, SYDNEY**

Burginphone, Beco and Becolian receivers; components.

In 1923, Ossie Mingay was Manager, Radio Apparatus and Telephone Department.

* **BYER INDUSTRIES PTY LTD, DORCAS STREET, SOUTH MELBOURNE**

Disc recording blanks, Junior disc recorder, AT12 Magnofilm tape adaptor, microphone stands and booms, crystal and ribbon microphones, Model 55 domestic tape recorder, Byer 66 and 77 and Magnecorder professional tape recorders.

(Max Byer, Proprietor; Leon Sebire, Engineer; Jack Richardson, Factory Foreman)

* **CADET RADIO CO., PTY LTD, ABBOTSFORD**

The company produced Cadet brand radios with at least six models being produced in 1946–47 in AC and battery-powered designs. All were five valve designs except Model GMA which employed four valves. Model P5 was a five valve portable set.

* **CLASSIC RADIO PTY LTD, MALVERN**

During 1946, three models of receivers, all AC powered were produced. Two models, 580 and TG8, were dual wave radiogram designs employing an IF of 453 kHz. The other was a dual wave mantle set.

* **COLONIAL RADIO PTY LTD, MELBOURNE**

Operatic receivers, Melbourne superheterodyne kits, potentiometers.

(Archibald Cawthorne, Myles Hayman and F R McBride)

* **COMMONWEALTH MOULDING CO., LTD, ARNCLIFFE**

Moulders to the radio and electrical industries with products under the Marquis label including:

• Knobs

The Marquis range of moulded knobs with case hardened grub screws designed to fit a 0.25 inch diameter shaft. The range offered a choice to harmonise with various styles of cabinets and escutcheon plates. Standard finishes were black, walnut and black/brown. Types were octagonal prism, octagonal prism with rim, ornamental, palm leaf ornamental, laurel leaf ornamental, ribbed ornamental, scroll ornamental, four-leaf clover ornamental, knurled edge, octagonal, indicator and lever switch knob.

• Improved wire wound with vernier drive potentiometers totally enclosed in specially moulded bakelite case. Resistance values ranged from 1500 to 2000 ohms.
• Multiple all wave switch designed for use with all wave receivers and short wave converters.
• Improved multiple all wave switch providing up to six positions with silver phosphor bronze contacts.
• Local distance switch fitted with two contacts.
• Moulded plate finished in walnut with numerals engraved in white.

* **CONLON S M, RADIO CO., SURRY HILLS**

The company was established by Samuel Conlon in 1937. Sam was educated at Melbourne Technical College where he obtained an Expert Electrical Engineers Certificate. He later graduated from Melbourne University with Degree of Bachelor of Science.

He obtained his early technical experience with the Postmaster General's Department, Melbourne where he worked for some 10 years as Engineer on installation and maintenance of telephone equipment including exchange and subscribers equipment.

He left the Department to concentrate on the commercial side of Electrical Engineering and made overseas trips spending three years in the USA working with several firms obtaining valuable experience in technical design and marketing techniques.

While in the USA, he negotiated arrangements with a number of electrical firms to represent them in Australia. On his return, he spent three years marketing their products.

In 1929, Sam made a visit to England and Continental Europe to study the latest in the development of Radio Technology, particularly in domestic receiver designs.

After returning to Australia, he took up a position of Sales Manager with the Lekmek Radio Laboratories which had been founded in 1931 by Norm Gilmour who, like Conlon, had been a former PMG's Department Engineer.

Sam later established his own company to design and manufacture receivers at 26 Kippax Street, Sydney with W P Lynch as Works Manager. From about 1938, operations were being conducted at 26 Rainsford Street, Surry Hills and later, at 60 Sophia Street, Surry Hills.

In 1937, the company was producing a range of chassis units and complete receivers under the Conlon label or as Badge Engineered models for other distributors.

During the War years, the company produced a range of Amenity receivers for the Services.

Production of domestic receivers was deferred during the War years but production resumed during 1946 with a range of models which included a five valve dual wave table receiver, a civilian version of a Services Amenity receiver. The range also included four valve mantle and portable sets featuring 1.4 volt filament valves produced during 1947–48.

* **CONTINENTAL CARBON RESISTOR CO., PTY LTD, REDFERN**

Components, including bakelite moulded insulated resistors and coils, IF transformers and switch units.

* **CORNEY'S RADIO, NEWCASTLE**

Founded by Eric Corney as Corney's Radio at 487 Hunter Street, Newcastle, later becoming Corneys Pty Ltd.

The business was established in 1929 as a Radio Retailer/Repairer and was one of the best-known Radio Shops in Newcastle operating continuously at the Hunter Street address until its closure on 2 May 1964.

At its peak, the business employed a staff of four in the workshop and showroom area and three on sales activities.

Corneys was the first shop in Newcastle to stock television receivers when a batch of BGE receivers was purchased for sale.

* **CRAIG AND CO., LTD, PERTH**
Craig Universal brand receivers.

* **CROWN RADIO MANUFACTURING CO., SYDNEY**
(Crown Radio Products Pty Ltd from 1937)
Range of radio components, kit sets and coil sets. Typical products in 1934 included TRF aerial and RF coils,; superhet oscillator coils; IF transformers for 175 or 465 kHz IF; midget IF transformers for auto and midget receivers; IF bases; wire wound resistors designed for voltage dividers, bias resistors etc; wire wound potentiometers in sealed bakelite cases; RF slot wound and honeycomb RF chokes; accessories such as soldering lugs, screen grid clips etc. In 1945, the company released a range of adjustable inductance Permatune coils designed to replace earlier broadcast band coils (J B Phillips; F P Jones; James Edwards, Chief Engineer; Allan Parcell; Layton Cranch, Chief Engineer; Arthur Spring; Harold O'Shea).

* **DARELLE PRODUCTS, BRISBANE STREET, SYDNEY**
The firm were Radio, Mechanical, Electrical and Construction Engineers. In 1932, Factory Manager, B F Israel and Technical Engineer, Eric Fanker were responsible for design and production of a range of superheterodyne receivers. They included Model 235S, a five valve receiver and Model 327, a seven valve set. A six valve model was included in the range. All were AC powered available as radio only, or as radio-phono combinations in standard and deluxe cabinets. Features included variable mu and pentode valves, electrolytic capacitors and electrostatically screened inductors in the power pack.
The Darellette table superheterodyne was also a popular four valve set. It employed a 247 type pentode valve as combined second detector and output valve.
In 1933, a new range of four, five and six models were released plus an eight valve set employing visual and silent tuning; AVC; noise suppression and dual dynamic loudspeakers. It was also available as a radio-phono combination. Cabinets for Darelle receivers were manufactured by Beard Watson and Co.

* **DAVIES AND CO., PERTH**
Ether Eagle receivers.
(R P Davies)

* **DICKIN PTY LTD, LEICHHARDT**
Radio cabinets.
(A J Dickin)

* **DOE A G, EPPING**
Manufacturer Arion test instruments, audio and power transformers.
(Founded by A G Doe, University Science and Engineering graduate, 1930)

* **DUNCAN AND CO., LTD, ADELAIDE**
A company established in Pirie Street, Adelaide, about 1931 as wholesaler of radio receivers including Vasco label made by local manufacturer Reg George. Company Managing Director was H F Peake. The company had a Branch Office in Commercial Street, Mt Gambier.

* **D W RADIO CO., NAREMBURN, SYDNEY**
The company was founded by Herbert and Frank Warby who established a factory at Willoughby Road, Naremburn to design and manufacture radio equipment.
One of the company's early products was the DW Short Wave Converter released just prior to Christmas 1931. It employed four valves including rectifier and was enclosed in an aluminium case. An updated version was produced 12 months later.
In 1934, a range of AC and battery-powered models were available. The battery models included:
- Model 50, a five valve receiver with 6C6, autodyne; 24, IF amplifier; B217, 2nd detector; B217, driver; and 240 Class B output. Amplion type 03 permag loudspeaker was employed. Batteries were 6 volt Clyde accumulator A battery; 150 volt heavy duty Ever-Ready B battery and WP42, Ever-Ready C battery.
- Model 60, a six valve set with 34, RF amplifier; 6C6, autodyne; 34, IF amplifier; two B217; and B240 Class B output. Batteries were similar to Model 50.

In 1935, the company produced a range of receivers under the label Tela-Verta. Included was Model 644, a six valve dual wave AC powered console featuring the newly-released Philips valves; AVC; preselector; RF stage; Efco push-pull type 8-50 dial; Colacode tuning with wave changes being indicated by coloured lights; Amplion Q type loudspeaker; Acorn chassis and cans; Precedent litz wound IF transformers; and IRC metallised resistors and tapered potentiometers. Band coverage was 200-500 metres and 19-53 metres.
At the time, the Tela-Verta range comprised over 30 models.
During the War years, the company diverted its resources to manufacture of equipment for the Services. Production of Tela-Verta receivers was resumed in 1946, with Model T46A being the first released. During that period, the company business was located at 466 Victoria Avenue, Chatsworth and was trading as D W Radio Co., Pty Ltd.
In mid 1947, the company produced Model TV65V, a vibrator battery-powered mantel set aimed at the country listener. It was a six valve set with features including valve types 1M5G (two), 1C7G, 1K7G, 1L5G and 6X5GT; low battery consumption; auto dial light switch; AVC; battery switch incorporated in volume control; Permatune IF transformers and coils; non synchronous vibrator and 6X5GT rectifier.
At least nine models were available during 1948 with the sets being available from Tela-Verta Radio Co., a Division of D W Radio Co., Pty Ltd, 466 Victoria Avenue, Chatsworth; Metropolitan Electronic Parts Pty Ltd, Broadway and distributors in Brisbane, Melbourne and Perth.
One popular Tela-Verta receiver was the Tela-Verta Musiclock, a five valve superheterodyne radio-clock combination with a Programme Selector with auto switch on/off facility. Another was Model 204C, a five valve MF band mantel set in plastic cabinet with colours walnut, cream or green, built-in aerial, and 5 inch (150 mm) loudspeaker.

* **ELECTRIC SUPPLIES AND ENGINEERING, SYDNEY**
Receivers, including Telefunken models, components and accessories.

* **ELECTRIC UTILITIES SUPPLY CO., SYDNEY**
Assembled receivers including crystal sets and multi-valve receivers, kit sets, a wide range of radio components including valves.
The company was formed about 1912 by Cecil Stevenson, a graduate of the Sydney Technical College, and Electrical Engineering Contractor, with a retail outlet shop at 605 George Street. After the War, the business was relocated to 619 George Street. A wireless telegraph set complete with high voltage spark coil and receiver with a coherer was part of the shop display at the time of the outbreak of the First World War in 1914. Like all wartime radio transmitting apparatus, the equipment was placed in a sealed crate for the duration of the War.
After the War, radio equipment and components were added to the stock of electrical goods with radio soon becoming the major

part of business. The premises were named Radio House about 1923.
(Cecil Stevenson, Proprietor; Murray Stevenson, Les Stevenson)

* **EXPRESS UNIVERSAL INSTRUMENT CO., PETERSHAM**
Radio test instruments.
Proprietor was Albert Thorrington who had been associated with the commercial side of radio since 1923. He founded Express Instrument Company in June 1932 with A J Simpson but became sole Proprietor on 5 February 1932.

* **FERRIS BROS, PTY LTD, EAST SYDNEY**
First receivers produced at Mosman works in 1932. The company later specialised in auto receivers. Four receiver models produced during 193–38 employed IF of 175 kHz. After 1939, IF was changed to 455 kHz.
Model 80, an eight valve set first produced in 1946, was designed for omnibus use and included a PA system facility.
Model 74, first released in 1947 operated as an AC powered mantel set or as an auto receiver operating from the car accumulator.
In 1962, Model 184 a transistorised radio was manufactured by Ferris. It was a very versatile unit being used as auto, home or portable receiver. By mid 1960s, several models were marketed and included the Volumatic II, a very popular receiver.
Receiver brands included Ferris and Ferris-Fultone.
(George Ferris, Managing Director; W M (Chum) Ferris, founder and Technical Executive; E S Wyatt; Karl Trankle; Bob Ditchburn; F B Allison; Stewart McGregor)

* **FINDLAYS PTY LTD, HOBART**
Radio Service Department.
(John Dodds, Service Engineer)

* **FIRTH BROS, PTY LTD, MELBOURNE**
The company was established by B G and E G Firth at 149 Lonsdale Street, Melbourne. The company were manufacturers of Precedent radio receivers, Monitor loudspeakers and radio parts. Chief Radio Engineer of the company was Fred Canning who was appointed to the position in 1931 and remained with Firth Bros, until about 1937 when he took up an appointment with The Gramophone Company Ltd. Other technical staff with the company during the period of its existence included Howard K Love and Lay Cranch.
The 1934 Precedent range included:

- Model G34, a four valve superheterodyne receiver in a console cabinet and fitted with 6 volt series valves. It featured dashboard control with micromatic tuning by a graduated cam action providing visual volume and tone control. Three dials on the receiver were indirectly illuminated. Manipulation of the volume control enabled the operator to set each station signal to a predetermined volume level.
- Model F34, a five valve superheterodyne set with dashboard control with micromatic tuning. Micrometrically centred coils housed in bayonet locking coil shield ensured maximum sensitivity of the receiver. Patented valve shields provided maximum shielding and effective envelope cooling.
- Model 034, a four valve battery-operated superheterodyne receiver employing 175 kHz IF and valve types 1A6, mixer; 34, IF amplifier; 32, detector; and 33, output. A battery was a 2 volt 50 Ahr accumulator, and B battery comprised three 45 volt heavy duty B batteries. Features included Saxon permag loudspeaker, auto bias, and capacity coupled preselector. Cabinet was a console type with flat finish.

An all wave kit set was also produced by the company. It was designed with 175 kHz IF and included valve types AK1; two E447; E424, regenerative power grid second detector, transformer coupled to E443H pentode; 1561, rectifier. Controls included tuning, reaction, regeneration, auxiliary tuning midget capacitor for short waves, and volume. Bands covered were 18–550 metres.
Other models included A34, three valve superheterodyne; H34, six valve superheterodyne with twin loudspeakers; J34, seven valve superheterodyne with push-pull output and twin loudspeakers; K34, five valve battery-powered set; and AC/DC six valve superheterodyne.
In late 1934, the company announced that some 30000 Precedent receivers were in use in Australia, with 10000 being sold to Victorian listeners.
The 1935 range included new models featuring delayed AVC; a mechanical muting device to eliminate noise between receivable station carriers; tuning meter; exclusive visual tone and volume indicator; new type Aero dial; phonograph replay facility; side contact valves; and Precedent loudspeakers. The company also released the Precedent Short Wave Selector which enabled any current MF band Precedent receiver to be converted into a short wave receiver.
The Precedent brand appears to have disappeared from the market about that time.

* **FOX AND MACGILLYCUDDY LTD, SYDNEY**
Fox receivers, coil sets and parts, Blue Spot loudspeakers.
(Terry Fox)

* **GAGE, H, NORTH FITZROY**
Radio cabinets.

* **GLADIOLA CO., ADELAIDE**
The company originally furniture manufacturers and later in the mid 1920s as the Gladiola Music Co., distributed pianos, pianolas and sheet music.
About 1932, the company assembled receivers and fitted them into cabinets which the company manufactured. Models produced included mantel and console receivers plus a radiogram console unit. Largest receiver released was a nine valve model. Receiver production ceased during the Second World War years but resumed for a few years after the War with the business closing down in the 1980s. Proprietor was William Black with son, William (Junior) being responsible for the firm's radio activities.

* **GRAND OPERA RADIO, ELSTERNWICK**
Grand Opera receivers.
(Leslie Yelland, Francis Yelland)

* **HARRINGTONS LTD, SYDNEY**
Imperia, Raycophone and Gilfillan receivers and components.
(Charles Tyrrell, Oswald Mingay, Daniel Morand, W S Corfield, John Duffy, William Gel, William Godfrey, John Harrington, S G Homberg, T J Matthews)

* **HAZELL AND MOORE LTD, SYDNEY**
Red Seal receivers.
(Managing Director, E J Hazell; Manager, J S Moore)
The business was registered on 26 June 1924.

* **HILCO TRANSFORMERS PTY LTD, CARLTON**
Radio transformers and chokes.

* **HOMECRAFTS PTY LTD, MELBOURNE**
The company stocked a large range of radio components for the enthusiast before the establishment of broadcasting stations. In 1922, components included loudspeakers, accumulators, dry cell B batteries, variable capacitors made with brass or aluminium plates, coils, coil sliders, honeycomb coils, coil mounts, dials, knobs, switch arms, AF transformers and crystal detectors.
In 1925, it marketed the locally assembled Homera Radiophone receiver brand.

By 1929, the company employed a team of skilled Technicians in its Radio Department to assemble a range of receivers and kit sets and to provide technical assistance to customers. Receivers assembled locally and marketed under the Elroy label included:

- Elroy De Luxe crystal set employing double circuit tuning to minimise adjacent station interference. It was housed in a small polished wooden cabinet with a bakelite sloping top. A Melba model was also produced.
- Elroy Selective Three, a three valve receiver fitted with dual wave adaptor enabling the set to receive bands 150–300 metres, and 300–500 metres. It had one dial tuning using a full vision dial, and was supplied with an Amplion AR38 loudspeaker.

The brand was named after Mr P H McElroy who founded the company about 1905 to cater for the needs of a wide range of hobbyists. In June 1925, the company began publication of a magazine 'The Homecraft Magazine', a practical constructional magazine for the hobbyist covering subjects such as model engineering, meccano, fretwork, photography, chemistry, practical electrics, model aeroplanes and radio.

In 1934, Homecrafts marketed two popular battery-powered receivers:

- Four valve superheterodyne receiver employing valve types 1A6, mixer; 32, IF amplifier; 19, 2nd detector; 19, output, feeding a Rola permag loudspeaker. A battery was a 2 volt accumulator and B battery comprises four 45 volt batteries in series. Controls comprised tuning, reaction on IF, volume and sensitiser on second detector.
- Three valve receiver employing valve types 32, RF amplifier; 19, detector and driver; and 19, output. A battery was 2 volt accumulator with 0.24 ampere drain, while B battery was 120 volts provided by two 60 volt batteries in series.

In the mid 1930s, Homecrafts were country distributors for Astor receivers and Diamond Radio Batteries as well as having a large stock of components.

During this period, Managing Director was Sladen Gibson and Sales Managers were D Campbell, Country; R Blackwell, City.

* **HOWARD RADIO PTY LTD, RICHMOND**

The company which manufactured Howard and Regent brand receivers was established about 1928 with Fred Henderson being appointed Manager and Director of the company. Before joining Howard, Fred had wide experience in the construction and operation of wireless telegraphy ship's installations and land-based radio stations in England, Antarctica and Australia. During the First World War, he served with the RAN Radio Service as Instructor, Inspector of Facilities, and later, as Supervisor of the Randwick Workshops which in its earlier years constructed the equipment for the Coast Radio Stations around the Australian coastline. He was an active member of The Institution of Radio Engineers (Australia) and was one of the inaugural members of the Victorian Division when it was established in 1933.

Two of the early receivers released by the company were 1934 models comprising a five valve superheterodyne console receiver with twin dynamic loudspeakers, and a four valve console model. The company had been manufacturers of pianos for many years and used the resources of the piano factory to manufacture high quality radio cabinets for its own receivers and for sale to other companies producing only chassis.

Up till 1934, the company manufactured receivers only, but during that year, set up a wholesale outlet to sell radio components and parts, including valves, to the industry. It also set up a Service Department for servicing its own receivers. The Parts side of the business was controlled by Jack Phillips who had some 10 years experience in wireless in the Air Force and the Navy. Les Adams who had previously worked on Navy and Police communications equipment for many years was in charge of the Service Department.

Battery-powered receivers formed a major part of the 1934 models. They included:

- Model 461, a four valve superheterodyne console cabinet receiver with 175 kHz IF and valve types 32, mixer; 34, IF amplifier; 32, detector; 33, output. A battery was a 2 volt accumulator and B battery, three 45 volt dry cell batteries in series.
- Model 462, a five valve superheterodyne console cabinet set with 175 kHz IF and valve types 34, RF amplifier; 1A6, mixer; 34, IF amplifier; 32, detector and AVC; and 33, output. Loudspeaker was a Rola permag type. Batteries were 2 volt accumulator A battery, and three 45 volt heavy duty dry cell B batteries in series.
- Model 450, a TRF with valve types 32, RF amplifier; 30, detector; and 33, output. Batteries comprised 2 volt accumulator A battery and three 45 volt dry cell B batteries in series.

* Model 450A, similar to Model 450 but with fixed bias using C battery.

By 1936, the company had expanded its range of wholesale radio products by including Mullard receivers and valves, Garrard motors, Erpees headphones, Meltron transformers, Diamond and Ever- Ready batteries.

About 30 models were available in the Howard 1938–39 range and included AC, Universal, battery and vibrator/accumulator powered models. Model 986, an eight valve combination radiogram set was provided with an automatic record changer. Model 986A was designed to play mixed 10 inch and 12 inch records. The receiver used an IF of 460 kHz and employed valve types, 6K7, 6K7, 6K8, 6Q7, 3/6F6G and 5Z3 in line.

Models 884/885/886 and 886A incorporated a band-spreading system in which the normal short wave range was split into three full dial scale for each section.

No receivers were produced during the War years after 1939 but production resumed for a time about 1948.

* **HYDRO PRESS CO., PTY LTD, RICHMOND, VIC.**

Manufacturers of a range of Hypresco brand receivers. Badge Engineering work was also undertaken for a number of distributors including Maples, D & W Chandler and others. A range of the company designs was displayed at the Amateur Wireless Exhibition, Melbourne in 1932. A distinctive feature of many early Hypresco models was the employment of high quality cabinets.

* **INSULATING TILE LTD, ADELAIDE**

Proprietor and Chief Engineer of Insulating Tile Ltd was Ronald Wigg. The company produced the Expona range of phonographs, radio receivers and loudspeakers during the period 1929 to 1932. The firm was originally founded to produce ITCO cast gypsum fireproof building materials but with the slump in the building industry during the Depression years, the company diversified into phonographs and radio receivers.

The tone arms, sound boxes and turntables for the phonographs were imported but the horns were locally designed and made in Adelaide by a tinsmith in North Adelaide. Horns were manufactured in lengths of five, six and a half, seven, eight and a half and nine feet. The completed phonographs were distributed through Harris Scarfe Ltd, Grenfell Street, Adelaide, who had a large Radio Department.

When sales of phonographs declined, the company manufactured radio receivers mostly three valve mains powered units fitted in a cabinet with cone mounted loudspeakers made on the premises and ranging in diameter from 12 to 22.5 inches. In 1930, about 100 receivers were manufactured with some designs featuring folded horn loudspeakers.

During 1931, Magnavox moving coil loudspeaker units replaced the locally manufactured cone loudspeakers. The company also designed and manufactured radiograms which embodied tweeter horns and Jensen concert dynamic loudspeakers.

Expona horns up to 14 feet in length were also manufactured for public address systems. In 1930, the company was awarded a Silver Medal at an Exhibition for one of its loudspeaker units.

* **INTERNATIONAL RESISTANCE CO.,(A/ASIA) LTD, MARRICKVILLE**
Components with specialisation in fixed and variable resistance units. In mid 1930s, range included Type BT insulated metallised; Type F metallised; Type MS noise suppressor; Heavy Duty wire wound types; Types FH and MG ultra high ohmage; Type BW insulated wire wound; Type WW1 precision wire wound; Type MCA noise suppressor; Type MD noise suppressor; Lug type precision wire wound; Type WW3 precision wire wound and Type C volume control.
Wm J McLellan and Co., were sole Australian Agents for IRC products.
Max Walker, William McLellan were Directors of IRC established November 1934.

* **INVINCIBLE RADIO CO., SYDNEY**
Invincible radio receivers.

* **JACKSON AND MACDONALD, SYDNEY**
Manufacturers of high class radio cabinets.

* **JAMES MANUFACTURING CO., LTD, LEICHHARDT**
Subsidiary company of New System Telephones Pty Ltd with NST receivers.
In 1934, Chief Engineer of James Manufacturing Co., Ltd was Richard Kennell. At the time, he held other important positions including Chief Engineer Telephone Division, New System Telephones Pty Ltd which later joined Electricity Meter Manufacturing Co., to become EMAIL; Chairman of Directors of Radio Interests Ltd; Radio Manufacturer's Representative with The Electrical Radio Association of New South Wales; foundation member of The Institution of Radio Engineers (Australia) and Councillor serving on the Institution's Examination and Papers and Lecturers Board. He was also a Member of the Institute of Radio Engineers USA. In the late 1930s, he became Manager of Siemens and Halske. Prior to joining Industry, he was employed in the Postmaster General's Department as Telephone Engineer in the Electrical Engineers Branch for 12 years.

* **A E JANSEN, EUDUNDA**
The company manufactured a range of B battery eliminators, battery chargers, filament transformers and aerial mast fittings. Proprietor was A E Jansen.

* **JENSEN RADIO MANUFACTURING CO., SYDNEY**
Loudspeakers.
(Charles Forrest)

* **JONES, DAVID LTD, SYDNEY**
D J Standard receivers, components and accessories.

* **LARKINS, A J, SYDNEY**
Rheola receivers.
(Albert Larkins)

* **LAWRENCE AND HANSON ELECTRICAL CO., LTD**
Sterling, Lekmek and Airway receivers and components.
(W H Stokes, Engineer, Alf Shuttleworth)

* **MAGNAVOX (AUST) LTD, EAST SYDNEY**
Magnovox loudspeakers.
(D T Hinchen, Bruce Beaver, Vic Harris and W M B Veitch. Mr Veitch who was a former Radio Inspector with New Zealand Post Office was company Technical Expert.)

* **MAJESTIC RADIO MANUFACTURING CO., SYDNEY**
Majestic receivers.
(Barry Philp, J Drummond)

* **MEADE MANUFACTURING CO., EAST SYDNEY**
Manufacturers of Mead chassis and Airmead short wave superheterodyne receivers.
Established by Max Mead, 1931.

* **MILLS, W J, LEICHHARDT**
Bifrost resistors.

* **MOULDED PRODUCTS (A/ASIA) PTY LTD, NORTH FITZROY**
Moulded cabinets and radio products.

* **MULLARD RADIO CO. (AUST), LTD, SYDNEY**
The company was established in 1930 and registered in May 1931 at 31 Clarence Street, Sydney to handle the distribution of Mullard valves manufactured in England by Mullard Wireless Service Co., one of the industry's largest suppliers of radio valves. Foundation Managing Director was Gilbert L Murray who was also Managing Director of Scott and Holladay Ltd, radio and electrical wholesalers located in the same building as the new Mullard company.
In August 1930, Eric Dare took up the position of General Manager to set in motion action for commencing business. He had served with Philips from 1926 until he left in June 1930 to take up the Mullard appointment. His experience in wireless dated back to the period before the First World War when he operated a spark wireless telegraphy station from 1912 until closure at the outbreak of the War in 1914. He carried out a number of studies into the use of several different types of materials for use as detectors in receiving equipment. He constructed a galena crystal detector with three steel cat's whiskers acting on a single crystal. He joined the AIF at the outbreak of the War and was attached for a period to Headquarters (Wireless), later becoming a Pilot. After the War, he joined C A Vandervell and Co., London, working in their Experimental Department on the development of crystal detectors, loudspeakers, capacitors, inductors, and transformers. He joined Philips on return to Australia, becoming Technical-Commercial and Advertising Manager.
Mullard entered the radio receiver industry in Australia in early 1935 when it marketed two battery-powered superheterodyne receivers designated Mullard Master Units Mark1 and Mark2.
Mark1 was a seven valve receiver employing valve types VP2., variable mu pentode RF amplifier; SP2, HF pentode frequency converter; two VP2, variable mu pentode IF amplifiers; TDD2(S), duo diode triode detector, AVC and first AF amplifier; PM2DX, triode and AF driver; PM2B, low consumption Class B output. The unit was enclosed in a sealed steel case with black enamel finish.
Mark2 was a five valve model.
At the time of release of these receivers, Robert (Bob) Chilton of Mullard's Technical Department played a leading role in their development. He began Apprenticeship in Electrical Engineering but with a change in his career path left Engineering to study Pharmacy at the Sydney University. Following two years practice in Pharmacy, he returned to the Engineering field becoming involved in experiments in television before joining the Australian Radio College in 1931 as Chief Instructor and later becoming Superintendent. He joined Mullard in 1934.
Mullard receivers were manufactured by Airzone (1931) Ltd and in December 1936, two AC powered models in zonite plastic table cabinets were released. They were marketed as Master Forty and Master Fifty Models. They were followed in 1937 by Master Eighty, the first Mullard console cabinet model and Master Mantel (Model 52), an accumulator/vibrator powered five valve table set.
In early 1938, Model 80B was released. It was a five valve AC powered, dual wave receiver in Beale manufactured cabinet of Macassar ebony, Tasmanian blackbutt and walnut veneers. About the same time, Model 81A, a dual wave receiver featuring tele-tuning became available. The tele-tuner operated on the principle of a rotating dial station selector. Eight preselected stations were provided with the tuner.

In 1940, the Mullardette Model 42 in moulded zonite cabinet was marketed. About this time, Philips began to supply receivers for Mullard.

By late 1941, there were at least 14 mantel/table and portable models available. Included were Models 45 and 69. Model 45 was a four valve AC powered MF band set, while Model 69 was a five valve AC powered dual wave set. Cabinet for both models was burr walnut moulded zonite of new assymetrical design.

New Mullard models were marketed after the War.

In 1947, they included Meteor, Model 99A and Model 98. Model 99A was a six valve AC powered dual wave receiver with RF stage, AVC and inverse feedback. Model 98 was a deluxe seven valve all wave AC powered receiver with Mullard valve types 6U7G, RF amplifier; ECH35, frequency changer; 6U7G, IF amplifier; 6B6G, detector and AVC; 6V6G, output; 5Y3G, rectifier and EM4 tuning indicator. Waveband coverage was 13–42 metres, 42–160 metres and 160–550 metres.

Mullard brand receivers were marketed until about 1955.

However, the company trading as Mullard Australia Pty Ltd remained an active part of the radio industry maintaining an Applications Laboratory. Staff members in the mid 1960s who were members of The Institution of Radio and Electronics Engineers, Australia included Maurice Brown; Clive Chaloner, Applications Laboratory; Graham Gale; Robert Jeffrey, Brisbane Office and John Pearce.

* **NEW SYSTEM TELEPHONES PTY LTD, SYDNEY**

NST and Hollingsworth receivers.

First Hollingsworth receiver produced 1931. Receivers made by subsidiary company, James Manufacturing Company Pty Ltd.

(Joe Carroll; R M Davies; Arthur Everitt; Jack Graber; Robert Grierson; Richard Kennell, Chief Engineer; H L Little; Ray Allsop)

The company was registered on 10 November 1920 with nominal capital £150000.

* **NEWTON, MCLAREN LTD, ADELAIDE**

Night Hawk and Mak receivers.

First receiver produced commercially 1921.

(John Hale, D Eardley-McLaren, A R Altman, W Nancarrow, Tom Govenlock, Radio Manager)

The business was registered on 13 February 1905.

David Eardley-McLaren worked in the Electrical Engineering field with Unbehaun and Johnstone, Adelaide for five years before joining J A Newton and Co., Salisbury Chambers, King William Street as Manager on 14 January 1901.

A few months after joining the company, it was awarded a contract to illuminate the Adelaide Town Hall for the visit of the Duke and Duchess of York. An engine was installed in the basement and a sailor was engaged to attach lamps to the top of the Tower.

McLaren purchased the business from Newton and the firm Newton, McLaren Ltd was incorporated on 14 February 1902.

In 1912, the trade name MAK was registered and locally manufactured products including radiators, fans and radio receivers were marketed under this name.

In January 1923, before broadcasting began in South Australia, decision was made to stock radio components to meet a growing local demand. McLaren became Chairman of the Radio Association of South Australia, a committee of seven brought together to press for the establishment of broadcasting stations in South Australia.

Under McLaren's influence the manufacture of radio receivers was started and the company sold the first receiver to a Doctor in Gawler. The receivers were marketed under the Mak and Night Hawk labels.

Local manufacture of receivers ceased during the Depression years. The company continued involvement in the broadcasting industry by becoming South Australian distributor for AWA receivers, Radiotron valves and radio components.

During his lifetime tenure of office as Managing Director, McLaren also assumed the function of Engineering Department Head.

John Hale joined Newton, McLaren Ltd on 12 March 1917. In 1922, he established the Radio Section and controlled the design and manufacture of receivers and components. Mak and Night Hawk brand receivers were produced in large numbers and a number can be seen today in vintage radio collections.

In 1924, John was a member of a deputation of South Australian Radio Dealers who met with the Deputy Postmaster General with a view to having a high power broadcasting station established in South Australia.

In 1936, he was appointed Assistant Manager and in 1937 became General Manager and a Director of the company.

He was a member of The Institution of Radio Engineers (Australia) and contributed a number of articles to the radio technical press.

* **NOMIS RADIO CO., ADELAIDE**

Nomis Radio Company was founded by John L Simon in 1929. The company designed and manufactured domestic radio receivers and public address systems under the Nomis brand. The label was derived by spelling Simon backwards. The factory was located at 11 Cudmore Street, Somerton with a display showroom being set up at 128 Jetty Road, Glenelg.

The founder had previously been a Motor Mechanic in Adelaide and later established a business in Renmark in partnership with his brother. The Renmark business was not profitable, so it was closed and John Simon returned to Adelaide with his family which included Laurie, the eldest of the children.

The Depression had a major impact on the motor industry so decision was made to move into the business of building radio receivers. By that time, radio was a growing industry in Adelaide with stations 5CL, 5DN and 5KA already on air and a fourth, 5AD being planned. It was not unusual at the time for owners of motor garages to become involved in radio receivers. Many garages had a thriving business charging and selling new accumulators and they soon took an interest in the technology. There were at least six local garage businesses who were agents for radio receivers in the late 1920s.

The decision was also influenced by the fact that son, Laurie showed an interest in making a career in radio. After leaving school, Laurie began work at Newton McLaren Ltd, a major Adelaide electrical and radio business. The company had manufactured the first commercially produced radios in Adelaide and marketed sets under the brand names Mak and Night Hawk. They were also agents for AWA receivers and components.

In 1929 when his father set up Nomis Radio Co., Laurie left Newton McLaren and began work with his father on assembly of receivers and undertaking servicing work.

During 1933, Nomis produced a range of receivers which included three, four and six valve models in table and console cabinets with lustre and piano finishes. They embraced high quality workmanship, first-class cabinet designs manufactured by a leading Adelaide cabinetmaker and good reliability.

Some of the components, particularly coils and transformers, were produced in the workshop. A number of Nomis receivers have been preserved in local vintage radio collections.

The company later specialised in public address systems pioneering many new techniques for large installations. Early microphones included Reiss and condenser types. Several of the condenser types had previously been employed at 5CL studios.

Major public address installations included Adelaide Children's Hospital; Embassy, Palladium and Kings Ballroom dance venues; Anzac Day processions; SA Centenary Celebrations at Glenelg Oval; Richard Crooks concert; Adelaide Town Hall; South Australian Hotel; Adelaide Oval and major racecourses.

In recent years, the company operating as Nomis Electronics Pty Ltd was located in South Road, Black Forest.

Laurie Simon retired in 1984 and sold the business with the new owners operating as Network Nomis at 51 Glen Osmond Road, Eastwood.
Laurie was a long-time member of The Institution of Radio and Electronic Engineers, Australia serving a period as President of the South Australian Division.

* **OHMEGGA RESISTORS (AUST) PTY LTD, CARLTON**
Ohmeg resistors.
(E Peterson, Factory Manager)
The company was registered on 25 February 1935.

* **OLYMPIC RADIO LTD, SYDNEY**
Olympic receivers were first manufactured in October 1933. The company was well-known for its 1935 14 valve all wave high fidelity radio gramophone housed in a large console cabinet of unusual design.
(Cliff Black, Proprietor)

* **ORPHEUS RADIO CO., PTY LTD, MELBOURNE**
Orpheus receivers.

* **PALMER F J AND SON LTD, SYDNEY**
Palmovox receivers and agents for others.

* **PAYNE, J RANDWICK**
Superlative receivers.

* **PEERLESS MANUFACTURING CO., LTD, REDFERN**
Moulded radio parts.
(Managing Director and Chief Engineer, H C Walker)
The company was registered in 1932 with paid up capital of £2000.

* **PHILCO RADIO AND TELEVISION CORPORATION (AUST) PTY LTD, WATERLOO**
Philco was a well-known brand of radio receivers in the USA from 1928 but very few were seen in homes in Australia due to Government restrictions on imported radio receivers at the time.
In early 1936, Philco Radio and Television Corporation (Australia) Pty Ltd announced that it was about to release a range of 17 models incorporating 42 features with the receivers being produced by EMMCO, an Australian manufacturer. The Australian company had the benefit of the extensive research and engineering design facilities of the USA organisation. The Directors of EMMCO were also Directors of Philco.
Company Superintendent was Richard Kennell who had been involved in the telecommunications industry in senior technical and managerial positions. He was a Member of The Institution of Radio Engineers (Australia) and a Councillor for many years. He was also a Member of The Institution of Radio Engineers, USA.
Prior to joining Philco he had been Chief Engineer and Manager of James Manufacturing CO., Ltd; Chief Engineer New System Telephones Pty Ltd and Chairman of Directors of Radio Interests Ltd. His experience also included 12 years with the Electrical Engineers Branch of the Postmaster General's Department working in the telephone exchange and subscribers apparatus areas. He left Philco after a short while to concentrate on telephone work and took up appointment as Manager Siemens Halske and also Chief Engineer, Telephone Division, New System Telephones Pty Ltd.
Mr J W Duncan Bain took over responsibility for Philco from Richard Kennell in March 1937. He had previously worked with British General Electric Company and New System Telephones Pty Ltd.
Receiver releases manufactured for Philco by EMMCO in 1936 included:

- Model 655, a five valve superheterodyne dual wave AC powered receiver in a San Pedro console cabinet.
- Model 609, a ten valve AC powered high fidelity receiver with response 50–7500 Hz, and housed in a San Juan console cabinet. It produced 10 watts output, had triple wave band capability and incorporated selectivity variation control of mechanical type operating on IF transformer.
  Both models featured a patented Wide Angle Projecting Inclined Sounding Board and Chrono-Radial dial. It was claimed that the sounding board 'preserves the sparkle and brilliance of the original and spreads the most delicate overtones evenly throughout the room'. The Chrono-Radial dial provided centre line tuning, ensuring the station to which the set was tuned always appeared at top dead centre position, eliminating the possibility of parallax error.
- Model 76B was a six valve accumulator/vibrator powered dual wave superheterodyne receiver in Dayton console cabinet. Valves were 2 volt filament types with filaments connected in series-parallel arrangement to enable operation with a 6 volt accumulator source. Valve types were 1A4, RF amplifier; 1C6, pentagrid converter; 1A4, 460 kHz IF amplifier; 1B5, demodulator, AVC voltage rectifier and AF amplifier; 30, driver; and 19, Class B output. Loudspeaker was a 10.5 inch (262 mm) unit.
  Power was provided by a Vesta 6 volt accumulator and vibrator unit. Total battery drain was 1.2 amperes.
  Dial was a Philco floodlit type. Doublet aerial terminals were provided with a special Philco noise reducing aerial system.

The 1937 releases comprised AC, AC/DC, battery and accumulator/vibrator powered models employing from five to eight valves and housed in table or console model cabinets. Model 75VB, a five valve accumulator/vibrator powered dual wave receiver, was fitted with a dial which provided 36 inches (800 mm) of effective station tuning, being 12 times the spread of conventional dials.
The 1938 range included the first Philco receivers employing band spread tuning and a 10 valve receiver fitted with 'Mystery Control' providing remote automatic tuning and volume control.
In the following year, Philco 'no stop' series of models was released. The console cabinets carried a contoured straight-line dial along the top front edge. The dial was floodlit by three lamps in a rotating mask type reflector controlled by the wave change switch.
During January 1940, several new models were marketed in Carnarvon, Lincoln and Windsor style console cabinets. Model 40/50 was fitted with a 10 inch (250 mm) loudspeaker, deluxe quadrant dial and built-in aerial. The Model 40/65, a six valve receiver featured 'Expression Maestro' tone control and Tertiary Intermediate Frequency System.
Models 40/40 and 41/40 were AC powered four valve MF band sets in mantel cabinets marketed as the Midgette range.
The 1940 year was a vintage one in terms of numbers of receiver models produced. There were over 30 models released with the range including four radiograms and a nine valve AC powered dual wave set in console cabinet.
At the time, Philco was part of Electricity Meter and Allied Industries Ltd (Email) group.
Philco models became available after the War with Model 4640, a four valve AC powered mantel cabinet type being released in 1946.
At least three models were marketed in 1948. They included Model 47/40, an AC powered MF band receiver in mantel cabinet; Model 47/54, an AC powered dual wave five valve set in table cabinet and Model 47/54V, a five valve portable set.

* **PRECISION ENGINEERING CO., PTY LTD, MELBOURNE**
Apparatus and equipment for transmitting stations.

* **PYROX PTY LTD, MELBOURNE**
Pyrox car receivers. First receivers produced 1934.

* **RADIETTE RADIO LTD, SYDNEY**
Radiette receivers.
(Ray Oxford)

* **RADIO EQUIPMENT PTY LTD, SYDNEY**
Radio test instruments.
(F W Freeman; Lance Graham; R Lackey, Chief Engineer)

* **RADIO SUPPLIES UNLIMITED, BRISBANE**
Components, receivers.
The shop had one of the best supplies of variometers and variocouplers in Brisbane. Brands included, Pathe moulded variometer, Excel variocoupler, Raven bakelite variometer, Superior variocoupler, Split-Stator variometer, Pfanstiehl variometer and variocoupler, Coto variometer and variocoupler.
(Eric Cantelin, Technician)

* **RADIX POWER SUPPLIES LTD, SUBIACO**
Radio transformers and chokes.
(E A Dix)

* **REGENT RADIO PTY LTD, CAMBERWELL**
Roadmaster car radio receivers.
(James McGrath, Harrold Parramore, Geoff Searle)

* **RELIANCE RADIO CO. (A/ASIA), SYDNEY**
First receivers produced in 1932. Company was founded by N S T Craven in May 1932.
Labels included Reliance, Reliance-York, York, De Luxe Convertible, Reliance-Oxford, Reliance-Bedford, Philharmonic, York-Royal and Sky-Raider. The York-Royal was a 20 valve set produced in 1937. Sky-Raider models were still being produced in 1948.

* **REYNOLDS R W LTD, SYDNEY**
Renrade components including capacitors, spark suppressors, generator cut-outs, spark plugs, valve sockets, wire wound resistors, solder lugs and screen grid clips
(Founded by Robert Reynolds, Electrical Engineer, 1924)

* **RICHARDSON H C PTY LTD, FOOTSCRAY**
HCR mica fixed capacitors, plastic mouldings.
(Founded by Harold C Richardson, 1931, E B Richardson, Electrical and Mechanical Engineer, Director)

* **RICKETTS AND THORP PTY LTD, ROCKDALE**
Designers and manufacturers of cabinets with piano, lustre or dull finish. Noteworthy cabinets of the 1930s included Burford M315 and Milford M316 console models.
The company was registered on 26 March 1920.
(F E Thorp)

* **ROLA CO. (AUST), PTY LTD, MELBOURNE**
Manufacturers of Rola loudspeakers and associated component parts. The company also produced a range of enamelled wires.
(Leonard Webb; G R S Allen; R H Yend, Manager; Maurice Smith)

* **SANDEL RADIO, WOOLLAHRA**
Founded by Otto Sandel at Oxford Street, Woollahra, on 1 February 1928 as retailing and manufacturing business. Otto became involved in radio when in Brisbane in 1922, attended the Marconi School of Wireless in Sydney in 1923, and operated Amateur station 2UW. He later built a 500 watt transmitter and operated 2UW as a licensed B Class station for about six years.
By 1934, a second business outlet had been established at 376 New South Head Road, Double Bay to handle the wide range of products which included:

- Dual wave superheterodyne kit set with RCA valves, Lekmek dual wave kit and Amplion loudspeaker. It could be obtained completely assembled, wired and tested, if so required by the customer.
- Short wave converter as kit set, or completely assembled.
- High fidelity receiver kit set including RCA valves and Jensen high fidelity loudspeaker, or completely assembled and tested.
- Sandel 30 watt power amplifier kit set with Lekmek AF transformers, power transformers and chokes; and valve types 55, 56 (two), 59 (two), and 5Z3 (two).

* **SIMPLEX PRODUCTS PTY LTD, PETERSHAM**
Component manufacturers specialising in fixed capacitors, pressed metal work, mouldings, tools and dies.
The company was registered on 7 April 1937 with £4000 subscribed capital.

* **SMALL, BRUCE PTY LTD, MELBOURNE**
The company introduced the popular Malvern Star bicycle but in 1931 became involved in the radio industry by marketing receivers with the Malvern Star label. They later marketed STC, Airzone and other brands. Bruce Small was Governing Director and Frank Small, Managing Director. Frank made an extensive overseas visit to UK and Europe to study the latest technology in broadcasting and marketing techniques.

* **SMALL, HENRY G AND CO., MELBOURNE**
The company were Electrical and Radio Engineers, wholesalers of receivers and radio components, and manufacturers of Kelvin brand receivers 1934–37. The company was registered in 1932. Henry Small, founder of the company, was a qualified Electrical Engineer having graduated from Swinburne Technical College and spent many years working with major electrical companies and power stations.
Chief Technician of the Radio and Service Department was Charles Small. He graduated from Swinburne Technical College in Electrical Engineering and gained practical experience with Metropolitan Vickers Electrical Co., and Carroll and Grunden, Auto and Electrical Engineers.
Engineer of the Radio and Electrical Department was Ern Bayley a graduate of Melbourne University in Electrical Engineering. He joined the Victorian State Electricity Commission in 1923, leaving 1925 to go to England to work with British Thomson-Houston Co., Ltd, where he gained valuable experience in Electrical Engineering and in the company's Radio Products Division involving the design and manufacture of amplifier units, multivalve battery-powered receivers, AF transformers, valves, loudspeakers, crystal sets, crystal detectors, coils and variable capacitors.
He returned to Australia in 1927 to take up a position with Johnson and Phillips until 1930, when he left to join Henry G Small and Co.

* **SPEAKERS (A/ASIA) LTD, SYDNEY**
Amplion loudspeaker manufacturers. Established 1930.
(Managing Director, Pat Manley)

* **STAN-MOR DRY CELL CO., BRIGHTON**
Dry cell batteries.
(Stanley Morgan, Proprietor)

* **STAR BATTERIES LTD, SYDNEY**
Manufacturers of A battery accumulators and rechargeable accumulator type B batteries assembled in 12 volt banks.

* **STERLING RADIO LTD, SYDNEY**
The company was established on 11 May 1934 by John Tait and Norm Buchanan.
John Tait worked for the British General Electric Co., Ltd for about 14 years. He visited England in 1925 to arrange with General Electric Company for the supply of Gecophone

receivers and a wide range of radio components and accessories. In 1931, he became Manager, Radio and Telephone Department of BGE and left in 1934 to form Sterling Radio Ltd.

Norm Buchanan, Co-Director and Chief Engineer had previously been Chief Engineer with Zenith Radio, and later Chief Engineer of Eclipse Radio Pty Ltd, Sydney Branch. He had also served a period with Thom and Smith.

The range of 1935 Sterling models included:

- Model 5B, a five valve superheterodyne receiver housed in Sussex console cabinet.
- Model 5BA, a five valve superheterodyne receiver equipped with AVC facility.
- Model 6BA, a six valve superheterodyne receiver.
- Model S7B, a seven valve dual wave superheterodyne receiver.
- Model S5A, a five valve AC powered dual wave superheterodyne set with AVC and 456 kHz IF.
  Features included 6.3 volt filament valves; large Efco Aero dial; 8 inch (200 mm) dynamic loudspeaker; pick-up terminals; wave change switch, Gloucester console cabinet.
- Model S6A, a six valve AC powered dual wave superheterodyne receiver with AVC, 456 kHz IF and RF stage.

Seven new models were released in 1927 and included four designed primarily for use with Eveready Air-Cell batteries but incorporating provision for changeover to a standard two volt accumulator if required.

Chas Dunn was in charge of company Country Sales Department.

* **SUPERHETERODYNES PTY LTD, MELBOURNE**

Manufacturers of Telescopic brand receivers and components. First receivers produced in 1934. Distribution direct to the public in Melbourne and through an Agent in Perth.

Managing Director, Alan Burch.

* **SYDNEY MAGNETS AND ELECTRICAL CO., SYDNEY**

Radio potentiometers.

* **TARGAN ELECTRIC CO., PTY LTD, BRUNSWICK**

The company designed and manufactured Air-Master receivers. Receivers produced during 1930 included Air-Master All Electric Three table model, and the Air-Master All Electric Phono-Radio combination.

Chief Radio Engineer was Fred Canning, former Wireless Telegraphist in the RNVR during the First World War, Ship's Wireless Operator with AWA Marine Service, and Chief Technician with Australasia Baird Television Company. He left Targan in late 1931 to take up a position as Chief Engineer with Firth Bros, Pty Ltd.

The 1932 range of receivers included the popular Model DXP/46, an AC powered receiver in deluxe cabinet and featuring two stages of RF amplification, screen grid valve detector and push-pull output stage feeding a dynamic loudspeaker.

The following year, 1933, an expanded list of models included three valve mantel; three valve console cabinet set; four valve console cabinet receiver; five valve superheterodyne; six valve superheterodyne set; and seven valve superheterodyne set in deluxe cabinet. Features included AVC; silent visual tuning indicator which eliminated noise in tuning and indicated volume level; manual interference control; and diode valve linear detector circuit. Console cabinets were veneered in Australian walnut and finished in golden-toned lacquer. The Model H95, seven valve superheterodyne AC powered phono-radio combination with push-pull output stage feeding twin loudspeakers was housed in a high quality cabinet with patented sliding grill. The sliding panel covered the dial and control knobs when the set was not being tuned.

In 1935, the company release included three new models:

- Model M30, a four valve AC powered superheterodyne receiver with valve types 6F7, frequency converter; 6F7, IF amplifier and second detector; 42, pentode output; and 80, rectifier. Features included 8 inch (200 mm) Rola loudspeaker; Air-Master patented Morse Code suppressor; 360 degree Efco Aero dial; 3 watts output; and mantel cabinet.
- Model T30, the M30 chassis housed in a console cabinet.
- Model A41, a five valve superheterodyne set with 175 kHz IF and employing Philips golden series valves. Features included Efco Aero dial; tapered tone and volume controls; Air-Master patented quench circuit to limit response from local high power stations when tuning across the band; balanced hum eliminator; image suppression circuit; ganged tuning capacitor mounted in special cradle to minimise microphonic problems; and Rola F6 loudspeaker.

Receivers released during 1936 included further technical improvements. Important features included Ray-Vizor dial with magic eye tuner; Colorzone feature providing identification of stations in various States; auto silent tuning device eliminating static and interference between stations; iron dust coils; balanced tone compensation circuit; delayed AVC; 12 inch (30 cm) Rola loudspeaker; extended short wave range to 16 metres; facility for connection of either doublet or single wire aerial; and smooth acting double reduction tuning control with twin knobs enabling precise short wave tuning.

At that time, Radio Kraft Pty Ltd was handling Air-Master receivers.

One of the early Targan employees was Edward (Ted) Coate who later became a prominent specialist in aviation radio.

He grew up in a country Victorian town where his father had a newsagency and Ted looked forward to the arrival of the latest magazines on radio and aircraft. He read them from cover to cover. His first job was with Targan where he started on the assembly of chassis. His keen interest in the work and dedication was soon recognised and young Ted was transferred to the final testing section. He showed great potential in chasing faults introduced during the assembly process. His mates referred to him as 'Marconi'. He also became expert in the alignment of superheterodyne receivers and a number of suggestions of his were incorporated in designs. He developed a series of anti-capacity screwdrivers using non-ferrous materials and insulated shafts for the alignment of receivers.

As part of his interest in aviation, Ted joined the Citizens Air Force and on the outbreak of the Second World War in 1939 he joined the RAAF, eventually becoming Squadron Leader responsible for airborne radiocommunications and navigation systems.

After the War, he joined the PMG's Department technical staff working at the ABC Melbourne studios. He worked on control and switch room duties, studio maintenance, recording and OB activities.

He left the Department in 1947 to join the Radio Section of the new Trans Australian Airlines continuing until 1959 when he left to open an office in Melbourne for the USA firm Collins Radio Company. Among the many Collins manufactured transmitters supplied to Australian broadcasters were three 250 kW Collins 821A HF transmitters for Radio Australia, Cox Peninsula.

Ted was an active member of The Institution of Radio and Electronics Engineers, Australia having joined as Associate Member in 1936 and being appointed Fellow in 1969. In 1969 he was a signatory to the application by The Institution for a Royal Charter.

* **THE AUDIOTONE CO., MELBOURNE**

The Audiotone Super receiver.

* **THE G AND R ELECTRICAL CO., DARLINGHURST**

The G & R receivers.

* **THOMPSONS RADIO LTD, SYDNEY**
Theatle and Theatrola receivers.
Founded by Derrick Thompson, 1926, inventor of Velona sound board with floating speaker and Theatle cabinet.

* **TRANSMISSION EQUIPMENT PTY LTD, MELBOURNE**
Transmitters, studio equipment, components.
(Rudolph Buring, Design Engineer)

* **TRAVELTONE RADIO PTY LTD, MELBOURNE**
The business was registered as Radio Maintenance Pty Ltd on 16 April 1932 and changed its name to Traveltone Pty Ltd on 23 March 1936.
The company were manufacturers of AC mains and battery-powered receivers and auto receivers.
Receivers released during 1935–36 included MF band and dual wave receivers powered from AC, AC/DC or battery sources; 6–12 volt six valve automobile radios and a six valve receiver with a special power supply system enabling operation from 6 or 12 volt DC or 230 volt AC sources.
Chief Engineer was E Evans.

* **TREE RADIO-ELECTRIC CO., CROWS NEST**
The company was founded by Ernest (Ernie) Tree. The company were Electrical Contractors but also manufactured Treeray brand receivers and were wholesalers of radio and electrical goods. Receivers were first manufactured about 1931. The company was still active at the outbreak of the Second World War in 1939.
Founder Ernie Tree was appointed Associate Member of The Institution of Radio Engineers (Australia) in 1932 and was still an active member 30 years later. During 1933 to 1935 he was a Councillor of the IRE, and President of the Radio Retailers Association of New South Wales.

* **TRIUMPH RADIO CO., LTD, KENSINGTON**
Manufacturers of Triumph brand receivers and chassis from about 1933. Managing Directors were Tom Sheedy and Leon Weingott.
The 1934 range included five, six and seven valve AC powered MF band superheterodyne receivers; seven valve AC powered dual wave superheterodyne receiver; six valve all wave battery-powered set; and an all wave converter.

* **TURNEY BROS, PERTH**
Manufacturers of high class radio cabinets.

* **UNIVERSITY RADIO CO., SYDNEY**
Chancellor, Dean, Librarian, University brand receivers.
The company was registered on 11 January 1933.
(Ben Broadhurst and Lance Graham)

* **WARBURTON FRANKI LTD, SYDNEY**
Wholesalers and distributors of electrical and radio goods with Branches in Brisbane and Melbourne. The company had been registered since 3 November 1919.
In the 1920s the product range included Olympian, Day-Fan and Waranki receivers; loudspeakers included Burndept Ethovox, Fairfax moulded wooden horn, Hartman pedestal, Racon exponential, Fairfax exponential and Tower cone.
In the late 1930s, the company were manufacturers of Watt Hour Meters, wholesalers of a range of electrical apparatus, and representatives for Weston, Sangamo and General Radio, stocking a large range of Weston Radio test equipment including Weston Selective Analyser Model 665, Weston Volt-Ohmmeter Model 663 and Weston Tube Checker Model 674.
They supplied many Commercial stations and National Broadcasting Service stations with General Radio test equipment and meters.

* **VESTA BATTERY CO., PTY LTD, SYDNEY**
Manufacturers of storage batteries for cars, home lighting and radios. The company whose experience in battery manufacture in the USA dated back to 1897 was registered in Sydney on 19 March 1928. In 1937, the range of storage batteries produced specifically for radio purposes included Vesta 2 volt, 4 volt and 6 volt batteries and a Vesta 6 volt heavy duty vibrator battery with patent recessed terminals moulded to the shapes of (+) and (-) so they could be easily distinguished by sight or touch to prevent incorrect lead connection when connecting power to the receiver. The battery also had a hard cover lid to guard against acid spray and terminals were positioned on one side, so preventing crossed leads.
In June 1931, Ern Ashworth was company Works Manager. He had been educated at Sydney Technical College and served an Apprenticeship in Marine and General Engineering at Garden Island Naval Establishment during 1916–21. He transferred into the battery industry when he took up a position with OS Light and Heat Corporation as Engineer/Draftsman becoming Works Superintendent in 1923. The following year he moved to Sydney Rubber Moulders Ltd and in 1925 joined Clyde Engineering Co., Ltd to take charge of company battery production facilities. Ern subsequently worked with other companies before joining Vesta in 1931. In 1935, he left Vesta to return to Clyde Engineering as Manager, Battery Production.

* **WATSON W G AND CO., PTY LTD, SYDNEY**
Exclusive factory representative in Australia of Erie brand resistors. Other lines included Readrite and Triplett measuring instruments, valve testers, radio set analysers; Enfield CMA cables and wires. The company were also distributors of Switchon brand radio receivers. In 1934, one of the most popular models was a seven valve all-wave console receiver with Efco Aero dial housed in a beautiful veneer cabinet.

* **WERRING RADIO CO., CARLTON**
Manufacturers of Werring receivers and components.
The company was registered on 6 August 1926.
(Oscar Werring, Proprietor; Stanley Levings, Workshop Manager)

* **WESTINGHOUSE SALES AND ROSEBERY LTD, SYDNEY**
The company marketed Westinghouse brand receivers from 1936.
The receivers were manufactured under contract by EMMCO and later by AWA. Joint Managing Directors at the time were Messrs F G Carr and W V Buzacott.
There were at least 25 models released during 1936 in five, six and seven valve designs employing AC, battery and Universal power sources. Model 276G was a dual wave band seven valve radiogram unit. Intermediate frequencies employed for the majority of models was 252.5 kHz with a few using 460 kHz.
The 252.5 kHz IF was also employed with the 1937 designs. This series was marketed as Third Dimension Radio.
The 1938 range included five valve models 358 V and 458 V fitted with octal power supply connector and adaptable for Air-Cell, 2 volt accumulator or vibrator/accumulator operation. Model 358 V was an MF band set while 458 V had dual wave capability.
During 1939–40, the early years of the Second World War, about 30 models were available. They included Model 840, an AC powered five valve mantle set with built-in loop aerial; Model 1960, a five valve AC powered dual wave receiver with six button auto station selector; Model 2820, an AC powered eight valve triple wave band set incorporating an eight button auto driven station selector; Model 3100, an AC powered five valve MF band radiogram unit; and Model 630, a four valve portable receiver with tuning, volume, tone and on/off switch controls. It was fitted with a 5 inch (125 mm) permag loudspeaker. Battery types were PR1 for filament and two PR45

types for high tension, providing an operational life of about 220 hours.

Westinghouse brand receivers were not marketed after the War. The Westinghouse company was one of a number acquired by EMAIL during 1940. The USA based Westinghouse Electric and Manufacturing Company had a branch office in Australia called Australian Westinghouse Electrical Company Ltd but in 1935 a new company, Westinghouse Sales and Rosebery Ltd took control and negotiated licensing arrangements for the importation and manufacture of equipment of the USA parent company.

By 1939, the company name had become Westinghouse Rosebery Ltd.

Although Westinghouse brand receivers were manufactured in the USA by the Westinghouse Electric Corporation in the 1930s, it is not known whether any were imported into Australia for distribution here.

* **WESTMINSTER RADIO TELEVISION CO., LTD, PARRAMATTA**
Westminster receivers.
(C Whatmuff)

* **WIDDIS DIAMOND DRY CELLS PTY LTD, SOUTH MELBOURNE**
Dry cells and batteries.
(T Anderson)

* **WINTERS WIRELESS, MELBOURNE**
Winterfone one control radio receivers.

From the very beginning, major Department stores realised that broadcasting had great potential, and they wanted to be in on the ground floor when it came to selling receivers to the public. Some saw the sale of domestic radio receivers as simply an additional service for their customers while others saw more clearly the future scene. They set up a Wireless or Radio Department with its own Manager and marketed components and parts as well as fully assembled receivers.

Retailers in Sydney were convinced that control of a broadcasting station was an essential component of their business plan. Farmer and Co., began discussion with AWA for the provision of a station while other major retailers and businesses banded together to plan for another station. This latter group which formed Broadcasters (Sydney) Ltd included Anthony Horden and Sons Ltd, David Jones Ltd, New System Telephones Pty Ltd, Marcus Clark and Co., Mark Foy, Harringtons Ltd and Lassetters. They received support and financial backing from Sir Joynton Smith, publisher of 'Smith's Weekly' and were granted a licence on 22 July 1923 to establish 2SB (later 2BL).

Many of the Department stores purchased radio receivers manufactured by factories or Radio Shops with the store preferred brand name fixed to the dial or cabinet, while others employed their own technical staff to assemble and service their products. They also provided an installation and maintenance service. Typical was David Jones Ltd of Sydney who marketed the D J Standard brand crystal set; and two, four and six valve battery-operated receivers, with the six valve model employing a Neutrodyne circuit. The company also stocked a comprehensive range of components. It engaged Frank Basil Cooke as Radio Director and Designer of their Radio Department located in a building not far from the main store. Frank (known as Basil to his friends) was also responsible for operation of the company experimental station 2DJ which provided programs to demonstrate the operating techniques of receivers on display in the store. In later years when the company had no further requirement for the station, Cooke retained the 2DJ callsign when he operated from his residence in Northbridge. Basil had been interested in wireless development for many years before the introduction of public broadcasting. His father William Ernest Cooke, an Astronomer, was also interested in the employment of wireless in the fixing of longitudes. He made significant contributions in this field while stationed at Adelaide and Perth Observatories and later as Professor of Astronomy at University of Sydney. When William Cooke was based in Sydney, son Basil held a licence for wireless telegraphy station XADW at the time of the outbreak of the First World War. He had been involved in experiments in wireless telegraphy transmission and reception in Perth since 1904.

About 1914, he received one of the first three electrode valves to be brought to Australia from USA and following construction of a receiver specially designed to take advantage of the properties of the valve, he received signals from stations in USA and Germany.

During the War years, Basil offered his services to the military and trained Signallers in the AIF prior to their departure to Palestine.

In 1917, Basil designed an umbrella type aerial system employing three cage arms to improve reception of wireless time signals at the Adelaide Observatory from the Sydney and Melbourne Observatories.

During 1919, Basil assisted Joe Reed in carrying out experiments in voice and music transmissions from the Sydney Observatory employing valve equipment operating on a very long wavelength.

A report indicated that whilst satisfactory reception was obtained over a distance of about 100 metres, the tests failed to increase this distance of reception. The transmitter employed an imported double-ended receiving type valve. It was about 90 mm in length and 20 mm in diameter. The valve incorporated two filaments.

Another of Basil's activities in wireless, was work undertaken with Major W H Newman of New South Wales Railways to determine possible applications of wireless technology for railway purposes.

In the March 1925 issue of 'Radio in Australia and New Zealand', Basil had an article published on the subject of 'Static'.

Farmer and Company were granted the first licence for establishment of an A Class broadcasting station in Sydney under the Sealed Set Scheme. The station commenced operation on 5 December 1923. The company had a well-equipped Radio Section in its Department store to meet the needs of customers who wanted to have a complete home radio receiver provided or to provide for customers who desired to purchase separate components or complete kit sets with construction and wiring instructions.

The company was established in 1869 by William Farmer and two partners and soon became a large Department store. It was an innovator in many aspects of retailing. It became a public company in 1897. In 1960, it was acquired by the Myer organisation.

In the mid 1920s, the Radio Section had an extensive stock of components including Grodan kits; Beede voltmeters; Philips B eliminators; Balkite battery chargers; Brandes variable capacitors, headphones and loudspeakers; Emmco products including the full range of audio frequency transformers and B eliminators; Tefag loudspeakers; a range of locally manufactured receivers as well as a selection of imported models. Included among the range of valves was the full range of Cossor valves made in England. They were amongst the best-selling line stocked by the company. They frequently discounted them to encourage boys to construct battery-powered receivers. In 1926, types stocked included bright emitter types P1 and P2; dull emitter types W1 and W2; Wuncell dull emitters types WR1 and WR2 and loudspeaker or output valves types W3 and P3. The Wuncell was particularly popular because of its low voltage and current requirements. It could be used as detector and audio amplifier using type W1, and as radio frequency amplifier using W2. The company imported Cossor valves direct from the Cossor Valve Company in England and on one occasion, Cossor included a display board showing the manufacturing stages of the Wuncell. It was on display for many years.

Receivers bearing the company name included Farmers Standard Two, Three, Five and Six models

The Standard Six, a very popular receiver in 1926 was a six valve battery-powered model enclosed in a highly polished

Tasmanian blackwood cabinet. It was equipped with Amplion loudspeaker, Radiotron valves type UX201A, Winchester B batteries and Masse 60 Ahr accumulator.

The Standard Five introduced in 1927, had a single dial control with each stage being enclosed in a sheet copper shield. The receiver was housed in a Queensland maple cabinet inlaid with walnut and provided with a Duco finish.

During the period 1923 to 1926, Manager of Farmer and Co., Radio Section was Eric Moore. He was an experienced Radio Engineer and did much to establish the business of the Section on a sound financial basis and a reputation for top class and reliable advice on all matters associated with the installation and servicing of home broadcast receivers. Eric left the company at the time Farmer and Co., decided to reduce its involvement in broadcast station operation with its 2FC interest. A new company, 2FC Ltd was incorporated on 17 November and the licence transferred to the new company on 1 December 1927.

Eric left Farmer and Co., in 1926 to take up an appointment with the USA-based Stromberg-Carlson which at the time employed some 1250 people with about 200 being engaged on the manufacture of radio receivers. One of the receivers being manufactured when Eric began work at the factory was the Model 501, a five valve Neutrodyne which employed individually shielded RF coils in closely fitting metal cans, a technological innovation at the time. In 1932, he returned to Australia to be Chief Engineer Stromberg-Carlson (A/Asia) Ltd.

In March 1923, eight months before the first Sydney station began operation, Anthony Horden and Sons Ltd, Brickfield Hill had stocked their Electrical Department with a wide range of imported receivers and components. The range of receivers comprised crystal sets and battery-operated valve types up to six valve models. Concert brand was one of the popular models sold during the first few months of operations.

Valves in stock included Myers, Expanse, Q, Radiotron, Philips, Osram and Mullard. The wide range of components included Murdock, Frost and Baldwin headphones; Columbia and Burgess batteries; Grodan products; Igranic and Signal fixed capacitors; Quickheat grid-leaks; United transformers; United honeycomb coils; Kellogg variometers and variocouplers; square law variable capacitors; All-American transformers; Ormonde variable capacitors; Advance and Framingham rheostats; square-tinned bus wire; de Forest plugs; crystal detectors including holders and crystals; aerial wire and others.

The company employed its own technical staff to install and service equipment it sold and in its well-equipped workshops it constructed a range of receivers designed by staff and sold as Hordenia. During the 1923 Christmas period, by which time 2SB (2BL) and 2FC were on air, the entire stock of receivers was sold out.

In November 1923 when 2SB (2BL) began transmission, David Jones had a large stock of radio components and fully assembled receivers in their Radio Department at 252 York Street, Sydney. The stock included a receiver specially designed to entice people in the country to purchase a radio receiver from their store. It was a one valve model capable of long distance reception employing the popular P1 circuit with C201 valve, 6 volt accumulator, B batteries, four honeycomb coils, headphones and a kit set comprising wire, insulators and lightning switch for an aerial. Components were mounted in a Rosewood cabinet and it was claimed that the receiver had a range of 200 miles (320 km). To commemorate the commencement of broadcasting and to encourage the building of crystal sets, the store offered Freshman crystal detectors at a special price. Other components in stock included Polar two coil mounting units; a range of audio frequency transformers including Airad, Marle, Crosley, Jefferson and Remler; radio frequency transformers including Marle, Master, Amrad, Killbourne, Lelark and the RCA All-Wave transformer covering the band 200 to 5000 metres.

By early 1925, the Radio Department was located at 22 York Street with 'Low Loss' sets being amongst the most popular lines sold with claims that they were capable of reception of station KDKA in the USA. Valves in stock included Cunningham 301A with bakelite base; Philips D, IV and DV valves; UV201A; and dry cell types AWA 199, Philips B11 and C299.

In time for an expected Christmas rush on receivers, the Radio Department was moved to the Lower Ground Floor of the large new store facing Market, Castlereagh and Elizabeth Streets. The D J Standard–4 was listed at a special price to encourage sales. The four valve set was made in the company's own workshop and employed two station tuning controls and volume control with capability of reception of stations in Brisbane, Melbourne and Hobart.

Another David Jones receiver was the D J Portable, a self-contained battery-operated model very popular during 1927–28. Four sets were purchased by the Adelaide Bedford Park Sanatorium Welfare Committee for use by inmates.

Even in the late 1930s David Jones was operating a large Radio Department in the Radio Hall of their George Street shop. At the time, they had in stock a large range of AC powered and battery-powered kit sets including Pentagrid Four receiver using a 6B7S as detector and intermediate frequency amplifier with a circuit employing reflex amplification; a dual wave Pentagrid Six, a battery-powered model; a dual wave four valve battery-powered receiver; and Advance All-Electric Five receiver. The receivers were also available as fully assembled, with or without a cabinet. To encourage sales, the company offered free assembly of kit sets to the first 20 buyers of kit sets purchased on a specified date.

The large range of components and accessories included table and console cabinets made from piano finished Maple with rolled top and cathedral fret; Recepticon aerial wire; mains filters; AWA transformers; Jensen, Amplion, Jubilee, Rola and Magnavox loudspeakers; Cossor and Puritron valves; Neutron crystals; Ebro glass enclosed crystal detectors; Beldas resistors; Chanex capacitors; Lomil electrolytic capacitors; Renrade valve sockets; Morse Code practice kits; IF transformers; aluminium valve and coil cans; cardboard and bakelite coil formers; Frost and Baldwin headphones; switches and others.

One early member of the David Jones technical staff was Langford Penny who began work in the Radio Department when 17 years of age after having been interested in wireless as a schoolboy. He had constructed a crystal set after obtaining parts from Universal Electric Co., at 244 Pitt Street, Sydney and listened to Coast Radio Station VIS learning the Morse Code. While employed at David Jones he was engaged on counter sales of radio components, assembly of their Low Loss receivers and home receiver repair work. He attended the Marconi School of Wireless during the evenings and after obtaining qualifications left David Jones and went to sea as an employee of AWA as a Ship's Wireless Operator. After two years at sea, he joined AGE Co., Ltd in Queensland as Country Salesman. Subsequent positions were with Aeolian Co., Radio Department, Newcastle and J A Booth and Co., Ltd, Sydney before establishing his own radio business at Northbridge, Sydney. In February 1925, he joined 2TM Tamworth performing Announcer duties. At the time 2TM operated with a 50 watt transmitter and a small studio but were planning to install a 2000 watt transmitter and expanded studio facilities.

Mr R C Marsden was also a member of David Jones Radio Department. He commenced his career in wireless by working with Father Shaw at his Maritime Wireless Station at Randwick. In 1911, he returned to England to complete a course in Electrical and Mechanical Engineering at Liverpool University. During the War he was with the Royal Garrison Artillery working on a secret Aerial Communications System. On return to Australia he obtained an Amateur licence and built station 2JM using it for experimental broadcasting purposes. He was President of the Metropolitan Radio Club and the Club Delegate to the New South Wales Branch of the Radio Association of Australia.

Another Sydney Department store to set up a Radio Department was Grace Brothers, Broadway. They became involved even before the first broadcasting stations went to air in late 1923.

In February 1923, the company installed a transmitter on the premises and placed receivers throughout the store. It did a lot to entice people into the store and there was an increase in sales as a result of the visitors, many of whom came to listen to the wireless.

During March 1923, the company mounted an extensive advertising campaign in city and country newspapers about its Radio Department and increased the stock of fully assembled receivers and components. The Radio Department had experienced technical people who were kept busy visiting people who had made enquiries about offers to provide and install complete wireless system in the home. Many of the enquiries came from the country with some as far away as Wagga Wagga and Tamworth. The company produced a booklet 'All About Wireless' which could be purchased for sixpence, with many thousand being sold within four months of publication. Mr W G Keogh was in charge.

The company maintained its Radio Department for many years and in 1929 when AC mains receivers became available, it arranged for Eclipse Radio Pty Ltd to supply an 'All Electric' four valve kit set of simple design which could be assembled by the home constructor on a wooden baseboard. Parts included Lewbury resistors, voltage dividers, power transformer and filter choke; Essanay variable capacitor; Dresner RF choke; Kelford AF transformer and valve sockets; National resistors; TCC fixed capacitors; Radiokes tuner; Amsco fixed capacitors; Dominion dial; and Radiotron valves. The circuit was basically a Reinartz type which had been employed for many years with commercially produced receivers as well as by home constructors.

Roy Cook, a pioneer broadcaster of South Australia recalled having visited Grace Brothers in Sydney when the kit sets were on sale. Sales staff told him that the kit sets did not sell well. Although home constructors were happy in assembling battery-powered receivers, they were reluctant to assemble AC mains powered sets because of the high voltages which were employed with these receivers.

A number of major Department stores in Melbourne were also active in radio retailing. Myer, and Buckley and Nunn were two such stores with large stocks of assembled receivers, kit sets and components. Because of competition from the many Radio Shops in the city, the Department stores held frequent sales in order to attract customers. In the Summer Sales of January 1926, both Myer and Buckley and Nunn offered large discounts. Myer had an exceptionally large stock which included some components not available from Radio Shops due to the company policy of direct imports from overseas manufacturers.

Some of these items which sold well at the Sale included Dr Nesper headphones, recognised as a premium product; Scientific Tower loudspeakers; Naturelle receivers; Supertron valves made by Supertron Mfg Co., New York, with individual serial numbers and wrapped in a Guarantee Certificate; Schickerling valves made in USA, featuring an unusual construction technique and claimed to be non-microphonic and Edison Bell variometers; Atwater Kent and Super Five receivers.

Myer also marketed their own brand name receiver, the Myradio 5 which featured single dial control and sold well in 1928. It was manufactured in USA to Myer specification and was sold with Adventurer or RFL cone loudspeaker, 2 Hellensen Triple Capacity 45 volt B batteries, 1 Hellensen C battery, one 55 Ampere/hour 6 volt accumulator, five Radiotron UX201A valves, complete aerial accessories and a station tuning chart.

In Queensland, Department stores in The Valley, Brisbane, established Radio Departments in their stores about the time broadcasting commenced in Brisbane when 4QG went to air in 1925. Stores included T C Beirne and Co., Overells Ltd and McWhirters.

T C Beirne and Co., established its Radio Department on 2 March 1925, some four months before 4QG began operation. They had a wide range of receivers and components specialising in AWA products. Stock included Radiola and Tunafone crystal sets; Radiola two and four valve battery receivers; Marconiphone two valve receiver; Amplion loudspeakers; AWA, Marconi, and Radiotron valves; Brandes Matched-Tone headphones; crystal detectors; Ormond variable capacitors; AWA audio transformers; Bradleystat, Ajax rheostats and potentiometers; Electrad variable grid-leaks; Eusco and Dutho rechargeable B batteries; Homecharger battery charger; Murdoch headphones and others.

By 1940, the company was trading as T C Beirne (Pty) Ltd and included among the large range of receivers in stock were:

- Theatrette Model, a superheterodyne circuit mantel receiver in a moulded cabinet and employing Philips valve types.
- Grand Model, a receiver covering the MF and short wave bands with a glass edgelit dial. Cabinet was a highly-polished veneer wooden console type.
- De Luxe Model, built by Kriesler with a five valve chassis featuring MF and short wave reception capability, air tuned coils, automatic volume control, continuous tone control and a highly polished console cabinet.
- Beirne Special Model, a five valve dual wave receiver housed in a veneer wooden console cabinet.

In 1926, the company stocked a full range of Astor brand receivers as well as other brands.

In 1925, Overells Ltd stocked the full range of Phoenix receivers and a wide selection of components. They provided a complete installation service with their Phoenix receivers including the erection of an outdoor aerial system and buried earth plate. The receiver models included Phoenix No 1 crystal set, Phoenix variometer tuned crystal set, one valve receiver with headphones, two valve receiver with Brunet loudspeaker and three valve receiver with Amplion Junior loudspeaker.

By early 1926, the Radio Department was very busy supplying the needs of customers and to meet a demand, the staff put together a kit set for a three valve receiver complete with all parts, accessories, wiring diagram and construction details. A polished silky oak cabinet was available as an optional extra. Valves supplied were three Mullard D.06 types. Batteries were three Columbia dry cells for filaments and Columbia 60 volt B battery for anodes. The company radio experts provided free technical advice for constructors who may have had difficulty in assembling the receiver or getting it to work. A group of schoolboy boarders at Nudgee College took advantage of the offer and invited the Technical Manager to the College to advise the group on assembly and to assist in erection of an outdoor aerial. During a follow-up visit by the technical expert, there were three boys constructing crystal sets, two building a one valve receiver and a senior student building a three valve model. In 1933, Bro. Geraghty operated Amateur station VK4CB at the College.

McWhirters, a major Mail Order house, stocked a range of locally assembled battery receivers under the brand name 'Valleola'. The four and five valve models were popular with country customers and during one consignment by rail, four sets went to Dalby, three to Pittsworth, six to Oakey and twelve to Toowoomba, all on the Darling Downs where listeners could receiver 4GR in Toowoomba and occasionally 4QG in Brisbane.

The receivers were supplied with accumulator for the filaments where standard valves were fitted, and dry cells where dull emitter valves were fitted. The Valleola Five was installed in a magnificent cabinet with a sloping top panel with twin doors and a slide out table so it could be used as a writing bureau. Batteries were housed in a double door section beneath the receiver unit while the loudspeaker, a Burndept Ethovox model with mahogany petal design flare, was mounted on top of the cabinet.

The company was still selling receivers during the Second World War and in 1940 when there was a high demand for receivers capable of short wave reception they marketed the McWhirters Special, a six valve dual wave receiver fitted with the latest double-purpose octal valves, a 12 inch (30 cm) loudspeaker and housed in a highly polished veneer wooden console cabinet.

One of a number of Department stores located in the central business district of the city with a Radio Department was Finney, Isles and Co. The company set up its Radio Department about

February 1925 in anticipation of brisk trade when the 4QG installation was completed. In addition to fully assembled, factory manufactured receivers capable of receiving medium and long wave stations, they stocked a wide range of components including valves, AF transformers, headphones, loudspeakers, coils, capacitors and batteries. However, they specialised in the crystal set market and had one of the largest stocks of assembled sets, kit sets and components in Brisbane at the time 4QG was officially opened.

Just before Christmas 1925, large discounts were offered to encourage boys and girls to become interested in the new technology. Their Radio Department technical experts which included some well-known Brisbane Amateur broadcasters, invited young people to attend a series of practical demonstrations in the assembly of crystal sets. The response was beyond expectations, and over a period of two weeks, more than 120 enthusiasts attended the demonstrations. It also was good business, as the store was hard-pressed to supply the demand for parts used in constructing the sets. Sets built included models with sliders, variometers, couplers, spider coils, basket coils and tapped inductors. Two boys constructed units with an audio amplifier following the crystal detector. On Christmas Eve, the names of all those who successfully completed their projects were entered in a raffle, with the winner being a boy from Banyo, Master Bell, aged 12 years who was presented with a kit set for a two valve receiver.

Businesses associated with the music industry were also active in selling radio receivers. Brisbane firms included Carnegie Bros, with Airzone, Stromberg-Carlson, STC, Radiola, HMV, Regent, Howard and Resident brands; Palings with Majestic and Victor brands; Grices with Tasma brand; and King and King with Airzone, Gulbransen, Philips, Kingsley and Claribel brands.

In South Australia, James Marshall and Co., Ltd, Rundle Street, Adelaide was one of the many active Department stores involved in marketing receivers and radio components. The company was also interested in the wider broadcasting field. It was one of the applicants for a B Class station licence in 1924. It had arranged for J H Chesterfield, a Radio Expert, and a company employee to visit the eastern States to look into the availability of broadcasting equipment to establish a 500 watt transmitter in the company city building with two 40 m high aerial support masts on the building rooftop.

In September 1924, Marshalls opened a Wireless Department with Chesterfield as Manager and had one of the largest stocks of receivers and components in Adelaide at the time. The stock included a complete range of receivers and components manufactured by Radio Communications Co., Ltd, London. They included Polar Radiophone seven, four and two valve models. The four valve model incorporated an interesting feature in that it provided two separate tuning circuits. Once adjusted, changeover from one station to another could be effected by a remote control which also governed the volume of reproduction. The circuit comprised a detector followed by three stages of low frequency amplification, using resistance-capacitance coupling between stages. The receivers employed Marconi LS3 valves in output stages and R types in the other stages. Crystal sets in stock included Polar with a plug-in inductance, Fortevox, Superior, Service, Revophone and others. The component range was very extensive including all popular USA and English valves, at least a dozen different brands of AF transformers, 20 different brands of rheostats and several variable capacitor kits. The rheostat stock included such well-known brands as Acme, Peerless, CAV, Atlas, Ericsson, Climax, Fortevox, Gambrell, Igranic, Lissen, Ellanpee, MH, Cosmos, Camden, Polar, Pye, Sterling, Goltone, Wates and Woodhall.

Charles Birk and Co., Ltd, Rundle Street, Adelaide conducted a thriving business in sales of radio receivers backing up their activities with a Service Maintenance Laboratory to install sets sold by the company and to offer a radio repair service to the public for all brands. Technician-in-Charge of the Laboratory was Gilford White who also worked for the local School of Mines as an Instructor.

Many of these Department stores were still involved in the marketing of radio receivers in 1997, although some no longer traded under their original names.

Besides Department stores, the majority of businesses which had dealt with the distribution of electrical goods before the advent of broadcasting were quick to establish a Radio Department in the organisation and acquire stocks of receivers and components.

One of these firms was Noyes Bros, Ltd. The firm had been registered in 1907 and by the 1920s had branches in all States and many major towns. It had one of the largest and comprehensive stocks of radio goods in South Australia. In 1934, receiver brands handled included Radiola, Stromberg-Carlson, Audiola, Tasma, STC as well as its own brand Seyon (Noyes spelt backwards) manufactured by Stromberg-Carlson. Components included Philips, Radiotron and Mullard valves; Magnavox, Amplion and Jensen loudspeakers; Whiting pick-ups; Ferranti meters, transformers, capacitors and resistors; Stromberg-Carlson ganged capacitors and superhet coil kits; TCC electrolytic and mica capacitors; Durham resistors; AWA components; Philips components; Exide radio accumulators; Ever-Ready and Diamond A, B and C dry cell batteries; Tasma wave traps; Hydra, Chanex and Renrade capacitors; Marquis components; Emmco products; Carboncels; Henderson power transformers and chokes; Paillard and RCA electric gramophone motors; Radiokes parts and coil kits and many others. They also stocked a wide range of accessories such as busbar wiring, insulated wires, aerial wire, insulators, terminals, dials, lamps, chassis etc.

TWO DECADES OF PROGRESS

Wireless, or radio apparatus and components were available from several sources in Australia well before the establishment of broadcasting stations in the early 1920s. War surplus equipment from Great Britain and the USA was readily available to meet the demands of experimenters whose ranks were swelled by the return of Servicemen who had been trained in the technical aspects of wireless in the Army, Navy and Air Force.

With the introduction of broadcasting in Great Britain and the USA, firms there geared up to meet the public demand for fully assembled receivers, kit sets, accessories and components, and by the time stations became operational in Australia those companies were in a good position to flood the Australian market. In Great Britain alone, in 1924, there were more than 300 companies involved in the production of about 1000 different component types and great quantities were shipped to agents in Australia. Some companies even saw fit to establish branches here. The situation was similar with USA manufacturers, so there was soon a proliferation of overseas products available to the public.

Agents, distributors and representatives were quickly established. Many lasted only a short time, but others are still active today, even though only a handful now are involved in radio products.

It was not long before local manufacturers set up business to produce their own receivers using imported components and in some cases, locally made parts. Some enterprising mechanics wound their own coils, chokes and audio transformers, wire wound resistors and rheostats, made grid-leaks by dusting carbon dust on to an insulated strip coated with an adhesive and many made their own wooden cabinets to house the receiver. Crystal sets and one valve receivers formed a large part of total receivers produced in the early stages of setting up a business. There was no standard circuit available and designers could choose from a dozen or more described in technical magazines of the day with the number of valves ranging from one to eight. Included among organisations involved in the design, manufacture, assembly, distribution, servicing or sale through Radio Shops during the first two decades of broadcasting in the various States, other than those recorded in some detail elsewhere in this Chapter, include the following:

* NEW SOUTH WALES

New South Wales was the first State to have a broadcasting station established when 2SB (subsequently 2BL) commenced transmission in November 1923, followed by 2FC in December of the same year. These were A Class stations as approved by the Government and on 7 November 1924 two B Class stations, 2BE and 2UE began operation in Sydney, followed by 2HD in Newcastle on 1 December 1924.

Even before the establishment of these transmitting stations, many Radio Shops, agents or distributors had begun stocking fully assembled receivers and a wide range of parts and components mainly imported from Great Britain and USA.

Many businesses lasted only a short time as competition increased and it would be extremely difficult to obtain information of every business. However, the following were active in Sydney during the first two decades of broadcasting with some still in existence today, even though only a very few still stock broadcast receivers or components:

* WM. ADAMS AND CO., LTD
Aerial wire and insulators, enamelled, silk and cotton covered wires.

* AMPLION (AUST.) LTD
Loudspeakers.

* ANTHONY HORDEN AND SONS LTD
Hordernia receivers, crystal sets, Myers and Expanse valves, and a wide range of components and accessories.
In 1934, Manager of Wireless Department was Mr S Hardy.

* ATKINS MACLEAN PTY LTD
Yale A, B and C batteries.

* AUSTRALIAN WIRELESS COMPANY
Radiair receivers and components.

* GEO BROWN AND CO., LTD
Distributors of Ultimate brand receivers manufactured by Ultimate Radio Ltd, New Zealand. Model brand names included Baby Grand, Classic, Embassy, Empire, Majestic, Regent, Roslyn, Royal, Symphony and others.

* BRANDTS LTD
Success receivers.

* A H CARTER
Cossor valves.

* CLUBB A M AND CO.
Presto, Universal recording equipment; Telefunken radio valves and receivers.
Established by Alex Clubb, Electrical Engineer, 1929. Company registered 13 August 1934.

* CONTINENTAL RADIO AND ELECTRIC CO.
Graham capacitors, coils and transformers.

* EASTERN TRADING CO., LTD
Ken Rad valves; receivers; chassis and a range of components including Solar capacitors, ETC mica capacitors, Hickok meters, Bradley units.

* ECONOMIC RADIO STORES
Philips receivers and components; Amplo B eliminators; Economic B eliminators; Renown kit sets; Radiotron, Philips, Radex, Mullard, De Forest valves.

* EDMANCO LABORATORIES
The business located at 27 Union Street, Paddington, released a five valve portable and a four valve AC powered MF band receiver in1946 and five models during 1948 which included a four valve portable receiver. The others were all four valve AC powered models in mantel type cabinets.

* ELECTROSOUND PTY LTD
The company at 422 Kent Street in the city, produced its first receiver in 1946 and by 1948 the total number of models released over the two-year period exceeded 26.
The largest receiver manufactured was model 82R a nine valve AC powered dual wave radiogram originally produced in 1946 but still marketed in 1948 with a few minor changes.
Fourteen of the designs had triple wave capability.

* ELECTRIC TRADING CO.
ETC, Crosley, Stromberg-Carlson, Telefunken receivers; Magnavox loudspeakers and accessories.

* ELECTRICITY HOUSE
An early pre-broadcasting era radio business in George Street, Sydney. In 1923, the business changed hands with new management comprising Ray McIntosh, Works Manager; J S Marks, General Manager and Ray Shaw a former Ship's Wireless Operator being in charge of the Radio Section of the business.
Main products included variable capacitor; variable capacitor component parts including plates, spindles and end pieces; Honeycomb coils and mounts; rheostats; dials and knobs; contact studs; switch arms; terminals; fixed capacitors; Murdock headphones; Meyer's valves; loose couplers; intervalve transformers; crystal sets; components for crystal sets; 1, 2 and 3 valve battery receivers fully assembled and in kit form; Radiotron valves; ebonite, bakelite and fibreboard insulating board; and a range of cabinets for receivers.

* ELLIS AND CO. (AUST.), PTY LTD
Columbia radio batteries.

* ERICSSON TELEPHONE MANUFACTURING CO.
Ericsson receivers, headphones and AF transformers.

* GIBSON BATTLE AND CO.
Exide batteries.

* G AND R ELECTRICAL CO.
G & R 'V' receivers.

* GUILLE AND CO., LTD
Furniture and Radio Warehouse company marketing Guilledyne brand receivers and radio components since 1926. Models included the Guilledyne Three and the Guilledyne Five. The Guilledyne Five was a screened Super Neutrodyne with low consumption Philips valves and provided with a switch to enable the receiver to operate with only three valves when tuned to a local station and so conserve the battery power. Cabinet was a table type of polished solid maple.

* GROSE AND DANIELL
Distributors of Grodan radio components; Solodyne, Browning-Drake and Neutrodyne kits.

* HARDY'S RADIO SERVICE
Manufacturer of Truvoice brand receivers including the Super Six employing two 235 variable mu screened grid RF amplifiers; 224A screen grid power detector; 227 AF amplifier; 247 pentode (two) in push-pull output stage plus 280 full wave rectifier.

* H HECHT AND CO.
Chanex capacitors, Chancery potentiometers.

* J J HOELLE AND CO.
Utilux electrical and radio products including chassis, kit sets and a range of components.

* INTERNATIONAL RADIO CO., LTD
Brandes Ellipticone loudspeakers; Supertran RF transformers; Goat valve shields; Audalion loudspeakers; Bright Star batteries; De Forest receivers, valves and loudspeakers; Crosley receivers and components.
Charles Forrest, Managing Director. Company registered 18 October 1924.

* LATIMERS WIRELESS SUPPLIES LTD
Chapin, Grebe, Arborphone, Paradyne and Magnavox receivers; TAB dry rechargeable batteries; Manhattan loudspeakers.

* LEVENSON J
Ideal receivers and components.

* MANUFACTURERS PRODUCTS PTY LTD
Deresnadyne receivers; Baldwin loudspeakers; Armax batteries; Airzone receivers; Bijou B eliminators; capacitors; Browning-Drake kit sets; chokes; MP Sterling loudspeakers; EMMCO products.

* MINGAYS WIRELESS MANUFACTURING CO.
Unique Super Five receivers.

* MURDOCHS
Range of receivers, Lissen pick-ups; battery charger; Amplion loudspeakers; accumulators and B batteries.

* NEW SYSTEM WIRELESS
  NST receivers; headphones; Philco Diamond Grid batteries; Burgess batteries; Everset patented detector.
* FRANK O'SULLIVAN
  Electrical Engineer and supplier of electrical and radio equipment and parts from business with 20 employees at 296 Pitt Street, Sydney in 1923.
* J PAYNE
  Manufacturer of a range of Superlative brand receivers.
* POLLOCK ELECTRICAL MANUFACTURING CO., BELMORE
  The company began manufacturing a large range of Pollock brand coils of high quality about 1929. The range included:
  - Reinartz tuners.
    Plain types, DSC wire in several diameters; plain types, enamelled wire 62 mm diameter; terminal type, DSC wire 62 and 75 mm diameters; variable aerial type, DSC 75 mm diameter; space wound type, two coil DSC and plug-in UX, DSC wire.
  - RF chokes.
    Slot wound type, 500 turns; bakelite type, 1000 turns.
  - Marco Four kits.
    Enamelled wire, 62 mm diameter; DSC wire, 62 mm diameter; DSC wire, 75 mm diameter; space wound, DSC wire; and plug-in UX type.
  - Wave trap coils.
    Space wound type, DSC wire; and close-wound type, DSC wire.
  - Screen grid kits.
    1930/4 screen grid type kits of three units; 1930/3 screen grid type kits of two units; All-Australian 3, screen grid kit of two units with gold sprayed shields; New Era 4, screen grid kit for Ross Hull battery receiver and New Era 3, screen grid kit of two units.
  - Miscellaneous.
    Single rotor three circuit tuners, 62 and 75 mm diameters; Renown kits; Browning-Drake kits, DSC wire 62 mm diameter; centre tapped resistors; plain aluminium cans; gold sprayed aluminium cans.

  In New South Wales, Pollock radio components were distributed by Fox and MacGillicuddy Ltd, Merino House, York Street, Sydney.
* PRICE'S RADIO SERVICE
  Radiomac products, component parts and kit sets for the home constructor, as well as locally assembled receivers with or without, cabinet.
  Assembled receivers included:
  - Aristocrat Three, a 1931 direct coupled design employing screen grid amplifier, detector and 245 output amplifier.
  - AC Super Six, a seven valve AC powered receiver employing valve types UY235, variable mu screen grid valve (two); UY224, screen grid valve; UY227, first audio, two UX245 power output valves in push-pull and UX280 rectifier.
  - AC powered nine valve dual wave receiver.

  Proprietor was Aubrey Frederick Price, a well-known Radio Shop owner since about 1922.
* PRIMA DONNA RADIO AND CABINET CO.
  Manufacturers of Prima Donna receivers, power packs, wire wound resistors, voltage dividers, RF chokes, aluminium shields, aluminium chassis, matched coil kits, console and table type cabinets. The company was well-known for its 'green and orange' products supplied to the trade and manufacturers.
  Prima Donna receivers in 1932 included the Variable Mu 3 and the Variable MU 4. A Pre Selector unit was also produced.
* RADIO CO., LTD
  Locally assembled receivers, crystal sets, sold under the Radico label; large range of components and accessories.
* RADIO EQUIPMENT PTY LTD
  Manufacture, sales and service of a range of radio receivers, amplifiers and test equipment. In 1942, the University Supertester was one of their best-known valve and circuit testers. Managing Director, Lance Graham; Manager, F W Freeman; Chief Engineer, Rex Lackey.
* RADIO HOUSE (ELECTRIC UTILITIES SUPPLY CO.)
  Myers valves; kit sets; components.
* RAMSAY SHARP AND CO., LTD
  Receivers; crystal sets; components and accessories.
* R W REYNOLDS LTD
  Renrade resistors.
* ROSE REG AND CO.
  Established 1923 by Reg Rose, former AWA Department Manager.
  Wholesale radio and electrical goods including Jensen and Rola loudspeakers, USA manufactured receivers, Thordason amplifiers and transformers, Diamond batteries.
* SCOTT AND CO. (SYDNEY), LTD
  Telefunken and Arcophone receivers and loudspeakers. In 1930, Telefunken receivers included:
  - Model Telefunken 9W, a six valve AC powered shielded Neutrodyne circuit receiver with one dial control.
  - Model Telefunken 40 W, a four/five screen grid set available for operation from 240–110 volts AC; 240–110 volts DC or battery power.
  - Model Arcolette 3W, a four valve AC powered receiver.

  All receivers were provided with facilities to enable gramophone record reproduction. Loudspeakers available included Arcophone 5, Arcophone 4 and Arcophone 3.
* MICK SIMMONDS LTD
  Eclipse and Splitdorf receivers; valves; Manhattan loudspeakers; components and accessories.
* SWAINS
  Radiovox and Sterling receivers; crystal sets; kit sets; amplifiers; Frost and Sterling components.
* TEN EYCK AND TATHAM
  Bradleystat rheostats; Baldwin radio products; Atwater Kent products; Electrodyne capacitors; Farrand loudspeakers.
* THE EDISON SWAN ELECTRIC CO., LTD
  Dulcivox and Televox loudspeakers; crystal sets; Ediswan receivers; valves and components.
* THE LAWRENCE AND HANSON ELECTRICAL CO., LTD
  Sterling receivers, kit sets, loudspeakers, headphones, transformers; Magnavox loudspeakers; Mellovox loudspeakers.
* THOMAS EDISON LTD
  Edison primary batteries.
* A A TRELOAR
  Sleeper receiver kits; Volta kits; Autovox loudspeakers; Teleradio headphones; Crosley receivers and components; Electrad valves; Bristol components.
* UNIVERSAL ELECTRIC CO.
  Universal receivers; Baldwin headphones; Audiotron, Cunningham and Radiotron valves; Thordarson's transformers; Murdoch loudspeakers; Universal loose couplers; components and accessories.
* WELBY RADIO CO.
  Gilfillan radio products, including full range of receivers.
* WELDON ELECTRIC SUPPLY CO., LTD
  Bosch receivers; components.
* WESTCOTT HAZELL AND CO., LTD
  Metropolitan and sole New South Wales country distributors of STC brand receivers during 1934. The company had been in business since 1914.
* W HARRY WILES
  Valve receivers, chassis, crystal sets; BTH valves; components and accessories.
* WILKS E F AND CO., LTD
  Gulbransen receivers. Branch office in Newcastle.
  The company was registered as a business in Sydney in 1917.
* WINKWORTH C AND SON LTD
  Established 1924, retailing pianos, players and gramophones. Began manufacture of Essex brand receivers about 1932 with models including:

- Carillion, a six valve superheterodyne set with IF 175 kHz and valve types 224 (two), 227, 235, 247 and 280.
- Standard, a four valve receiver.
- Cloister, a four valve set with pentode, variable mu and screen grid Radiotron valves.
- Celeste, a six valve set with two pentodes in push-pull output.

In 1934, a range of Essex Ultimate series was produced and included six valve all wave AC powered superheterodyne set; eight valve all wave AC powered model; and five, six and seven valve battery-powered models.

* WIRELESS SUPPLIES LTD
Range of high performance Volmax receivers including RD, RE and RF models with the RF model featuring push-pull audio output.

These firms were located in the metropolitan area, but there were also prominent traders and dealers in New South Wales country areas. With some businesses, radio formed only a part of the total business activity. They included:

Clancy, Bros., Griffith; C M Croke, Koorawatha; Duncan and Peadon, Narrabri; Glenn Innes Motors and Radio Specialists, Glen Innes; Goulburn Radio House, Sales and Service, Goulburn; L B Landers, Coonamble; Miltons Radio and Electrical Service, Mudgee; E M B Peel, Bega; Rapley and Whyte, Tocumwal; E A Dowse, Radio Mechanic, Boorowa; Reads Radio Service, Newcastle; E F Wilks and Co., Ltd, Newcastle; Home Recreations, Newcastle; Hutchison Radio Co., Newcastle and others.

Of all the Radio Shops in Sydney in the 1920s, and indeed even in the 1930s, one of the best remembered by veteran buffs today is the business conducted by Miss Florence Violet Wallace, and later known as McKenzie and Wallace when she merged with Mr McKenzie, a fellow Radio Shop owner.

The shop at 6–8 Royal Arcade, opposite Queen Victoria Building in George Street, and later with a Railway Branch at 495A Pitt Street, was a Mecca for boys of the period 'bitten by the radio bug'. Many people today, recall the help given by Miss Wallace, or Vera as she liked to be called, in keeping alight their enthusiasm at a time when pocket-money was so scarce, and the price of a pair of headphones or tuning capacitor seemed beyond reach.

Miss Wallace was a qualified Electrical Engineer with a Diploma in Electrical Engineering from the Sydney Technical College.

She formed an Electrical Contracting business installing electrical equipment and undertaking repair work on motors and generators. She later purchased an existing electrical business in Royal Arcade.

Vera had an interest in radio, being a licensed and active Amateur with station 2GA located at her home at Greenwich Point and decided to add radio receivers and components to her shop stock from September 1921. Demands on the radio side of the business soon outstripped that provided by the electrical sales and she subsequently closed down the electrical side of activities.

Because of her academic training in Electrical Engineering, and experience as an Amateur experimenter, her advice was valued by the many radio enthusiasts who visited her shop. She produced a series of circuits with full construction details and provided them free of charge to customers.

In 1922, together with W J Maclardy, W M Maclardy, A Mitchell and R C Marsden, the group published the 'Wireless Weekly', still in publication 75 years later in 1998, but under the title 'Electronics Australia with ETI', published by Federal Publishing Company with Jamieson Rowe, Managing Editor and Rob Evans, Technical Editor.

At one stage, the business was advertised as 'The oldest Radio Shop in town' and carried a very large stock of assembled receivers, kit sets and components. These included Kriesler, Radiokes, Economy, the 1932 Advance and other kit sets ranging from crystal sets to complete superheterodyne receivers. Each kit included stamped and drilled chassis, professionally drawn blueprint, full assembly and testing instructions as well as all necessary parts. Kit sets could also be purchased fully assembled, tested and guaranteed for those who did not wish to tackle the job of assembling and wiring.

A four valve Volmax receiver assembled by staff in the shop was popular in 1932. It featured two stages of variable mu RF amplifiers and screen grid detector coupled to a UY247 pentode.

About April 1934, Miss Wallace, who by that time became Mrs McKenzie following marriage to her business partner, was instrumental in establishing the Electrical Association for Women and became its first Director. It was intended that the body would function along similar lines to a body which had already been formed in England.

The Association had a small stand at the Electrical and Radio Exhibition to publicise the Aims and Objects of the Association and those in attendance were hard-pressed to deal with the large number of enquiries from women visiting the Exhibition.

Establishment of the Association was an immediate success with about 1000 women becoming members within three months of formation.

The Electrical and Radio Association of New South Wales through its Electrical and Radio Development Association (ERDA) was keen to provide support for the new women's organisation. Following a meeting between the two groups, an Agreement of Understanding was reached whereby the Electrical Association for Women would adopt a policy of co-operation with ERDA in return for which ERDA would enlist financial backing from its members of the trade in order to subsidise the Association for the first two years to ensure it could become self-supporting by that time.

Just before the outbreak of the Second World War, Mrs McKenzie started a school to train women as Wireless Operators and Signallers. She established the Women's Emergency Signalling Corps and had trained about 1000 women when War broke out.

In response to a newspaper advertisement appealing to radio Amateurs to enlist as Telegraphists in the Navy, Mrs McKenzie offered the services of members of the Corps. The Director of Signals and Communications recommended to the Naval Board that the women be employed as Telegraphists at shore establishments to release men to seagoing duties. The Navy selected 14 from the applicants and they took up duty at the Harman Wireless Station on 28 April 1941. From that beginning, the WRANS grew to a peak wartime force of 105 Officers and 2518 Ratings who were engaged on a wide range of duties at Naval installations. Some of Mrs McKenzie's former students also joined the other Services.

She also trained Servicemen, and by the end of the War, some 12000 operators had attended her classes. The school in Clarence Street continued after the War, training Pilots and Ship's Wireless Operators until 1955 when the school closed.

Mrs McKenzie who died in 1982, at age 90 years, was awarded the OBE in 1950 for her voluntary services to the Women's Emergency Signalling Corps.

In the 1930s, in co-operation with Walter Hardy of Hardy's Radio Store, also located in the Royal Arcade, Sydney, Miss Wallace compiled a 50-page booklet, 'A Handbook for the Home Constructor' which was distributed at no charge at both stores as part of the efforts of these two people to encourage enthusiasts to construct their own radio receivers.

Like Miss Wallace, Walter Hardy was an Engineer and commenced involvement in the radio trade before the advent of broadcasting. He was one of the early Amateur operators after the First World War with his station 2RD being one of those transmitting programs on the 200 metre band. He later became Secretary of the Wireless Institute. Walter attended the University of Sydney where he studied Mechanical and Electrical Engineering and Science following education at the Tamworth District High School. He began selling radio parts in 1921 and later spent three years as Engineer for Economic Radio Stores, one of Sydney's largest radio mail order organisations.

During the period 1930 to 1933, he was partner in Hardy's Radio Store, Royal Arcade, and subsequently established W R Hardy and Co., at Hurstville.

Another lady active in the radio business circles in Sydney in the 1920s was Miss Sachs, Knox Street, Randwick. She specialised in the manufacture of a molybdenite crystal detector for crystal sets or as a detector in valve receivers. It was sold under the trade name 'Sacrystal', and was sold by most Radio Shops in the city. Its main advantage was that it was not subject to annoying signal loss as often happened with a standard crystal and wire cat's whisker. Once the contact had been adjusted for maximum signal, it remained fixed due to the high pressure exerted by the contact on the crystal element. The small box containing the crystal claimed it to be 'the most sensitive wireless detector'. The molybdenite detector had been made popular by the German Telefunken Company which used it in their ship's wireless installations in the pre-valve era. The Company used a stiff silver spring as contact. Molybdenite detectors were also widely used by Australian spark wireless station operators prior to the First World War, including Peter Kennedy XYB in Western Australia, Ern Stanton XVN and Lance Jones XVB in South Australia, and Eric Bowden in Tasmania.

Of the New South Wales Consulting Engineers who were prominent in the design and construction of custom-made high quality receivers, Charles D Maclurcan conducted a successful business. A business known as Radio Electric, manufactured a model under the brand name Maclurcan Low Loss receiver.

Maclurcan was one of the early wireless experimenters being involved from 1910 when he constructed a spark wireless station on the roof of the Wentworth Hotel in Sydney where he lived with his parents who owned the hotel. He was only 19 years of age at the time. The station with callsign XDM was licensed in the name of Maclurcan and Lane.

In the same year he was a foundation member of the Wireless Institute of New South Wales which had been organised by George Taylor. It was considered to be the first organised amateur wireless society established in the British Empire.

Shortly after the end of the First World War when the Government decided to issue experimental licences, his station 2CM at Strathfield began to transmit regular broadcast type programs and had a large following. The majority of the programs broadcast were concerts of a classical nature and he was considered to be a pacesetter in the field before broadcasting began officially with the commissioning of A and B Class stations. One of his outstanding broadcasts was a program by the musical comedy star Josie Melville in 1923.

In 1924, in co-operation with AWA, he carried out low power experimental transmissions while on board 'SS Tahiti' sailing from Australia to America. Using only 7.6 watts of transmitter power he established communication with Australia while in San Francisco using Morse Code. During 1926–27, he conducted a series of experiments using short waves proving the success of 20 metre (15 MHz) transmissions between Australia and England during daylight hours.

He was a regular contributor to technical magazines of the period with his feature in 'Radio Broadcast' during 1925 being eagerly read by experimenters.

He was the designer of a range of receivers manufactured by The Colville-Moore Wireless Supplies in 1925 and sold under the label 'Chas Maclurcan'. They were noted for their ease of operation and excellent tonal qualities. A tuning chart was affixed to the set to enable easy setting-up of dials for station reception. Each receiver was provided with a rosewood inlaid polished cabinet and a certificate certifying that the receiver had been tested and was guaranteed by Chas Maclurcan himself.

Maclurcan undertook a number of visits to England and the Continent to study the latest in Broadcasting Technology and in 1929 was appointed Australian representative of the English company A C Cossor Ltd, manufacturers of Cossor valves, Cossor receivers and kit sets. The Melody Maker kit sets were popular in Australia and some can be seen today in vintage radio collections in operational condition.

During the mid 1930s when he represented Cossor, the company produced a number of new valves which sold well in Australia. Included were the type MS/PenA, one of the first RF pentodes available and the 220VSG, a battery type variable-mu screen grid valve. The company continued to manufacture valves until 1949.

Another Sydney Consulting Engineer well-known for the design of high quality receivers was Chas Smith. He specialised in custom built single dial receivers fitted into a range of high quality cabinets selected by the customer.

Albert Thorrington who had been associated with Radio Engineering since 1923, operated a practice as Radio Consultant at 14 Harrington Street, Marrickville for the construction of custom built receivers, modification of commercially produced receivers to improve performance and installation of home receivers for distributors and manufacturers.

On 26 June 1932, he founded Express Universal Instrument Company in partnership with A J Simpson at 50 Parramatta Road, Petersham for the design and manufacture of high quality radio test equipment. He became sole proprietor of the company on 5 February 1934. Albert was a Full Member of The Institution of Radio Engineers (Australia) and held a Diploma in Radio Engineering.

*** VICTORIA**

In the period just prior to the establishment of regular broadcasting in Victoria, there was ample opportunity for the public to become familiar with what broadcasting had to offer as an entertainment medium. In addition to experimental transmissions by AWA, there were many active Amateurs transmitting on a regular basis in the 200 metre band and providing excellent programs including recorded music, talks on a wide range of subjects, local news and performance by local singers and music groups.

The demand for parts, and even fully assembled receivers resulted in high growth in the number of Radio Shops being opened not only in the Melbourne metropolitan area but in the suburbs and a few in the country.

One of the early distributors of radio receivers and components, and which continued in this field for many years, was Suttons Pty Ltd. The business was originally established as a music store in 1884 in Elizabeth Street, Melbourne by Alfred Sutton, one of four Ballarat brothers who included Henry Sutton a prolific inventor and Frederick Sutton founder of Featuradio Sound Productions Pty Ltd, Melbourne. Included amongst the many inventions of Henry Sutton were equipment and devices for use in telephony, telegraphy, television, wireless and photography. Although his work was carried out before 1912, many of the devices which included 23 different telephone designs were years before their time and not appreciated at the time.

By the late 1920s, with headquarters at 290–292 Bourke Street, Melbourne, Suttons had branches at Ballarat, Bendigo, Geelong, Adelaide and Sydney stocking one of the largest range of radio receivers in Australia.

Brands included Radiola, STC, Philips, Astor, Essanay, Precedent, Beale, Crosley, Emmco, Van-Ruyten, Air Master, Stromberg-Carlson and Centurion.

For convenience of prospective buyers, the store included a Radio Salon in which the various models in stock could be demonstrated to assist the customer in arriving at a decision. The Centurion All Electric Phono-Radio was one of the most popular receivers sold, with the company investing considerable expenditure in promoting the model during 1927–29 period. The receiver was claimed to be 'a musical achievement unique in the history of radio'. Literature distributed at the time indicated 'Suttons Radio Engineers, working in close collaboration with trained Musicians, have produced the Phono-Radio after many years of painstaking research and experiment'. The receiver employed five valves in a Neutrodyne circuit design with two operating dials plus volume control and a voltmeter. It was mains powered and was a combined radio/record player fitted with a Pacent Phonovox Reproducer. It was available as Console or Table models with the Console model provided with space for storage of records and an in-built loudspeaker.

Other shops and distributors and some of the major stock items included:

* ALLANS
 Sonora Melodon and Vogue receivers; GE Co valves; Samson PAM super power amplifiers; Columbia Kolster electric reproducing phonograph.
* ARGOSY RADIO CO.
 Manufacturers of Argosy brand receivers. The company specialised in battery-powered designs. One of the popular 1935 models was Model 8B, a five valve superheterodyne receiver with Class B output. It was an upgraded version of an earlier four valve design. The set employed valve types 1C6, oscillator-mixer; 34, IF amplifier; 13, detector; B217, driver and B240 or 19 twin valve output. A battery was a 2 volt accumulator with 0.7 amperes drain while B battery comprised two 45 volt Diamond P5 triple duty batteries. HT drain varied between 5.5 and 11.5 milliamperes. Loudspeaker was Rola FR6 dustproof model. Component brands included National Union and Philips valves, Sprague capacitors and Ohiohm resistors.
 In late 1935, the company produced a Dual Wave 6 Model in console cabinet and employing valve types 1C4, RF amplifier; 1C6, converter; 1C4, IF amplifier; 255, AVC; 30, detector; 19 Class B output. It was equipped with Diamond 60 volt triple duty B batteries and Rola 8-20 loudspeaker.
* ASSOCIATED RADIO CO., OF AUSTRALIA LTD
 Radio-Phone and Radiophone Emperor receivers; Neutrodyne kits; Neutrodyne transformers; Claritone loudspeakers and headphones; Manhattan headphones; Radion valves; Sheltran transformers.
* BRITISH AUSTRALIAN RADIO CO., PTY LTD
 BAR battery receivers; BAR crystal sets; King Neutrodyne receivers; Silverdale B eliminators; accumulators; Crosley receivers and components.
* BROWN AND DUREAU LTD
 Radiotechnique valves.
* BUCKLEY AND NUNN
 Invicta receivers; circuit diagram blueprints of a range of receivers; imported components and accessories.
* CHANDLER D AND W, LTD
 Radiolette, Aladdin, Hypresco, Cassin and other brands of receivers; crystal sets; Radiokes kit sets and components.
* J CONRY
 Wireless cabinets of distinction.
* CORBETT, DERNHAM AND CO., PTY LTD
 The company was established in 1921 by Robert Corbett and John Dernham, initially to import wireless components.
 Dernham established another company Tunafone Wireless Pty Ltd. He was assisted by Frank Hall, a former Post Office Telegraphist. They set up operations in the Corbett Dernham Building in Lonsdale Street, Melbourne where they manufactured Tunafone battery-operated receivers and crystal sets. Many of the components were made on the premises. About 100 sets per week were produced during the peak period of production.
 In 1925, the company went into liquidation but resurfaced in new premises in Little Bourke Street. The following year it relocated to North Melbourne still manufacturing Tunafone brand receivers and components.
 About this time, Dernham registered a new company, Radio Corporation of Australia which later changed hands to become one of the largest manufacturing organisations in Australia.
 When Tunafone fell into financial difficulties about 1927, Dernham left the wireless industry to set up a company to manufacture plastics. At one stage, well-known Radio Engineer Max Howden was employed as Design Engineer by Tunafone.
 The company had large branch offices in Sydney and Adelaide in 1925. The Adelaide office was managed by F Isaacs at 19 Twin Street, Adelaide and at the time, the most popular receiver marketed by the company was the Tunafone Complete 3. Accessories provided with the basic receiver included a set of seven coils, Tunatalker loudspeaker, 3 valves, 60 volt B battery, 5 volt accumulator, headphones and plug, 50 mm length of stranded copper wire for aerial, 8 egg-type insulators, ebonite lead-in tube, lightning arrester and lead-in wire.
* COYLES RADIO PTY LTD
 Coyles Master brand receivers, components and accessories.
* CRYSTAL CLEAR RADIO CO.
 Assembled battery receivers, crystal sets, kit sets, De Jur amplifiers, a wide range of components and accessories.
* ALAN DUKE PTY LTD
 Wetless capacitors and kit sets.
 Founded by Alan Duke, 1931.
* EASTERN TRADING CO., LTD
 Ken Rad valves; electrolytic capacitors; and a wide range of components.
* EUTROPES RADIO
 Lisenola battery receivers; Reinartz assembly kits; Burndept loudspeakers; CAV batteries; aerial equipment and components; Majestic receivers.
* C R FOSTER
 Western Electric receivers, transformers, loudspeakers, valves and microphones.
* J GADSTEN PTY LTD
 Rabar busbar, S type rectifier.
* D GLYNNE
 Superheterodyne specialists. Utopia Super receivers and Comet kit sets, short wave adaptors.
* GOLDMAN H MANUFACTURING CO.
 Radio cabinets.
* GRAND OPERA RADIO
 Manufacturers Grand Opera products comprising range of AC, DC and battery-powered models including Baby Opera midget receivers; transformers chokes; variable capacitors; and special apparatus.
 Founded by Leslie Yelland, Electrical Engineer, 1927; Sales Manager, Francis Yelland.
* HARRINGTONS LTD
 Raycophone, Imperia, Gilfillan and other brand receivers; Radiokes kit sets and components; Pilotron and Radiotron valves; AWA products; Philips valves, transformers and loudspeakers; Wirt cone loudspeaker; Melodia cone loudspeaker; Columbia batteries; Ace Reinartz kits; DX short wave kits; Warren heaphones; Klip-on fixed detector; Amplion loudspeakers; Signal dials; Frost products; Burgess batteries; Grodan products.
* HARTLEY'S PTY LTD
 Bosch Cruiser, Herbert, Olympic, Ferguson, Page and Priess receivers; Baldwin and Lyric loudspeakers; Kellogg components; Carborundum detectors; components and accessories.
 The company was in business before the turn of the century, being established in 1896.
* ALFRED HARVEY PTY LTD
 Kellogg receivers and components; Helios headphones; Harkel radio masts; Harkel batteries and battery chargers; TKD valves and sockets; DAR battery solution.
* FRANK HARVEY
 Airzone receivers, components and accessories.
* H HECT AND CO
 Chanex capacitors and Chancery potentiometers.
* W T HENLEY'S TELEGRAPH WORKS CO., LTD
 Bare and tinned copper wire, bare enamelled wire, silk covered wires, cotton covered wires, insulating varnish, aerial wire and resistance wire.

* INTERNATIONAL RADIO CO., LTD
  De Forest valves; Radion insulation panel board; Brandes headphones and loudspeakers; Audalion loudspeakers; components and accessories.
* KIERNANS
  Erla receivers; Qualtone loudspeakers and a wide range of components and accessories.
* KODAK (A/ASIA) PTY LTD
  Kodak receivers.
* LANGFORD, PICKLES AND CO., PTY LTD
  Euphone battery receivers, crystal sets, Brunet phones, a range of B eliminators and components.
* LOUIS COEN WIRELESS PTY LTD
  Pinnacle, Paton, Astor and Crosley receivers; crystal sets; Advance products; Sferavox loudspeakers; Ormond variable capacitors and transformers; All-American transformers; Na-Aid sockets and dials; Scientific, Brunet and N and K headphones.
  The business was owned by Arthur Abrahams and Arthur G Warner. The name Louis Coen was taken from Louis Coen who was a tobacconist and owner of the premises.
* J J LOVE AND SONS PTY LTD
  Masts, towers and aerial accessories plus installation services.
* E A MACHINE CO., PTY LTD
  CAV radio batteries, Unitron battery chargers.
* ALEXANDER MAIR AND CO.
  De Forest valves.
* MCEWANS
  McEwan Neutrodyne, King Neutrodyne, Chelsea Super Five receivers; components and accessories.
* MORRIS AND CO.
  Excellatone receivers and kit sets; Hegra cone loudspeakers; batteries; Pilot components and accessories.
* MUIR'S RADIO LOUNGE
  Atwater Kent receivers, components and accessories.
* MUSIC MASTER
  Atlas loudspeakers; Reliance and Signal capacitors; United batteries and coils; Quickheat grid-leak; Signal dials and transformers; Frost headphones, rheostats, potentiometers and sponge absorber valve sockets; Cossor valves.
* MYERS
  Naturelle receivers; Senior, Hegra and Magnavox loudspeakers; Hellensen batteries, accumulators and a wide range of components.
* J L NEWBIGIN PTY LTD
  Ever-Ready A, B and C radio batteries.
* NEW SYSTEM WIRELESS
  NST receivers; De Jur components; Sangmo capacitors.
* OLIVER J NILSEN AND CO.
  Receiver assembly kits; Autrophone crystal sets; Federal and Jackson variable capacitors; Crosley AF transformers; Polar coil kits; Federal components including headphones; Yale batteries; Nilseno; New Majestic and Victoreen Superheterodyne receivers.
* NORRIS AND SKELLEY PTY LTD
  The company was founded in 1917 by Cyril Norris and Dave Skelley as an Electrical Engineering business. Radio receivers were first imported from England but later manufactured locally in Melbourne. They operated experimental station 3NS, frequently transmitting on the 200 metre band. In late 1925, the business went into voluntary liquidation.
  Supermum AF transformers; De Forest and Philips valves; N & S crystal sets; N & S battery receivers; Aristo battery receivers; Radion insulators, knobs, dials and panels; Gilfillan, AWA, Crosley, Western Electric, Atwater Kent, Murdock and Kellogg products.
* NOYES BROS (MELB.) PTY LTD
  Seyon receivers; Igranic receivers and kit sets; Philips, Radiotron and Cossor valves; Philips B eliminators and battery chargers, accessories.
* OSBOLDSTONE AND CO., PTY LTD
  McMichael receivers and components.
* P & L WIRELESS SUPPLIES
  Genwin receivers and crystal sets.
* PAROSA LTD
  Parosovox, Astor and Philmore receivers; crystal sets; Bullphone, Amplion and Sferavox loudspeakers; Uralium and Neutron crystals; Ormond variable capacitors; DWT headphones; components and accessories.
* A BEAL PRITCHARD (AUST.) LTD
  Burginphone receivers, Mullard valves.
* RADIO DOCTORS AND SUPPLY SERVICE
  McMichael receiver kits, transformers, resistors, neutrodons, Ediswan valves and batteries; toriod HF transformers; NST Superior headphones and variometers.
* RADIOGRAM DEVELOPMENT
  A small organisation specialising in high fidelity radiograms from premises at 443 Hawthorn Road, Caulfield.
  Three radiogram units were released during 1947–48. They were all AC powered, dual wave types employing five valves. They were Models P3, RGD1 and RGD2 with receiver IF of 455 kHz. A four valve portable receiver released in 1946 was one of the earliest products of the organisation. Products used the Imperial brand name.
* RADIO SALE EXCHANGE
  Gilfillan receivers, Browning-Drake assembly kits, locally assembled receivers, components.
* RADIO SALVAGE PTY LTD
  Crosley and other brands of receivers, components.
* A ROBOTHAM PTY LTD
  Herbert-Minifone receivers.
* RUNDLES
  Genwin receivers, Chapin vernier dials, Ebyphone posts, Dubilier capacitor and other components.
* SCOTT AND CO. (A/ASIA), PTY LTD
  Telefunken receivers, Arcophon loudspeakers.
* SILVERTOWN CO.
  Silvertown AF transformers.
* HENRY G SMALL AND CO.
  Stromberg-Carlson receivers and loudspeakers; Jewel instruments; Burgess B batteries; Stromberg-Carlson headphones and transformers; Kester Radio solder; Beanco lightning arresters; Durham metal grid-leaks.
* STILLWELL AND PARRY PTY LTD
  Healing, Atwater Kent receivers; Electrad products; Pertrix batteries; Finston Solodyne kits.
* C H TAYLOR PTY LTD
  Panel and designation plate engineering.
* DANE TAYLOR AND CO.
  Radiola receivers; Edison batteries and cells; Amplion loudspeakers; Radiotron and Philips valves; components and accessories.
* THE AUDITONE CO.
  Audiotone Super receivers; Apex Audiotone valves; Rola loudspeakers.
* THE EDISON SWAN ELECTRIC CO., LTD
  Dulcivox and Televox loudspeakers; Ediswan receivers; Ediswan valves.
* THE LEVIATHAN
  Leviaphone, Airking, Astrophone, Superdyne battery receivers; crystal sets; Bullphone, Nightingale loudspeakers; components and accessories.
* TILBURY AND LEWIS PTY LTD
  The company located at 45 Wangaratta Road, Richmond were manufacturers of Van Ruyten brand receivers and general radio products.Managing Director was Reg Lewis and Sales Manager was Norm Lewis.
  In 1934, Van Ruyten receivers included:
  - Model 101, a five valve AC/DC set.
  - Model 103, a five valve battery-powered superheterodyne

receiver with IF 175 kHz and valve types 34, mixer; 32, IF amplifier; 34, detector; 30, driver; and 19 Class B output.

- Model 104, a five valve AC powered superheterodyne set in midget cabinet with valve types 6A7, pentagrid converter; 6D6, duplex diode pentode operated as diode detector, AVC and AF amplifier; 42, pentode power amplifier; 80, rectifier.

In 1935, the Assembly Factory was located at Margaret Street with Rupert Peterson as Factory Manager. Rupert was Chief Design Engineer and later Factory Manager of the company's Radio Department during 1930–36. He later transferred to the Transformer Department in a similar position. He subsequently became Director and Chief Engineer of Meltran Engineering Pty Ltd.

Eight models were produced in 1935 and included a four valve MF band receiver designed to operate from a 32 volt home lighting system with a Gen-e-Motor to provide HT for the receiver. A 6/12 volt car radio was also manufactured during the year.

In 1936, six models were released for operation from various power sources including AC, AC/DC, battery and vibrator/accumulator.

Production appears to have ceased about the end of 1936.

Reg Lewis, first Managing Director of Tilbury and Lewis, later became a Director of Van Ruyten Radio Supplies Pty Ltd and Managing Director, Meltran Engineering Pty Ltd.

* TREMON WIRELESS CO.

Pierce-Airco receivers, Super Selective Tremon 2 receiver and Comet Super kit set.

* TUNAFONE WIRELESS PTY LTD

Advance and Viking radio products.

* UNITED DISTRIBUTORS LTD

United and Disco receivers; Signal, Pilot and Carter radio products; Pico headphones; Ray-O-Vac batteries; Quam loudspeakers; Centralab components.

* ARTHUR J VEALL PTY LTD

One of the most widely-known and largest radio and electrical stores which conducted an extensive Mail Order business as well as local sales in Melbourne.

The company was founded by Arthur J Veall who opened a retail electrical business in Prahran and in 1923 opened a shop in the city where radio items were added to stock. The company imported huge quantities of radio components, accessories and fully assembled receivers from UK and USA and set up a Mail Order Department in order to handle the demand from interstate purchasers. Regular sales were a feature of the business with specials being advertised as 'Veall cutlets — a tempting dish for the listener's-in'.

In 1927, the company were the wholesale distributors for FADA Harmonated Neutrodyne receivers for Victoria and Tasmania and by that time, was acknowledged as one of the largest radio houses in Melbourne. In 1928, the company acquired the A Robotham Pty Ltd, 183 Bourke Street radio business with its large Mail Order Department.

One of the major lines sold during 1933 was a large consignment of four valve AC powered receivers made as a Badge Engineered order by one of the local radio receiver manufacturers. They were sold in the hundreds as the price was some 25 % cheaper than equivalent sets at other Radio Shops.

By 1934, Vealls had five Branches in Melbourne.

In addition to fully assembled receivers the company purchased a large range of components as Badge Engineered products and sold them under the Veall or Velco label. They included such items as receiver kit sets; test equipment; meters; microphones; amplifiers; radio and loudspeaker cabinets; coil sets; power transformers; battery cable tags and others. The company stocked one of the largest ranges of commercially manufactured receivers in Melbourne.

One of the company's well-known Sales Managers was Allan Parcell who joined Arthur J Veall Pty Ltd about 1936. Allan had worked with F L W Fear and Co., Ltd New Zealand, distributors of the well-known Micromatic brand of receivers and came to Australia in 1934 when he joined Radiokes as Sales Manager. After about 12 months, he left Radiokes and joined Crown Radio Manufacturing Co., but left after a few months to join Vealls as Sales Manager, a position he held for many years.

* VELCO SOUND SYSTEMS PTY LTD

At least two models of receivers were produced during 1937 but after the War, the company specialised in design and production of high quality table and console radiogram units. One noteworthy unit was Model C2 manufactured in 1946. It was a 10 valve AC powered radiogram with all wave band capability and fitted with automatic record changer. A 9 valve dual wave band version was also available.

* WARBURTON FRANKI LTD

Distributors of Olympian receivers; Philips valves and components; Day-Fan receivers; Waranki receivers; Burndept Ethovox, Hartman, Music Master, Fairfax, Racon and Tower loudspeakers.

* WARNES WONDER WIRELESS

Genwin receivers; Selector crystal sets; Kellogg components; Beltron valves; Ashley components; Amplion loudspeakers; Neutron crystals; accessories.

* WILLS AND PATON PTY LTD

Deal B and C batteries; Mohawk and Air Master receivers; components.

Included amongst the most active Consulting Radio Engineers in full-time practice during the period and engaged in the design and construction of custom-built receivers were Maxwell Howden of Howden Bros, Box Hill; The Progressive Radio Co., Hawksburn; W F Winter, Proprietor, Winters Wireless, Melbourne; Arthur Killingworth, Carlton; and Wood and Bennett, Kew.

*** SOUTH AUSTRALIA**

In the period preceding the decade of the 1930s, from about 1923 to 1930 there was a proliferation of small and large organisations formed in South Australia to take advantage of the enormous demand for receivers and components. The great majority ceased to exist within a few years of being established. For example, in the city of Adelaide alone, in mid 1925 there were over 40 businesses engaged in manufacturing, sale or assembly of complete receivers or kit sets. These included the well-known firms of Duncan and Fraser, Dunfra receivers; Newton, McLaren Ltd, Mac and later Night Hawk receivers; Transatlantic Wireless Manufacturing Co., Newkrodyne receivers; Harland Radio and Electrical Co., Harland receivers; Bullock Cycle and Radio Stores, Reactodyne receivers; Adelaide Radio Company, Arcoflex receivers; Harringtons Ltd, Imperia receivers; 5CL Radio and Electrical Co., Demon and Eagle receivers; United Distributors Ltd, Udisco and Capacidyne receivers; Behrens-Thiem Co., Serenade receiver; A W Dobbie & Co., Ltd, King Radiodyne, Claritone receivers; James Marshall & Co., Marshall receivers; A M Rodda, Rodaphone receivers; Millswood Auto and Radio Co., Ltd, Millswood receivers; Corbett, Dernham & Co., Tunafone receivers; C M Lowe, Lowe receivers; Rodda Stevens Ltd, Quality receivers; H L Austin, Perflex receivers; Oliver J Nilsen, Nilseno receivers; Varcoe and Co., Varcola receivers; Bateups Garage, Melotone receivers; Southern Traders Ltd, Melodius receivers; Hannan Bros Ltd, Radio A and B batteries; Buckerfield and Jervois-Draysey, Special BJ–D receivers; Reg George, Vascoe, Standard and RWG receivers; W Black and Son, Gladiola receivers and others.

There were also a number of Consulting Radio Engineers, who designed and constructed receivers to meet a customer's specific needs including assembly of the receiver into special cabinets such as combined radio/writing desk, radio/drinks cabinet, and, in one case, a radio/butterfly collection cabinet. People undertaking this class of work included 'Cocker' Randell, W H Barber, A C Silby, Fred Williamson, Hal Austin, Roy Buckerfield, L Whibley and others.

Of particular interest with these South Australian firms were Newton, McLaren Ltd, and the Transatlantic Wireless Manufacturing Co.

Newton, McLaren Ltd, had the distinction of manufacturing the first broadcast receiver for commercial sale in South Australia. The receiver made in the company's workshop was sold to a Doctor living in Gawler in 1921, well before broadcasting stations were established in Australia. The owner listened to the many Amateur broadcasters who operated on the 200 metre band providing regular programs of talks and music. The receiver was a three coil unit and was the forerunner of a range of other designs. In 1922, the company established a Radio Department with John Hale as Engineer-in-Charge. This led to the production of six models under the MAK brand name including Type A crystal set; type D1 one valve receiver with valve and tuning coil mounted on a sloping front bakelite panel; type D2 two valve receiver with valves and coil on sloping front bakelite panel and capable of loudspeaker operation for stations within 40 km; type D3 three valve receiver similar to the type D2, but with an extra stage of audio added so increasing reception range to 160 km from the transmitting station; type HF4, a four valve receiver with all components mounted inside a wooden cabinet with bakelite front panel and with reception capability of up to 1200 km; type HF4A, a four valve long range receiver which, unlike the type HF4, did not require a number of plug-in coils to cover the bands; type HF5A, similar in appearance to the HF4A with high tension batteries concealed in the base of the cabinet, and recommended for use in large rooms or halls.

All receivers were supplied with Sterling headphones or one of the range of Sterling horn loudspeakers, the Sterling Dinkie, Sterling Baby or the Sterling Audiovox. The MAK series was followed by a series under the brand Night Hawk which was still being produced in the late 1930s.

John Hale who was in charge of the production, was a Member of The Institute of Radio Engineers (Australia) and was appointed Assistant Manager of the company in 1936. The following year, he became a Director.

South Australia was the only State in Australia where AWA did not have a branch office for the distribution of its receivers in the 1920s and 1930s, and Newton, McLaren Ltd undertook this role. In the 1930s, General Manager was Len Ferrar and Assistant General Manager was Bill Govenlock. Bill Govenlock served a period as Secretary of the local branch of The Institution of Radio Engineers, with meetings being held in the company office. In addition to distribution of AWA receivers in South Australia, they distributed them in Broken Hill and in the Northern Territory.

The Transatlantic Wireless Manufacturing Co., was located at Prospect, a suburb of Adelaide and produced three, four and five valve receivers using Neutrodyne circuits marketed under the brand Newkrodyne. The receivers had a sloping glass front panel on which variable components such as tuning capacitors and rheostats were mounted. The inside back of the cabinet contained a large mirror with the silver film being connected to earth. There was a high demand for the receivers and a staff of five were hard-pressed to meet the demand. All glass drilling operations and winding of the coils were carried out in the workshop which had the capability of producing 200 receivers per month. Another receiver was the Model NF Superhet Transatlantic 6 produced in 1926.

The Company later applied for a licence to erect a B Class broadcasting station, but the local Radio Inspector requested that the company change its name. A new application was submitted under the name Sport Radio Broadcasting Co., Ltd, and a licence was granted with callsign 5KA — the letters KA signifying the address of the station, Kintore Avenue. The station commenced operation on 25 March 1927 with a 300 watt transmitter. It was the second B Class station established in Adelaide with Roy Buckerfield in charge of installation.

Roy was a well-known Amateur operator. He was the first South Australian to obtain confirmation report of contact with an American station operator. On 2 February 1925 he established contact from his station OA5DA with U6AKW in California using 20 watts continuous wave on 90 metres.

Before the outbreak of the Second World War, Interstate radio businesses were well represented in South Australia.

Interstate representatives and South Australian manufacturers not covered elsewhere, and local radio businesses included:

* ADELAIDE RADIO COMPANY

The company was one of the best-known radio companies in Adelaide in the 1920s. It was founded about 1922 by Lance Jones, Harry Kauper and G A Miller-Randle.

Located at 146 Rundle Street, Adelaide, the Adelaide Radio Company catered for both the retail and wholesale trades and manufactured a range of radio receivers in its workshops under the Arcoflex label. Included amongst the large range of radio products were Gilfillan, Gecophone, Frost, All-American, Dubilier, Nutmeg, De Forest, Atlas, Brandes, Firth, Remler, Igranic, Polar, Arcol, Arco, Arcoflex, Silver Marshall and Connecticut brands.

In addition to fully assembled receivers, the company produced several kit sets of crystal sets and valve receivers including regenerative, reflex, TRF, superheterodyne, and Neutrodyne circuits.

When the Government decided to abandon the Sealed Set Scheme, the company had a large number of sealed set type receivers on hand and decided to sell them at heavily discounted prices. The receivers which were sold during October 1924 comprised 25 single valve and two valve models.

Lance Jones, the company Manager and Chief Engineer, was one of the early South Australian Wireless pioneers. He operated a spark wireless station before the First World War; was one of a group who conducted the first radio telephony trials in Adelaide; represented South Australian Radio Traders at the 1923 Conference in Melbourne convened by the Government to discuss the establishment of broadcasting in Australia; and constructed 5DN, the first B Class station in South Australia using one of his own transmitters and employing the 5DN callsign licensed to the Adelaide Radio Company.

As a boy Lance Jones followed with interest reports in the newspapers and magazines of the developments in wireless telegraphy technology overseas. A family friend who was a subscriber to the USA magazine 'Scientific American', knew of Lance's interest in matters scientific, and passed on his copies of the magazine to Lance. Lance noticed an advertisement in one issue placed by The Electro Importing Company of New York advising of the availability of a range of components to allow assembly of a wireless telegraphy station for experimental purposes. He sent away for a catalogue and several months later after receiving the publication, placed an order for some parts. In 1909, a spark coil, spark gap balls, relay, a self-restoring coherer and a sounder arrived by mail. A circuit was included to illustrate how to construct and set to work on a small station with a 'guaranteed working range of one mile'.

He made a number of components not supplied and assembled transmitting and receiving facilities using a bank of telephone type dry cell batteries to power the spark coil. At the time he lived at Hyde Park, an Adelaide suburb, and put up an aerial with one end being tied near the top of a tall Norfolk Island pine tree.

He arranged with Ern Stanton, a friend who was also interested in wireless experiments, to listen while he transmitted over several nights. Ern had made a receiver using an electrolytic detector containing nitric acid in a carbon cup and was keen to try out his new detector. The trials were very successful and both boys decided to do further experiments.

In 1910, he shifted to a house in Hawthorn and designed and built new equipment including a powerful coil which was housed in a box of dimensions 37 cm square and 45 cm in length. A crystal detector replaced the earlier coherer arrangement.

In 1911, Lance was granted experimental licence with callsign XVB, the second licence to be issued to South Australian experimenters. He continued experimental work until the outbreak of the First World War in 1914 when all stations were closed down by the authorities.

Harry Kauper, one of the other partners, was a pilot in England prior to the First World War. During the War years, he served with the Royal Air Force and was co-inventor of a machine gun interrupter fitted to aircraft.

After the War, he was associated with the aircraft industry but with the granting of experimental radio licences by the Government he switched interests to radio and was one of the first in the State to be granted a licence. During his period in England, he acquired some radio equipment which included Telefunken valves and put these to use in building his Amateur station 5BG. In 1922, he was actively involved in the development of transmitters for the transmission of speech and music, and about 1925 made quartz crystals for transmitter frequency generation purposes. He obtained the raw quartz materials from sites in the Adelaide Hills and also some samples from a friend on Kangaroo Island.

In 1926, he was appointed Chief Engineer of A Class station 5CL which began operation on 20 November 1924. He remained at the station until 1930 when the Government took over the station as part of the establishment of the National Broadcasting Service. During his period at the station, he made many improvements including the introduction of condenser type microphones in the studio to replace the carbon granule type in use from the time the studios went to air. He also made major improvements with the transmitting facilities.

In 1927, the high power stage was remodelled to include WE 4220B water-cooled valve to replace the original multiple air cooled types, the sub-modulator stage was upgraded and a superior neutralisation system installed to improve transmitter stability. New mechanical and electrical plant included a 1000 volt AC 200 watt generator driven by a 200 volt single phase motor and a 24 volt 130 ampere DC generator driven by a three phase motor.

After leaving 5CL, Harry (his real name was Henry) was associated with the installation of Commercial station 5AD Adelaide in 1930. He then moved to Melbourne where he worked on 3DB. During the Second World War, he joined the Aeronautical Inspection Directorate and was in charge of the Radio, Electrical and Instrument Section.

Mr Miller-Randle, although not in the radio industry, took an active interest in it. In 1924, he was a Councillor on the Committee of the local Wireless Institute and at the 1925 Radio and Electrical Exhibition exhibited an eight valve superheterodyne receiver incorporating gramophone replay facilities. A common horn was employed for both radio and gramophone outputs.

* B L ANDREW

TCC capacitors, IRC resistors, Howard receivers, Bunbach insulators, Bruno microphones.

* HAL AUSTIN

Hal Austin was a leading South Australian Radio Engineer, Licensed Dealer and experimenter in the 1920s, conducting business at 8 The Parade, Norwood.

In 1924, he conducted regular broadcasts on 220 metres on weekday evenings and on Sundays from his experimental station 5BN. A major feature of his crystal controlled transmitter was the use of large plug-in type coil units to enable easy change of the operation to various bands. Power for the crystal oscillator was supplied from a power source separate from the main transmitter supply which employed Amrad S valves in the HT power supply unit.

Hal was an active member of the local WIA and in 1922 served on the council. When the WIA held its first Social and Radio Dance on 28 June 1923 in the hall of the Royal Institution for the Blind, North Adelaide, recorded dance music and music from a gramola concert machine were broadcast from Hal's station in Norwood and picked up by a three valve receiver at the hall and fed to a two valve power amplifier coupled to a bank of horn type loudspeakers in the hall.

Hal Austin was a recognised authority in receiver technology and developed a number of circuits some of which were published in the local technical press. His design of a two valve reflex receiver resulted in great interest by members of Radio Clubs, and many were constructed by members.

He manufactured a range of receivers and components under the Perflex label. Receiver models included crystal sets, one, two, four, six and seven valve types with the six valve model being a Neutrodyne circuit and the seven valve a superheterodyne circuit with a crystal detector.

He exhibited a range of his receivers at the Radio and Electrical Exhibition held in Adelaide in December 1925, and also at the First Radio Trade Exhibition in June 1926.

Major components manufactured in 1926 included Perflex Neutroformers designed for Neutrodyne and Aperiodyne circuit receivers. He also produced a resistor labelled as '5BN Resistor' designed specifically for use with one of his reflex circuits.

One of the Perflex Neutrodyne receivers using Gilfillan parts, BTH loudspeakers and a Perfectum accumulator type B battery with the receiver mounted in a polished oak cabinet was purchased by a Mrs Martin a listener in Minlaton on Yorke Peninsula and was still operational in 1934 when it was replaced by another brand for operation from the 32 volt home lighting system.

The Perflex Neutrodyne receiver and a sample of the 5BN Resistor are in a local vintage radio collection.

Hal Austin was Principal of a loose consortium of three radio pioneers. The others were Fred Williamson and Harry Kauper. The group, known in 1924 as 'The Big Three', were manufacturers of TSF Radio Frequency Transformers, square copper busbar wire, 5BN Resistors, and low loss inductors. Members of the group had designed several circuits of receivers and these were used in receivers manufactured by them for sale to the public.

The group produced one of the first receivers in South Australia employing a push-pull output stage when they released a battery-operated receiver in 1926. The first model employed a Philips triode valve as a phase splitter but although the circuit worked satisfactorily, they replaced the valve phase splitter with an All-American transformer with centre tapped secondary in order to reduce total battery drain. The output transformer with centre tapped primary was also an All-American type. The receiver known as The Double Decker Six was sold to several country listeners including Hank George, a fisherman at Port Lincoln and Harry Price, a grazier out from Port Augusta. Mr Price's receiver was still in operational condition in 1934 when he traded it in with Newton, McLaren, Adelaide for an AWA Model 138, a six valve battery-operated receiver with Class B output stage.

* BULLOCKS CYCLE AND RADIO STORE

Located at 65 Rundle Street, it was known as 'The House of Reliable Radio', holding a very large stock of radio components and accessories. Rectodyne receivers were manufactured on site and supplied as fully assembled models or in kit form. Crystal sets and a range of multivalve receivers were available. Receiver design and assembly was under the control of Mr C A Maddern.

* CLARKSONS LTD

Westinghouse receivers.

* LOUIS COEN (WIRELESS) LTD

In the 1920s, the company had a retail outlet at 75 Rundle Street, Adelaide and a wholesale outlet at 1/2 Gays Arcade. Company policy was to 'Stock everything wireless' and the stores had one of the largest stocks in the State of Australian and overseas radio products. They included Walnart dials; USL variable capacitors; Pinnacle coils; Dayton vernier rheostats; Window lead-in tubes; Reverso phone plugs; Garbant, Trimm, All-American and Sferavox loudspeakers; English and USA

valve sockets; Tunatro valves; Peerless and All-American AF transformers; Bring-it-in coils, and a range of crystal sets and valve receivers.
In later years, the company stocked the full range of Astor receivers and Radio Corporation radio products.

* H COLLOCOTT
Croyden, Univox receivers; Alpha and Saxon parts; Tungsol valves; Empire pick-ups.
* COLTON, PALMER AND PRESTON LTD
Masterpiece, HMV, Philips receivers; Eveready batteries and radio accessories.
* J CRAVEN AND CO., LTD
The company located in Rundle Street, Adelaide was one of several Department Stores in the city which had a Radio Department. The shop sold a wide range of radio components, accessories and Craven brand receivers. One of the most popular lines in 1926 was the Craven Crystal Set mounted in a highly polished rosewood box with bakelite front panel.
* A W DOBBIE AND CO., LTD
Alexander William Dobbie served an Apprenticeship as a brass founder and established his own business A W Dobbie and Co., Ltd in 1862. He was a man of wide interests and while a member of the South Australian Chamber of Manufacturers he was described by one member as 'Scientist, Astronomer, Hypnotist, Manufacturer and Apiarist'. He made significant contributions in all these fields. He was one of the first people in South Australia to construct a telephone and in 1877 provided a working demonstration of his model. He also constructed the first phonograph in the State.
Prior to the commencement of broadcasting in South Australia, he imported a large range of radio components and fully assembled King Neutrodyne receivers from USA for sale from his business then located at 99 Rundle Street. Locally assembled receivers were marketed under the Claritone and Alphadyne labels. Examples of his King Neutrodyne and Claritone receivers were held in the former Telecommunications Museum collection in Adelaide.
The business was later transferred to 53 Gawler Place. After the Second World War, Dobbie manufactured Peerless brand receivers in Mitcham and supplied several hundred to Allied Occupational Forces in Japan. Several Peerless receivers are held in vintage radio collections in Adelaide.
* DUNCAN AND FRASER
The company had been established in 1862 to manufacture bicycles. It later expanded into manufacturing railway and tram carriages, business wagons, pleasure carriages and windmills. In 1916, it began the manufacture of bodies for Ford motor cars. It entered the radio business in 1924 because of the interest in radio of one of the company Directors.
Hugh Duncan, grandson of one of the founders became interested in radio as early as 1910 when a Cadet Chemist at the University of Adelaide Chemistry Department. A keen student of physics, he was fascinated by the early work of Professor Bragge in wireless telegraphy experiments before 1900. He acquired some of the original equipment used in the experiments from University stores and the Post Office who has also participated in some early work, and did a number of tests to determine the sensitivity of various coherers to reception of wireless signals.
In 1920, he was a member of the party which fixed the South Australia/Western Australia border by employing wireless signals transmitted from wireless telegraphy stations in France and USA. It was the first time wireless signals which girdled the earth had been used to fix a longitude in Australia.
In 1923, the company employed Ken Adamson, a well-known local radio experimenter, as Manager and Chief Engineer of the newly-formed Radio Department to set up manufacturing facilities to produce a range of high quality radio receivers.
The first receivers became available for sale to the public in 1924 using the Dunfra label.
At the Radio and Electrical Exhibition held in Adelaide in December 1925, a range of Dunfra receivers was exhibited. They included crystal sets and single, two, three, four and six valve designs. There were four different crystal set designs with all sets being enclosed in polished rosewood cases with bakelite panels. The designs comprised single slider tuning; double slider circuit with the aerial connection being taken to the slider bar; multi-tapped coil; and a circuit employing a variometer. The valve receiver designs included a two valve receiver with an aperiodic auto coupling arrangement; a two valve receiver with tuned intermediary circuit; a four stage detector-amplifier in which auto transformers coupled successive valves; and a two valve receiver employing retroaction. A six valve receiver on display was housed in a highly polished wooden cabinet with a rotating loop aerial fixed to one side of the cabinet.
The company also stocked a large range of radio components and several receivers manufactured overseas.
During the Depression years, the company encountered financial difficulties and ceased operation.
* EDDYS LTD
Eddys Ltd, 12 Rundle Street, Adelaide, manufactured Eddyola brand receivers from the 1920s. At the Radio and Electrical Exhibition held in Adelaide in December 1925, Eddys displayed a combined gramophone-receiver set which created a lot of interest with the visitors. It was one of the earliest such sets in South Australia.
The company had a large Radio Department with Eric Ahrenot who had wide experience in sales, design and servicing of radio receivers being in charge for some six months.
After leaving Melbourne University, Eric founded his own radio business specialising in custom designed and built receivers. After two years, he closed the business and moved to Adelaide to take up an appointment with Charles Birks and Co., as Manager of the Radio Department. He was responsible for sales and oversighting the assembly of receivers in the company workshop. After two years with Birks, he transferred to Eddys and developed a range of battery receivers under the Eddyola label which soon became very popular with local listeners.
Charles Birks implemented plans to expand their operations, combing radio and electrical activities into one large Radio and Electrical Department and invited Eric to return to take charge of the new Department. He was still in charge in the mid 1930s.
* ERNSMITHS
A company Ernest Smith and Co., Ltd, was set up in Adelaide about 1929 to sell radio receivers. They obtained receivers from Interstate manufacturers and from Reg George, a local receiver builder.
The company was initially located in a small building in Currie Street but in order to expand, premises were acquired at 114 Grenfell Street at the corner of the Adelaide Arcade. In addition to selling receivers made by others, the company began manufacture of a locally designed receiver under the Scharnberg-Strauss label.
Sales were so encouraging that the National Radio Corporation Ltd was established in 1933 with Ern Smith as Governing Director and Oswald Smith as Director. The company mass-produced receivers under the National label for Interstate dealers as well as the Scharnberg-Strauss model for local markets.
In 1939, Electronic Industries Ltd acquired the National Radio Corporation Ltd.
After the War, manufacture of Scharnberg-Strauss models was resumed by Ernsmiths Ltd in premises in Gawler Place. Operations were later shifted to North Adelaide with Ralph Baker being Factory Manager.
When television was introduced to Adelaide in 1959 the company manufactured TV receivers under the Scharnberg-Strauss label. One model of particular interest was a combination radio receiver, radiogram and TV receiver in a large console cabinet.

Production of receivers ceased in 1979 but in 1997, Ernsmiths was still a major retailer of electrical, radio and TV equipment in Adelaide.

* H W FARLEY
  Agents for Hungarian manufactured Tungstram valves, Dubilier capacitors, NSF resistors, NSF volume controls, Oak vibrators.
* A H GARTH
  IRC resistors, Aegis transformers, Alpha switch units, Marquis moulded products and a range of valves.
* REG GEORGE
  Manufactured RWG, Vasco and Standard brand receivers. First models released 1929 and continued until outbreak of Second World War. Production of Standard brand receivers was resumed after the War with television work being undertaken in the late 1950s. The business was sold in the late 1960s.
* Harringtons Ltd
  One of the largest Radio Shops in Adelaide, distributing Imperia, Raycophone and other brand receivers and a wide range of radio components and accessories.

  Senior staff of the Adelaide office included F B Oldfield, Bill Corfield and Arthur Cotton.

  Mr Oldfield a University graduate with a Bachelor of Science Degree, was one of the early Managers. He was credited with a number of designs and innovations in radio receivers and had considerable experience in their construction. He contributed many articles to the technical press on Radio Engineering technology. Articles published in the 'South Australian Wireless and Radio Weekly' included 'A Valuable Three Valver' in June 1926 and 'Locally Built Superhet' in October 1925. Another article, 'Past and Future' was published in the October 1925 issue.

  Bill Corfield received his education at Sydney University and in London. He joined the AIF during the First World War and after the War joined Harringtons Ltd North Sydney Branch in 1920 where he was responsible for the design and manufacture of a range of Imperia and Popular Four model receivers for distribution to Interstate and local Branches.

  He transferred to the Adelaide Branch as Manager where he took control of the Radio Department. With the company Engineer Arthur Cotton he was instrumental in carrying out research to improve the performance of receivers brought in for repair and alignment and for design of receivers to suit remote country listeners. Many of his designs were used as company standards for many years.

  Bill subsequently left Adelaide to become Manager of the firm's operations at the Melbourne office where he remained for about eight years.

  Arthur Cotton, Engineer for the company's Adelaide operations was an early South Australian experimenter. He operated experimental wireless telegraphy station XVS following receipt of a licence on 14 April 1913.

  In 1915, he went to Sydney to attend a course at the Marconi School of Wireless conducted by AWA.

  After the War, he resumed experimental work and was active in the 200 metre band using callsign 5HY.

  In 1924, he became foundation Vice President of the Port Adelaide and Suburban Radio Club.

  Arthur was an active designer of radio transmitters and receivers and contributed a number of articles on the subject in the technical press. Two of the articles, 'How to Build a Neutrodyne' and 'The Four Valve Tuned Anode' created a lot of interest when they were published in 1925 and many Radio Club members constructed receivers to the designs outlined by Arthur.

  He was an active member of the local Wireless Institute and during his term as Secretary, gave evidence in 1927 to the Royal Commission on Wireless.
* D HARRIS AND CO
  Rola loudspeakers, Public address systems, components including Simplex, Marquis moulded products, distributors of Gulbransen receivers made in Sydney by E F Wilks and Co., Ltd.

  About 1930, D Harris and Co., began manufacture of receivers under the brand name 'Radion' producing a range of battery, DC mains and AC mains powered units. One of the most successful lines was a design employing two valves plus rectifier. Dual wave models were also in demand, particularly during tour of Australian cricketers overseas. Loudspeakers used in the receivers included Jubilee, Rola, Jensen and Monitor. Local Department stores, particularly Myers which had been established in Adelaide in 1928, purchased bulk quantities of receivers for sale in their stores.

  In the mid 1930s, the company ceased production of radio receivers to concentrate on distribution and supply of technical equipment for theatres. At the outbreak of the Second World War in 1939 the company was manufacturers' agents and wholesalers of Rola loudspeakers, Sentry electric shavers, washing machines, vacuum cleaners, a range of radio receivers, and 'Hygrade' receiver cabinets.

  One of the company's early employees was John Allan.
* HARRIS SCARFE LTD
  Harris Scarfe Ltd, Grenfell Street, Adelaide had been in business many years before the establishment of broadcasting in Australia.

  Frederick George Scarfe who joined the company in 1888 became Chairman in 1919, and the following year decided that the company should become involved in the radio business in view of the Government's plan to consider granting licences for setting up broadcasting stations.

  A Radio Department was formed and the company ordered direct from overseas manufacturers, and also from Australian distributors a large range of assembled receivers and radio components and accessories. The Department opened for business about 1922.

  The company mounted one of the best displays at the Radio and Electrical Exhibition held in Adelaide in December 1925 and won the Champion Prize for Best Trade Display.

  The wide range of receivers and components included Sterling, Igranic, Brown, Condor, Cardwell and King Radio products.

  Receiver brands included Sterling Threeflex and Anodian; King five valve Neutrodyne and Radiola Super Six.

  Component brands included Cardwell, King, Brown, Igranic, Condor, Hart, Prestrolite, Magno and many others.

  The company also provided displays at subsequent Radio Trade Exhibitions.

  In later years, Harris Scarfe Ltd were distributors for Radiola, Philips and Tasma receivers; Volta batteries and Condor valves.

  Alick Clarke, Manager of the Radio Department in 1925 was in charge of company radio displays, sales and repair activities. Alick had been involved in radio since he was a boy. He became friendly with J W Hambly-Clark who had operated a spark wireless station at Kent Town before the First World War. Alick assisted him with building equipment and winding coils. He also participated in some of early broadcasts from Mr Hambly-Clark's station.

  In 1921, Alick imported a Marconi V24 valve direct from England and built his first receiver employing a valve. He had previously constructed sets employing coherers and crystals but had not attempted a valve model.

  He received his experimental licence in February 1922 and constructed his first transmitter using a single valve with high tension being supplied by an accumulator type B battery charged by a chemical rectifier.

  Alick entered the radio trade with Harris Scarfe Ltd and in 1925 was appointed Manager of the Radio Department. He remained with Harris Scarfe for some 14 years and then transferred to A G Healing Ltd, Hindmarsh Square as Radio Manager. He later moved to Ernest Smith and Co., as Tape Recorder Manager and retired in 1969. In 1946, he gave one of the first demonstrations of the commercial application of the Pyrox wire recorder. When tape recorders were introduced he gave one of the first demonstrations of the technology in the State in 1952.

* INTERNATIONAL RADIO CO., PTY LTD
National Union valves, Jensen loudspeakers, Sprague electrolytic capacitors; and a wide range of component parts and accessories.
* R E JACKMAN
R E Jackman had built up one of the largest stocks of USA manufactured radio sets and radio components and accessories in South Australia before the establishment of broadcasting in the State.
The company Head Office was located in Verco Buildings, North Terrace, Adelaide while there was a large warehouse holding the stock in Nelson Street. The office was later relocated to 44 Eagle Chambers, King William Street.
In June 1924 at the time 5DN began transmission as the first broadcasting station in Adelaide, the company was sole South Australian Agents for United Distributing Companies, New South Wales; Agents for Radiovox receivers and Distributors for products of USA companies Remler Radio Manufacturing Co., Charles Freshman Co., United Manufacturing Co., Cutler-Hammer Manufacturing Co., Howard Radio Corporation and Herbert H Frost.
* JAMES MARSHALL AND CO., LTD
Known as 'The Shopping Centre' in Rundle Street, Adelaide, James Marshall, well-known drapers and warehousemen, opened a Wireless Department in September 1924, staffed by several well-known radio experimenters with Mr J H Chesterfield being Manager. Mr Chesterfield was formerly with the South Australian Radio Company. He had been responsible for an early broadcast experiment when Election Results were broadcast on 5 April 1924 using a 20 watt transmitter.
In the mid 1920s, the well-stocked Wireless Department included receivers and a range of radio components. One of the receivers was a Polar Radiophone seven valve receiver with Amplion loudspeaker, 120 volt HT battery, 70 Ahr accumulator, five Marconi R valves and two LS3 power amplifier valves. Two and four valve Polar models were also in stock. The large stock of valves included UV201A, amplifier and detector; UV199, amplifier and detector; UV200, detector; UV202, transmitting valve; LS3, power amplifier; Marconi R, amplifier and detector, DV1, amplifier and detector, DV2, amplifier and detector; and DV6 amplifier and detector.
* R J JARRET
Manufacturer of Audak brand receivers and Badge Engineered receivers for Birks, Saverys, Allans and others. Specialised in design and manufacture of transformers and chokes for receiver power supply units.
* LAWRENCE AND HANSON ELECTRICAL PTY LTD
Airway and Lekmek receivers, Philips valves, component parts and accessories.
* LENROC LTD
STC receivers, Raytheon and Brimar valves, component parts.
* C M LOWE
Charles M Lowe established an electrical business at Alberton in 1911 with a partner but later traded on his own account as C M Lowe.
The business was subsequently transferred to other premises in St Vincent Street, Port Adelaide, then to Commercial Road in the 1920s and finally to Todd Street, Port Adelaide where the business was still in operation in recent times under management of a third generation of the family.
Charles Lowe had been interested in radio for many years and followed with interest plans for the establishment of broadcasting in Australia. He was one of the first businesses in Adelaide to import radio parts and had one of the most comprehensive stocks in the city. In the mid 1920s, he assembled in his workshops a range of Lowe brand two and four valve battery-powered receivers employing tuned anode and reflex circuits for two valve models and TRF circuit for four valve models. He later employed a Universal circuit for one of his four valve models employing impedance coupling. Three inductances each 100 henries were used as the coupling impedances. The B battery supply was 150 volts because of voltage drop across the inductances. Many other manufacturers had produced Universal circuit receivers but they suffered from severe oscillation problems, particularly at the low wavelengths. Charles overcame these difficulties by making a number of changes to the normal circuit.
In the late 1920s, receivers were sold under the Argosy label. During the 1930s, the company was agent for Philips and Atwater Kent receivers and a range of radio components.
* MACKENZIE AND CO.
The business began trading as H C Mackenzie at 13 Twin Street, Adelaide about 1923 with a wide range of USA manufactured Federal receivers and radio products. Receivers were available in two, three, four and six valve models. James Ingoldby of McLaren Vale who purchased a six valve Federal receiver from Mr Mackenzie reported regular top quality reception from station KGO in the USA.
Federal components included valve sockets, adaptors, plugs, AF and RF transformers, variable and fixed capacitors, resistors, rheostats, potentiometers, dials, knobs and terminals.
In 1924, the business began trading as Mackenzie and Maddern, Electrical and Radio Engineers at 102 Grenfell Street, Adelaide with the component range including such brands as Frost, Federal, Ormond, TMC, Signal, Philips, Dubilier and Polar products.
Locally assembled receivers and kit sets were available in three crystal set designs, and one, two, three, four, six and seven valve models mounted in a selection of cabinet designs.
In 1924, Kevin Wadham who had previously been in charge of the Production Department of Paraso Ltd joined the company to take control of receiver assembly and receiver repair activities. He left in 1926 to set up business on his own account.
By mid 1925, the company name was changed to Mackenzie and Co., and facilities expanded to include a Service and Testing Department to deal with the increasing demand for testing, modifying and rewiring receivers brought into the shop. There was also a demand for assembly of special receivers to meet particular listener requirements. Mrs Eardley who lived not far from the high power 5CL transmitter at Brooklyn Park had trouble with her receiver when she tuned to the B Class station 5DN at Parkside. She could not isolate the 5CL signal completely because of blanketing effect. The company redesigned the front end of the receiver to provide a parallel rejector circuit with reaction. It comprised an LC rejector circuit wired across the existing LC tuning circuit plus a reaction coil coupled to the rejector circuit inductor.
* W T MATTHEW
Ducon capacitors and metallised resistors, Sirufer iron dust cores and Calit high frequency ceramic.
* MATULICH C DE C
Matulich was a well-known Radio Engineer and founder of Southern Traders Ltd, 115 Unley Road, Unley. In 1928, he manufactured a range of receivers under the brand Melodius, stocked a large range of radio parts and accessories, and carried out radio repair work and modification to receivers to improve their performance.
One of his four valve receivers was fitted with a sensitivity control to prevent oscillation, but at the same time ensured operation with maximum sensitivity. Other designs included two designs of crystal sets, one of which was fitted with a variometer, one valve regenerative receiver, two valve reflex circuit, four valve TRF design with one RF stage, detector and two AF stages.
He also built receivers to customer special requirements. When 5KA began transmission in Adelaide there were three broadcasting stations on air and one listener at Belair had difficulty in isolating the stations when all three were on air

together. Mr Matulich designed a selective circuit in which the detector was coupled to the preceding RF amplifier by means of a tuned oscillation transformer. By connecting variable capacitors across the grid and anode oscillatory circuits it was possible to tune them to the required frequency and thereby obtain better signals because of the greater selectivity characteristics.

* MILLSWOOD AUTO AND RADIO CO., LTD

The business located at 109 King William Street and 261 Goodwood Road, Millswood were sole South Australian Agents for Kellogg and Dimac radio products. They manufactured a range of receivers including crystal sets, one valve regenerative receiver, combined crystal detector/two valve receiver, four valve Standard, four valve De Luxe, and five valve De Luxe. They also built custom-built models to suit customer requirements under the Millswood label.

The company had been originally formed in 1923 for the purpose of applying for an A Class broadcasting station licence and at the same time importing motor cars. They were so confident of obtaining the licence that by March 1924 they had already built a 250 watt broadcast transmitter. However, the Regulations restricted company activities and they withdrew their application.

* NORWOOD RADIO DEPOT

The Norwood Electrical Depot was established at 119 The Parade, Norwood by Proprietors D Green and Sons. Initially, business was concerned with all classes of electrical installations and repairs. Mr Green Senior was an Electrical Engineer and when the Australian Government announced in the early 1920s that it intended to consider the establishment of broadcasting in Australia, Mr Green made an Interstate visit to Sydney and Melbourne to look at Radio Shops being established there to profit from the Government's plan.

Shortly after his return, he changed the name of his business to Norwood Radio Depot and obtained a Radio Dealers Licence.

He imported a large range of fully assembled receivers and radio components and accessories from overseas manufacturers, as well as from Australian Agents and Distributors.

In 1925, the year that 5DN and 5CL began transmission in Adelaide, his stock list included standard stranded copper, Electron and Triumph aerial wire; Hellensen's A and B dry batteries; Eveready B batteries; LCL accumulators; Ormond, Harmo, Calypso and Gilfillan variable capacitors; variable capacitor kit sets; Therla mica capacitors; Watmel, Lissen, Cutler Hammer and Bradleyleak grid-leaks; Honeycomb coils in the range 15 to 400 turns; Duplex coils in sets; Honeycomb, Spiderweb and Swivel coil plugs; Polar, De Luxe, Igranic, Advance, Elsie and W&M coil holders; crystal set kits; crystal detectors; crystals including Hertzite, Midite, Harmatone, Galena, Iron Pyrite, Molyodenite, Gneiss and Neutron; dials; ebonite and bakelite sheets in standard sizes and cut to size; formers; insulators; jacks; lightning arresters; loudspeakers including Brown (Baby), Atlas, Brandes, Amplion Dragonfly, Amplion Junior, Brunet; potentiometers; peep screens; filament rheostats; switches; valve sockets including Advance, English A, Frost, Mack, Tilman and Magnus; slider rods; AWA, Ormond AF transformers; Philips, Marconi and Radiotron valves; valve adaptors; wire in a range of coverings and gauges; Gecophone and Scientific headphones.

A range of valve receivers to several designs employing two to six valves were available in fully assembled or kit forms.

To encourage enthusiasts to visit his suburban Radio Shop, the Proprietor offered to refund tram fares from the city for all purchases over ten shillings. However, many clients complained that the business was too far out of town, so in 1926 a shop was opened at 129A Rundle Street, and to mark the opening, a special price was announced for a five valve Neutrodyne kit set.

The company also had a branch at 154A Henley Beach Road, Torrensville. Although a range of parts was carried at the store, there was a permanent display of the complete range of crystal sets and battery receivers made by the company in the Norwood workshop. All sets were set up complete with batteries and loudspeaker/headphone so that buyers could trial all models. In mid 1925, display sets included slider crystal set; Tens Units crystal set; two valve reflex set with headphones; three valve reflex set with Atlas loudspeaker; four valve reflex set with Amplion loudspeaker, and five valve TRF circuit set with Brandes loudspeaker. The company guaranteed loudspeaker reception from Melbourne and Sydney stations at loudspeaker strength for the three, four and five valve receivers.

* PAROSO LTD

A branch of Paroso Melbourne and located at 113 Gawler Place, Adelaide. It was a popular meeting place for radio enthusiasts due to discounts on many lines in the large range of components and fully assembled receivers.

In 1924, stock included TMC headphones, Watmel and Lissen grid-leaks, crystals, Ormond variable capacitors and AF transformers, Mullard valves and Frost radio products.

They had the largest and most comprehensive stock of loudspeakers following arrival of a consignment from English manufacturers, on display for Christmas 1924. Suppliers were Ashdown, Brandes, BTH, Edison Swan, Ericsson, General Radio, Alfred Graham, Siemens and Sterling. The display drew a large number of people to the store to look at the range of loudspeakers available.

Manager of the company Production Department was Kevin Wadham who oversighted the assembly and testing of locally assembled receivers and repair of receivers brought into the shop for service.

An interesting feature of the shop display was a set-up Kevin put together to enable customers to select a loudspeaker for their receiver. Seven different models of loudspeakers were set up and wired to a switch box so that the listener could select any loudspeaker for assessment. The set-up was in position for about twelve months and several other Radio Shops installed similar facilities for their customers.

* RADIO WHOLESALERS LTD

Brimar valves; Raymant components; Calstan instruments; Lekmek, Audiola, Stromberg-Carlson and Slade receivers; aerial accessories.

* A M RALPH

Crown Radio products.

* RAMSAY BROTHERS

George Ramsay, one of the founding brothers of Ramsay Brothers, became interested in radio while a student at Scotch College, Adelaide. In 1923, he made several crystal sets and sold them to fellow student boarders at the College. In 1924, he built the first cone loudspeaker in South Australia using horseshoe magnets from a motor cycle ignition system. Today, the unit is in a vintage radio collection.

In 1925, George commenced work in an Engineering business owned by his father. In 1929, he took over the business in partnership with his brother and traded under the name Ramsay Brothers.

In 1931, the company began manufacture of domestic radio receivers under brand name Romley. Many components including power transformers, power chokes, audio chokes, resistors, valve sockets, dial parts and chassis were made on the premises. In one contract, Ramsay Brothers provided 200 mantel and console receivers for Chas Birks Ltd, an Adelaide Department store.

In 1933, Owen Kelvin Griffiths went into partnership with Ramsey Brothers, with the new organisation trading as Kelvin Radio Company. Owen had extensive previous experience in Radio Engineering dating back to 1932 when he designed and constructed receivers for R E Jackman and Co., Adelaide. He was later employed by New System Telephones Pty Ltd in 1926 and Eclipse Radio Pty Ltd in 1931.

On joining Kelvin Radio Co., he took charge of design and manufacture of receivers and all components manufactured on site.

After 12 months, he transferred to A G Healing Ltd as Service Manager for radio, refrigeration, public address and talk-back equipment.

In 1938, Owen took up a position with the PMG's Department working at the Adelaide ABC studios and the NBS 5CL and 5AN transmitters.

The company also manufactured transmitter and studio consoles and racks for Adelaide broadcasting stations and 5CK NBS regional station.

In the mid 1930s, 1500 receiver chassis per week were being produced for local radio manufacturers and distributors including National Radio Corporation, A G Healing Ltd, Vasco and Nomis.

* RANDELL ELECTRICAL AND RADIO STORES

The Proprietor, A B Randell, well-known as 'Cocker' Randell established his business at 225 Unley Road, Unley between Fisher Street and the Town Hall.

'Cocker' Randell had been an Electrical Engineer with the Adelaide Electric Supply Company, but his experience and interest in radio went back to the years of the First World War when he was in the Wireless Corps of the 5th Army gaining experience with Marconi pack-saddle type spark wireless telegraphy apparatus. He also served a period with the Flying Corps.

After the War, he joined the Adelaide Electric Supply Company, Adelaide serving some 15 years with the company before leaving to establish his electrical and radio business in October 1924.

By mid 1925, when 5DN commenced transmission he was assembling 18 receivers a month to keep up with demand for his high quality receivers. The most popular models produced in his workshop were Cocker crystal set, one valve regenerative receiver, three valve reflex receiver and a four valve TRF receiver. He constructed a number of custom-built receivers with one model being a seven valve receiver with transformer and impedance-coupled audio amplifier for a customer at Port Lincoln. The receiver designed by 'Cocker' was unusual at the time in that it had one stage of tuned radio frequency using a special coil which comprised a tuned radio frequency transformer mounted on the shaft of a low loss capacitor so that it could be tuned simultaneously with the loop circuit. The audio stage of the receiver used three valves with impedance, transformer and impedance coupling with the last stage employing a resistance leak. A letter from the owner in mid 1927 indicated that the set was still performing in top condition with all three Adelaide stations 5DN, 5CL and 5KA being received at good strength, as well as many interstate stations during evening periods.

The business stocked a wide range of radio components and accessories heavily discounted to encourage buyers to his suburban Radio Shop. Fully assembled receivers were sold under the Cocodyne label.

He offered an accumulator recharge service with free pick-up and delivery to listeners within one mile of his shop.

In 1930, he manufactured B battery eliminators in the workshop and some can be seen today in vintage radio collections. He also manufactured complete self-contained power supply units for listeners who wished to have their battery-operated receivers changed to AC mains operation.

'Cocker' Randell was a foundation member of the Southern Suburban Radio Club when it was established in 1925 and he did a great deal to encourage boys to become interested in radio as a hobby. Every Saturday morning, he had a 25% discount on his crystal set kit 'The Cocker Special' and offered a free variable capacitor for any boy who could prove he received an Interstate station on an assembled set. One boy who lived at Belair claimed to have received without interruption on 3 September 1932 a half hour program from 3LO Melbourne on 375 metres of Dance Music provided by the Wireless Dance Orchestra. He used an aerial supported by two 20 metre high poles on a hill at the back of the house. The aerial was normally used with the family's Stromberg-Carlson console receiver.

* STEVE RAY

Manufactured Savoy brand receivers from 1931 until 1956 except for the years of the Second World War.

* W H ROOK AND CO.

The company concentrated on the wholesale side of the radio trade from their premises in Barlow Building, 93 Rundle Street, Adelaide. They were representatives for Volton B and C batteries; Radio Technique valves; Kellogg products and several USA valve brands.

They had a wide range of Kellogg radio components and receivers including capacitors, coils, chokes, dials, couplers, grid-leaks, headphones, jacks, plugs, transformers, rheostats, valve sockets, loudspeakers; switches and resistors. The most popular Kellogg receivers were the five valve Wavemaster table model with separate loudspeaker and the seven valve Wavemaster, both produced in 1925.

* ROUTLEY AND WIGSALL

R & W receivers first produced in 1932.

* SAVERY PIANOS LTD

Stromberg-Carlson, Audiola and Beale-Panchromatic receivers.

* W A SMITH

Stromberg-Carlson and Audiola receivers, Radiotron valves, batteries, components.

* SOUTH AUSTRALIAN BROADCASTING COMPANY

The South Australian Broadcasting Company was originally established to install and operate an A Class broadcasting station in Adelaide. However, shortly after registration, the company went into liquidation, and from October 1924 the company was wound up.

Just prior to being wound up, the company had in stock a large range of radio receivers and components. Stock included crystal set with headphones; single valve receiver with English valve; single valve receiver with USA valve; two valve set with English valves, detector plus audio; two valve set with USA valves, detector plus audio; three valve set with English valves, RF amplifier, detector, AF amplifier; three valve set with USA valves, RF amplifier, detector, AF amplifier; three valve set with English valves, detector, two audio and Loud Talker; three valve set with USA valves, detector, two audio and Loud Talker; four valve set with USA valves, RF amplifier, detector, two AF amplifiers; four valve set tuned anode, RF amplifier, detector and two AF amplifiers; five valve set two RF amplifiers, detector, two AF amplifiers; six valve set, USA valves, two RF amplifiers, detector, two AF amplifiers, one power output valve; seven valve set, USA valves, four RF amplifiers, detector, two AF amplifiers; six valve set show model in cabinet with sloping control panel; six valve set show model in polished upright cabinet; and four valve set York type cabinet, show model.

All stock had been heavily discounted and was cleared before Christmas 1924.

* SOUTH AUSTRALIAN RADIO COMPANY

Like the South Australian Broadcasting Company, the South Australian Radio Company had plans to establish an A Class broadcasting station in South Australia.

In 1924, the company had been operating experimental station 5AB on low power with one of its major activities being the broadcast of election results on 5 April 1924.

The company was heavily involved in the receiver and component business from its premises at 33 King William Street. It was sole Agents for Burndept and Polar radio products and manufactured its own range of receivers from two to eight valve models. A feature of the receivers was the high quality cabinets. They were made of highly polished Tasmanian blackwood and were available in table, upright and Jacobean designs.

After a poor response from attempts with a temporary 100 watt transmitter, the company decided to abandon attempts to finance and establish a high power A Class station and the business was wound up.

* H STANDEN
  Aegis coils and components, Marquis moulded parts.
* ALEX STEPHEN
  Breville receivers.
* STOTT AND HOARE LTD
  Breville and Maestro receivers.
* THE INSULATING TILE COMPANY
  The company, originally a tile manufacturing organisation entered the radio manufacturing business about 1928 producing Expona brand receivers. The first model was a two valve battery-operated design employing a large once folded horn loudspeaker about 4 ft (1.2 m) high. The horn was designed and manufactured in the factory.
  In 1930, a three valve AC powered receiver was produced using a 20 inch (500 mm) cone loudspeaker. The company made many of its components including loudspeakers, capacitors, resistors, coils and AF transformers and chokes. The company ceased business just prior to the outbreak of the Second World War. Company Chief Engineer was Bill Blackfer who contributed a lot to the design of large exponential horn loudspeakers.
* UNBEHAUN AND JOHNSTONE LTD
  The firm was founded in 1916 by two partners Carl Unbehaun and Ted Johnstone.
  Carl Unbehaun was an Electrical Fitter in the Postal Telegraph Workshops, Adelaide in 1877. After installation of the first telephone exchange in Adelaide he took charge of the Electrical Department in 1894.
  He became the first Engineer in the South Australian PMG's Department when Telegraph Departments in the various States were consolidated.
  Carl played a leading role in early wireless telegraphy experiments being conducted by University and Post Office staff in Adelaide. He later became an active experimenter with his station 5AX.
  He left the Post Office in 1916 to form Unbehaun and Johnstone Ltd with Ted Johnstone.
  Ted Johnstone was a qualified Electrical Engineer and became Managing Director of the company on its formation.
  The firm specialised in electrical installation work where Ted Johnstone played a major role in design of facilities and products. Components manufactured in the workshops included transformers, auto transformers, chokes, motor starters, switchboards and auto electrical equipment. The company also produced a range of radio receivers under the brand name U and J. One of their most popular products was the U and J Kit Set which Ted Johnstone designed.
  About 1924 when sale of radio receivers was at a peak, the firm established the Electrical Supplies Department at 9 Rundle Street and this became the major outlet for the U and J radio lines. The company stocked a wide range of WE parts.
  In April 1924, Rupert Barker joined the company as Manager and Chief Engineer of the Radio Department. He brought with him wide experience in Radio Technology, having worked in USA and Europe radio assembly factories and spent time at sea as a Ship's Wireless Operator. While in the USA, he was Receiving Engineer with Radio Corporation of America.
  Rupert was an active experimenter having his own Amateur station 5RM and licensed operator of The Electrical Supplies Depot station 5BK. He designed and built the 5BK transmitting and receiving facilities in 1925 and they were considered to be amongst the best in the State at the time. The transmitter employed the popular loose coupled Hartley circuit while the receiver was a seven valve tuned anode design based on a Scott Taggart circuit. Loudspeaker was a Western Electric horn type.
  Rupert was a popular speaker on radio technical subjects and was in high demand for talks to Radio Club members. He also contributed several articles to the local technical press.
  In early 1925, the large stock of radio accessories and components included aerial damping springs; Exide celluloid case accumulators; aerial wire; Columbia A, B and C dry batteries; Lungen buzzers; Philips battery charger; Warnier and Ormond variable capacitors in plain and vernier designs; Watmel variable grid-leaks; rubber ear pads; fixed mica capacitors; Honeycomb and Spiderweb coil plugs; Polar vernier coil holders; Honeycomb coils in the range 20 to 300 turns; contact studs; brass crystal cups; Hertzite and Neutron crystals; brass and nickel wire cat's whiskers; ebonite dials; fixed grid-leaks; Western Electric headphones; egg-type porcelain insulators; Frost single and double circuit jacks; Western Electric Baby, Adjustable and Large loudspeakers; lightning arresters; Frost potentiometers; peep holes; Nutmeg and H & H rheostats in 6–30 ohm range; SPDT porcelain base, push-pull and DPDT switches; sliders and rods; bakelite and Weovalve sockets; WE and Signal AF transformers; brass terminals; Weco, radiotron and Philips valves; Ambassador coils and others.
  The company also had a large supply of English made sheet ebonite in 3/16 and ¼ inch thickness in matt finish which could be cut to suit any receiver front panel size. Standard size sheets off the shelf, were 24 inch by 12 inch (600 mm by 300 mm).
  During the 1925 Christmas period sale, the shop sold several Tropadyne Outfits which had been manufactured by Radio Industries Corporation, New York. The Outfit or Kit Set was supplied in a cardboard box and an enclosed leaflet described the tropadyne circuit as 'The simplest and most super-sensitive, most wonderful and most efficient radio circuit, superior to the superheterodyne and featuring greater distance, superior volume, no distortion, positively non-radiating, six tubes do the work of eight and the only super radio set with tuned intermediate frequencies'.
  The Kit included a well-illustrated booklet describing the operation and construction of the tropadyne circuit using the kit.
  The heart of the Tropadyne Kit was the Tropaformer. A Rico straight line variable capacitor was built into every Tropaformer allowing for pretuning of each transformer in the factory.
  In later years, Unbehaun and Johnstone distributed Tasma and STC receivers.
* VARCOE AND CO.
  The company was located at 57 Gawler Place, Adelaide in the mid 1920s and had in stock a large range of receivers and radio components as well as Edison Diamond Disc phonographs and records. A range of Varcola crystal sets and valve receivers up to four valve models were produced on the premises in fully assembled or kit set formats. The premises included a Radio Hall where demonstrations were provided of the operation of radio receivers and phonographs.
  Stock included Gecophone receivers and a full range of Frost and Ediswan components.
  The company manufactured three models of crystal sets. They were Little Wonder Super, Varcola and De Luxe models. Demand was so strong that 200 crystal sets were being produced each week in 1924. The staff included two Apprentices.
* WILLIAM ADAMS AND CO., LTD
  Philips receivers, valves and components.
* WISE L S AND CO., LTD
  Distributors of Rexonola receivers. The 1932 range included Granville 5 valve; Bell Bird 5 valve; Ashfield 3 valve; Cremorne 4 valve; Fairfield 7 valve and Dalton 7 valve.
* WOOLARD R C
  Mullard receivers, valves and components.

Among the many people engaged in the radio industry in South Australia was Elizabeth (Betty) Geisel — later Mrs Wallace.

Betty received an Amateur Operators Certificate of Proficiency on 11 November 1936 while living in Murray Bridge. She was one of the first ladies in South Australia to obtain an AOCP. She built her station from limited resources with the transmitter operating with an input of 10 watts. The receiver was a two valve regenerative type employing a type 30 valve in the RF stage and a type 19 in the audio stage. The transmitter was powered from the town 230 volt DC supply but the receiver was powered from a supply Betty built herself using Marmite jars to hold sal ammoniac electrolyte, positive carbon rods recovered from old dry cells and strips of zinc amalgamated with mercury for the negative terminals.

In 1939, Betty moved to Adelaide where she took up a position with National Radio Corporation Ltd, manufacturers of National radio receivers.

Following study, she obtained Second Class Commercial Operators Certificate of Proficiency No 448, and on 7 November 1941 received First Class Certificate No 554. Betty subsequently left the radio industry to become a High School teacher.

* **WESTERN AUSTRALIA**

In Western Australia, where 6WF commenced transmission on the long wavelength of 1250 metres, the standard medium wave receivers with a range of 200 to 500 metres were unsuitable, and so one of the problems of Westralian Farmers Ltd., in establishing their broadcasting service was to ensure that their country and metropolitan shareholders, clients and others were able to obtain suitable receivers at reasonable cost to receive the transmissions. The company had more than 6000 clients throughout the State in 1924.

The Westralian Farmers Ltd, with which was amalgamated The Graziers Ltd, was one of the major business organisations in the State with Head Office in Perth, and Branches at Albany, Fremantle, Bunbury, Geraldton and Narrogin. There were at least 15 separate Departments dealing with wheat, livestock, machinery, wool and skins, fruit export, real estate and other matters. It also included a Broadcasting Department with the objective of manufacturing radio receivers to ensure availability of high quality, easy-to-operate and low-cost receivers with simple power supplies.

The Company set up a well-equipped Laboratory and Workshop with the aim of manufacturing as many of the components as possible. After trials with several designs, the Department decided on a design to be used as a standard and called it the Mulgaphone. It was claimed that farmers appreciated the meaning of a 'mulga' wire, and its suitability for a wireless receiving set was immediately apparent. Colloquially, 'mulga wire' was likened to 'bush telegram'.

The Workshop included an overhead belt system to drive drills, grinders and several lathes. One lathe, a capstan type, was the only one of its size in the State and was used for mass production of screws, terminals, shafts, lugs and other components required in the assembly of a receiver. At least six Tradesmen and Trainees were employed in the assembly area where work was carried out in stages by different assemblers. Following completion of assembly, the receiver was thoroughly tested by a Radio Expert and certified as operational and ready for sale. A Display Room open to the public, housed a full range of the receivers and components available for sale.

Production was under the control of W R (Bill) Phipps, with Malcolm Murray as Foreman.

By early 1925, receiver models included the Mulgaphone Receiving Crystal Set, claimed to be suitable for operation up to 30 miles (48 km) from the transmitter with a normal outside aerial. It was supplied with BTH headphones, six insulators, lead-in ebonite tube and crystal with cat's whisker in a small metal tin. A two valve audio amplifier was produced to allow the receiver to operate a loudspeaker. The amplifier employed DE3 dull emitter valves and was supplied complete with low and high tension dry cell batteries. A third model comprised the crystal set and audio amplifier built into a combination cabinet. It was normally supplied with a 21 inch Sterling horn type loudspeaker.

Another product was the Mulgaphone Receiving Unit and Loud Talker built into a single tall cabinet. The Sterling loudspeaker was built into the bottom of the cabinet and was supplied with a long extension lead to allow the loudspeaker to be taken out of the cabinet and operated on a stand in the listening room.

Where it was necessary to employ imported components for their receivers, the company had a policy to use British-made products only.

Sale of the Mulgaphone receivers was the responsibility of Mr F Anderson.

The Listener's Subscription Fee for 6WF was the highest in Australia, being 84 shillings, compared with 63 shillings for 2FC Sydney and 3AR Melbourne, and 10 shillings for 2SB (2BL) Sydney.

Receiver sales were small, mainly because the programs provided by the station did not encourage people to purchase a receiver. The programs were restricted in diversification because of financial problems of the company operating the station. Operating costs greatly exceeded licence fee revenue and management was not prepared to pay high fees for top class performers.

The company also produced kit sets, and by 1926, the two valve battery-operated RD Junior receiver was one of the most popular models. Receiver production ceased shortly before the station was transferred to the PMG's Department in December 1928, as part of the Government's plan to set up the National Broadcasting Service.

C S Baty and Co., Perth, manufactured Batyphone receivers from the early 1920s until well into the 1930s. The Proprietor was Stan Baty, who was one of the first manufacturers in Australia to provide a package deal for listeners. Stan would travel around the back blocks of Western Australia in a big truck loaded with Batyphone receivers, batteries, aerial wire, insulators, lightning arresters, earth systems, spare valves and long lengths of sawn timber for aerial poles. He would arrive at a homestead without warning, convince the farmer that a radio receiver was a necessary part of life, complete the installation in an hour or so, and leave the bedazzled farmer while he travelled to the next property. He was so successful that he tried to entice George Moss, a friend and leading Amateur operator, to work for him. However, George was not keen about travelling around the countryside to earn a living and joined the Perth Technical College as Instructor in radio subjects.

One of the early Batyphone models was a five valve model with separate loudspeaker. Large numbers were in service throughout the State. In 1933, screen grid valves were introduced into the receiver designs with one of the models selling for £23–10–0. The company provided an Installation Service at £2–10–0 for their receivers. By 1937, console models were included in the production schedule.

Another Perth receiver manufacturer was Craig and Co., Ltd. Proprietor was R Wilkes, and Foreman-in-Charge was Syd Botterill, who had been associated with radio in England. The factory was located at 37 King Street, Perth, with a shop located at 19 Brennan's Arcade. One of the popular models produced in 1925 was the Craig Universal receiver, which sold for £45 and included valves, batteries, duolateral coils, aerial wire, insulators and headphones or loudspeaker. The receiver covered long and medium waves using plug-in coils.

Other organisations in Western Australia associated with assembly, distribution or servicing of radio receivers to the period up to the outbreak of the Second World War included:

* AIRZONE (1931) LTD
  Airzone receivers and components.
* ATKINS LTD
  Rola loudspeakers.
* AUSTRALIAN RADIO SUPPLY CO.
  Healing Golden Voiced receivers, components and accessories.
* M J BATEMAN LTD
  Exide radio batteries, aerial insulators, wire, STC receivers, components.
* BRITISH GENERAL ELECTRIC CO., LTD
  Genalex receivers and battery chargers.
* BUHLERS LTD
  Range of radio receivers, accessories.
* T G BUTEMAN
  Peerless receivers, components.

* CARLYLE AND CO.
  Amplion loudspeakers; Radiokes parts; Ken Rad valves; Efco dials; RCS wire wound components; Diamond batteries; Astor, Tasma, Slade receivers.
* DAVIES AND CO.
  Receiver manufacturers.
* J R W GARDAM
  Philips Radioplayer receivers, Philips valves and components, Volta batteries, accessories.
* C L HEPPELL
  Range of receivers, components and accessories.
* LAZARUS AND CO.
  Superheterodyne brand receivers, components and accessories.
* H C LITTLE AND CO., LTD
  Lekmek receivers, kit sets and components.
* MUSGROVES LTD
  Stromberg-Carlson receivers and components.
  Fred Kingston was Manager, Radio and Electrical Department.
* NOYES BROS
  Seyon receivers, Igranic kit sets and components.
* PARAMOUNT STORES
  Grand Opera receivers, components and accessories.
* PHONOGRAPHS LTD
  AWA Radiola receivers and components.
* ARTHUR PIDGEON
  Range of receivers, components and accessories.
* J G PRITCHARD
  Crown Radio parts.
* H E READ
  Radio Corporation receivers and components.
* SCOTT AND HOLLADAY
  Components, particularly resistors, voltage dividers and capacitors.
* SCOTT AND HOARE LTD
  Breville receivers, components and accessories.
* THE BAIRDS CO., LTD
  Range of receivers and components.
* THE RADIO SHOP
  Range of receivers, components and accessories.
* UNBEHAUN AND JOHNSTONE LTD
  Tasma receivers, components and accessories.
* WYPER HOWARD LTD
  Westinghouse, HMV and Radiola receivers, accessories.

*** QUEENSLAND**

Queensland had a great number of Radio Shops and distributors who catered for the listening public from the 1920s. There were also a few small manufacturers. With the establishment of A Class station 4QG Brisbane and B Class station 4GR Toowoomba in 1925, a large area of South Eastern Queensland received acceptable signals for good reception. With the commissioning of 4RK Rockhampton and 4TO Townsville in 1931, the Northern area of the State also was within a service area. This led to the rapid growth of Radio Shops and dealers handling radio receivers and components. During the first two decades after commencement of broadcasting in Queensland, local businesses as well as Interstate representatives included:

* AMALGAMATED WIRELESS (A/ASIA) LTD, KING AND KING BUILDING, QUEEN STREET, BRISBANE
  The AWA Branch office stocked a full range of AWA products including Radiola receivers and AWA manufactured components.
* AMICO (QLD) LTD, QUEEN STREET, BRISBANE
  Distributors of Burginphone receivers and Burgin parts made by Burgin Electric Co., Ltd, Sydney. In 1925, the range of receivers included Burginphone Master set manufactured in four, five, six and seven valve models; Burginphone Grand model; Burgin Radio/Phonograph console model; Junior model complete or in kit form. Within a few months of 4QG going on air, a Burginphone Grand model receiver was taken to Toowoomba, 160 km west of Brisbane, and performed well even with the built-in aerial being used in place of an outside type.
* S L BEARD, LOSE STREET, SOUTH BRISBANE
  Designer of Beard Standard receivers. Policy was to manufacture high quality receivers which would perform as well as the best designs on the market and were reliable. Only top quality components were employed and each component was pretested before being cleared for installation. Other features included simple tuning procedure, adequate power to drive a matching loudspeaker without distortion, good tonal quality, each model having a distinct panel design and all models fitted into highly polished Silky Oak cabinets.
  The Beard Standard single valve model with regeneration was capable of loudspeaker working with a receiver within 15 km of 4QG, and up to 150 km with Brandes headphones. The two valve model with one amplifier stage provided loudspeaker reception with Amplion model AR111 and interstate stations including 5CL Adelaide with Brandes headphones. The Beard Standard three valve model gave ample output with Sydney stations using Amplion AR111 loudspeaker with low noise level, while the top of the range, the Beard Standard four valve receiver gave good performance of Sydney, Melbourne, Adelaide, Bathurst and Toowoomba stations with Amplion AR19 loudspeaker.
* BUZACOTTS (QLD) LTD, 443 ADELAIDE STREET, BRISBANE
  A range of about six models was marketed under the Wondatone brand between 1945 and 1948. They included Model 46G, a five valve AC powered dual wave and radiogram unit.
* G A CAMPBELL, 356 STANLEY STREET, SOUTH BRISBANE
  Manufacturer of GAC brand top quality receivers.
* J B CHANDLER AND CO., 45 ADELAIDE STREET, BRISBANE
  The company was established by John Beals Chandler in 1914 to sell Gloria lighting systems mainly to country clients. In 1916, he opened an Electrical Department in Charlotte Street, Brisbane but due to expanding business, the premises became too small, and in 1923 he purchased a building of five floors in Adelaide Street. At the time of occupying the new premises he established a Radio Department which became operational in November 1924. The Radio Department was so successful that it soon became the major focus of the business. Mr Miller, well-known in the broadcasting industry, was Manager of the Department.
  Major items stocked within 12 months of the Radio Department being opened up for trading included a range of Gloriola receivers comprising one valve, two valve, three valve and four valve models. Each model was also available in kit form which included, in addition to the circuit components, batteries, headphones or loudspeakers and material for the aerial system. There was a section in the store devoted to the crystal set enthusiast. There was a high demand for fully assembled sets and kit sets as soon as 4QG went to air. In the afternoon, after school hours, it was necessary to have two Salesmen at the counter to handle the requirements and queries of schoolboys. Stock included single slide crystal sets fully assembled or in kit set form; loose coupler crystal sets, fully assembled or in kit set form; Gloriola crystal sets; loose coupler formers; maple baseboards for loose couplers; maple ends, predrilled; secondary slide rod supports; nickel-plated secondary slide rods; Edison Bell twin detector with crystal; Grip patent crystal detectors; Melbourne crystal detectors with ebonite ends; Melbourne glass enclosed plug-in type detectors; Perikon detector; assorted crystals; gold, silver, steel and phosphor bronze cat's whiskers; AWA headphones; Heath low loss variable capacitors and many others.
  By 1930, the range of products in stock had increased considerably with the company being kept very busy in handling AWA products for which they were Queensland distributor. The company had a same day country order service and it was one of the busiest parts of the Radio Department.

Overseas products were also stocked, with Electrad radio products being one of the most popular. Stock included jacks, fixed mica capacitors, Tonatrol or Royalty mounting bracket for variable rheostats or potentiometers, glass grid-leaks, switches, Royalty variable rheostats, Trivolt variable power resistors and others.

A Sydney-based company J B Chandler Ltd was established in 1935.

Many Chandler employees worked for the company for many years. George Ham was one of those long-term employees, spending his entire working life with Chandlers. In 1930, he was Secretary of the Toombul Radio Club when it was disbanded. The Club had originally been known as the Nundah Radio Club when established in 1925. George retired from Chandlers in 1979.

On 16 August 1930, broadcasting station 4BC was commissioned and licensed to Chandlers Broadcasting Service with John Chandler as General Manager. The three studios were located in the same building as the radio and electrical business, with the transmitter being situated at Oxley.

In 1933, the station technical staff included Fred Steven, Chief Engineer; Frank Elliot, Chief Studio Engineer; George (Jack) Sutherland, Assistant Engineer; Patrick Lindsay, Assistant Studio Engineer; E C Little, Chief Technician; and Robert Hare, Control Engineer.

A few months after 4BC began full operation, Mr Chandler received a letter from the Reverend R H Wilson, the only white man on the Mornington Island missionary station in the Gulf of Carpentaria commenting on the high quality of the 4BC signal being received on the Island. He had a six valve battery-powered AWA Radiola table receiver Model 80/C65 which Chandlers had supplied. The receiver was a TRF type employing valve types 22 (three), L410 (two) an P410 and fitted with a magnetic loudspeaker. Chandlers had supplied several of these models to listeners in the Darling Downs area who also reported good signals from 4BC.

Today, the name Chandler has been carried on by Chandlers (Aust.) Ltd established in 1987 and based at MacGregor, Brisbane and one of Australia's largest stockists of household electrical goods including radio receivers. In mid 1996, the company had 160 stores throughout Queensland, New South Wales, Victoria, South Australia, Australian Capital Territory and Northern Territory with annual sales of the order of $410 million.

* COLO COIL COMPANY, IPSWICH

The Colo Coil Company was formed in August 1927 by Messrs B V Cole and N C Lowe for the purpose of manufacturing a range of coils for broadcast receivers. The company derived its name from the first two letters of the surnames of the principals.

Bert Cole was a Radio Engineer who manufactured a range of receivers as early as 1925 under the label 'Bercolian' in his workshop at Sinclair Street, Booval near Ipswich. He sold to both wholesale and retail outlets. The receivers were assembled using only top quality components and he was one of the very few manufacturers who gave a five-year guarantee on receivers. Included with the receiver was a free installation service for the aerial system.

Before setting up business in Ipswich, Bert Cole had, for some years, been Manager of Star Electrical Co., Ltd in England designing and manufacturing radio components and accessories. Coils manufactured included Colo Modified Reinartz Coil for two and three valve receivers; Colo Masterdyne Kit designed for a four valve receiver and being basically a modified Reinartz unit with one stage of RF added; Colo Multi circuit made to enable an experimenter to employ a range of circuits without the necessity of mounting new coils each time a change was made. Every kit was supplied with circuit and instructions for using the device to best advantage. The company also provided a rewinding service for repair of headphones and loudspeakers.

* WALTER F DENBY, 80 EAGLE STREET, BRISBANE

Wholesale distributor of Tunafone crystal sets and battery receivers, Claratone loudspeakers, Na-Ald components, Crosley transformers and components and others.

* DENHAMS (M'BRO) PTY LTD, MARYBOROUGH

One of the largest manufacturers and distributors of radio and electrical goods in country Queensland.

In the 1940s, the company was wholesale and retail distributor on behalf of many well-known organisations including RCS Radio Pty Ltd, RCS coils, capacitors, dials, kit sets etc; International Radio Co., Pty Ltd, Radon cables, Amphenol products and radio components; Ducon Condenser Pty Ltd, Ducon and Chanex products; Stromberg-Carlson, gang capacitors, AF transformers; Paton Electrical Pty Ltd, Palec test equipment and meters; J J Hoelle and Co., Utilux products and radio components and accessories; Commonwealth Moulding Co., Marquis moulded products including knobs and coil formers; W S Tait and Co., WST potentiometers, trimmers, padders etc; Zenith Radio Pty Ltd, Calstan test equipment and radio receivers; Masterradio Ltd (England), loudspeakers; Taylor Electrical Instruments (England), test equipment and meters; Kriesler Radio, receivers and components; Wingrove and Rogers (England), Polar gang capacitors, and others.

Trading as Denradio Industries, the company was one of the most active Post War organisations in country Queensland producing radio receivers and test equipment.

During 1946, seven receiver models were released and in 1948 at least 26 models were produced for sale. Designs covered a wide range of power supply inputs including AC, Universal, 12 volt accumulator, and 32 volt DC home lighting systems.

A feature of the designs was the largest number of models employing 9, 10 and 12 valves. Four 10 valve and three 12 valve models were available. One of the 12 valve models was purchased by a resident on Thursday Island.

The receivers were sold under the Denradio label.

John Bristoe, the company Radio Manager, was well-known throughout the industry. He made major contributions to the design and manufacture of Signal Tracers employed in Radio Servicing work. Several of his designs were described in 1940–41 issues of 'The Australian Radio World'. In 1950, he was Queensland Representative for the magazine.

* EDISON, SWAN ELECTRIC CO., LTD, 156 CREEK STREET, BRISBANE

Retailers of Ediswan receivers, headphones, loudspeakers, valves, AF transformers etc. Edison, Swan Electric Co., was an English organisation which manufactured a wide range of radio components and receivers. Items in stock at the Brisbane office in mid 1920s included Ediswan accumulators in celluloid cases; dry batteries types DE200 and DE201 designed for dull emitter valves and producing 3 volts output; one valve AF amplifier designed to provide greater output from a crystal set; two valve AF amplifier designed to provide loudspeaker strength from a crystal set and employing Marconi Osram DE5 Valves; variable capacitor with cam-shaped vanes of hard brass; Model 1924 crystal set with sliding type inductor; crystal-valve receiver with reflex circuit embracing HF amplification followed by crystal detector; Dulcivox and Televox loudspeakers both with diaphragm adjusting facility; Ediswan valve types AR, R, ARDE, AR.06, PV6DE, PV5DE and PV8DE.

* EVANS ELECTRICAL CO., IPSWICH

Manufacturers of a range of Simplex brand receivers, kit sets, components and accessories.

* J T GREENLEES AND CO., 129 ANN STREET, BRISBANE

After the War years, a range of Queen brand receivers were distributed. In 1948, seven models were available including portables, mantel and console cabinet types.

* W HAIGH AND CO., IPSWICH

Distributors of AWA receivers and components.

* HAMILTON AND PASS, BURNETT LANE, BRISBANE

Retailers of locally manufactured receivers and a range of components and accessories.

* HARRINGTONS LTD, 93 QUEEN STREET, BRISBANE
Imperia receivers in one, two, three, four, five and six valve models; Gilfillan receivers, kit sets and components; Hercules products; Amplion loudspeakers; Marco products; AWA products; Grodan radio parts; Bradley radio products and many others.
* HOME RADIO SERVICE LTD, FIRST FLOOR, COURIER BUILDING, QUEEN STREET, BRISBANE
Queensland distributors of Stromberg-Carlson, Splitdorf, Crosley, Rotofor and Kennedy receivers; Jewell radio instruments; De Forest valves; Audalion loudspeakers; and Rico-Dyne receivers assembled locally from Rico parts; and Radion panel.
In 1927, the company had one of the largest ranges of USA manufactured Kennedy receivers including the one dial model 20, a five valve unit fitted with a specially designed tuning circuit to give equal spacing of stations on the tuning dial. In addition to the tuning dial, an aerial tuner and volume control were mounted on the sloping panel of the satin finished mahogany cabinet. Dial markings and engravings were in gold and exposed metal parts were in a permanent black finish.
Included among purchasers of this model were two graziers who lived on adjacent properties near Bell on the Darling Downs. One of the owners reported good reception from 4GR Toowoomba, 4QG Brisbane, 2FC Sydney, 5CL Adelaide and 5KA Adelaide.
Unfortunately, the business ran into financial difficulties and was placed in liquidation in early 1928 with the entire stock being purchased by R M Graham, a Director of Radio Products Ltd.
* EDGAR V HUDSON PTY LTD, CHARLOTTE STREET, BRISBANE
One of the largest and best-known Radio Merchants in Queensland for close on 50 years, was Edgar V Hudson Pty Ltd. The business was founded in 1924 by two partners, Edgar (Ted) Hudson and Fred Hoe, initially distributing Radiokes and Mullard components from an old brick building located at 45 Charlotte Street, Brisbane.
Fred Hoe was a qualified Electrical and Mechanical Engineer having served an Apprenticeship with Austral Otis Engineering Co., and studied Electrical Engineering at the Melbourne Technical College. On completion of training and studies he worked as a Marine Engineer on merchant ships followed by a period with the Australian Navy during the First World War. Fred then became involved in agricultural machinery serving as Engineer and Manager of Dalgety and Co., Machinery Department in 1915. Two years later, he moved to Buzacott and Co., Machinery Merchants as Sales Manager, subsequently to become a Director of the company.
With the establishment of broadcasting in Australia, and as a result of involvement with a Brisbane Radio Club, Fred developed a keen interest in the new science and decided to establish a radio business with his friend and fellow Engineer, Ted Hudson. They started business in a small room of a cottage in Charlotte Street, the year before A Class station 4QG became operational.
In 1930, Edgar V Hudson Ltd, and King and King, an old established Brisbane music house formed the Brisbane Broadcasting Company and established Commercial station 4BK Brisbane. Fred was Managing Director of the company.
Fred Hoe's son, also called Fred, a qualified Broadcast Engineer joined the company after obtaining experience on the technical side of operations and installation of broadcasting stations. In February 1931 Fred junior commenced training as Trainee Broadcast Engineer at 4BK where his father was Managing Director and Arthur Dixon was Chief Engineer of the station. The station had begun operations in October 1930. In October 1931, Fred junior was appointed Assistant Engineer and during 1935 assisted with the installation of the 2000 watt station 4AK at Oakey, a relay station of 4BK. On completion of the 4AK installation, he took up an appointment as Chief Engineer on 12 August 1935 for the Ipswich Broadcasting Company station 4IP.
In 1937, Fred junior joined Edgar V Hudson as Manager of the Communications Department. About 1941, he began work in the Radio Transmission Department of Standard Telephones and Cables Ltd, Sydney reporting to David Abercrombie. One of his colleagues was Winston Muscio who at the time had just transferred over from the Receiver Development Laboratory.
In addition to testing MF and HF transmitters from 500 watts up to 20 kW, Fred was involved to a considerable extent in the accelerated development program for the AT20 500 watt transmitter for the RAAF as well as other Service related projects. The AT20 was also known as AMT120 or 4SU6A depending on whether it was used by the RAAF, RAN, USN or USA Army. It was a counterpart of the AT13B and provided CW operation, with five preselected frequencies in the range 2–20 MHz. Following development by STC, duplicate production was undertaken in Melbourne by Eclipse Radio Pty Ltd.
When Fred began work with STC there were some 1000 employees working in factory space of 100000 square feet (9300 sq m). When he left STC to return to Edward V Hudson after conclusion of hostilities there were 2200 employees working in factory area of 250000 square feet (23230 sq m).
In late 1925, when the company distributed Radiokes products, coil units were among the best-selling items with high demand from enthusiasts throughout Queensland and Northern New South Wales to build their own receivers following the commencement of transmission by 4QG in July that year. The honeycomb and duolateral coils were the standard coils for broadcast receivers, being available in sizes from 19 to 250 turns. They were available in both unmounted or mounted formats. The diamond mesh 'Lo-Los' coils were low capacity types with turns from 10 to 75. Although 4QG operated in the medium wave band, some listeners wanted to listen to 2FC Sydney which operated in the long wave band, so axial coils were used for receiving that station. The axial coils were available in sizes of 8 turns of 16 SWG to 30 turns of 18 SWG.
A subsequent addition to the Radiokes coil line, was the Circloid De-Luxe a most difficult coil to manufacture but specified by many designers for circuits popular at the time.
By 1928, stock of components was extended, and included Cyldon thumb control three gang capacitor and shield assembly used by set constructors with the Screen Grid Solodyne circuit; Cyldon short wave capacitors with insulated extension spindles and bushings; Cyldon Bebe reaction capacitors; Emmco Pep Punch AF transformers; Mayolian 615 B battery eliminator with input voltages 22, 45, 90, 150 volt tappings and providing 100 milliampere output; Philips eliminators; Amplion loudspeakers; Jackson capacitors, Clyde batteries; and Advance, De Jur, Deal, Emmco and Ferranti products.
In early 1929, the company which up to that time had specialised in the component trade, embarked on a policy of distributing factory manufactured home receivers. They came to an arrangement with Stromberg-Carlson (Aust.) Ltd, Sydney and became distributors of a range of receivers including three, five and six valve sets for battery or B eliminator operation and also three and six valve models designed for AC operation. The receivers were assembled on steel chassis and fitted into handsome metal cabinets with 'moire' lacquer finish in tones of old gold, with silver plated escutcheon plate. Art consoles were also available. The 'moire' finish was a popular finish at the time, giving a wave-like pattern on the surface.
Among major component assemblies made by Stromberg-Carlson which became part of Edgar V Hudson's stock, were four gang capacitor with super aerial tuner using rigid aluminium base plate, fully adjustable and supplied with gold lacquered escutcheon and illuminator; tuning coils and RF transformer chassis assembly with matched tuning coils on Paxolin formers with art-black drawn copper shields;

transformer choke assembly comprising AF transformers, AF choke, grid-leak and capacitor all mounted on a steel base.

In 1930, Eric Cantelin who later became Chief of Technical Staff and Manager Radio Components, joined the company. Eric began his career in radio in 1927 when 17 years of age as a Technician with Radio Supplies Unlimited who were located in T&G Building, Brisbane. The following year, he left Radio Supplies to join Crammond Radio Manufacturing Co., as Technical Designer and remained there until 1930 when he joined Edgar V Hudson. For some time, he combined his normal work with the company with that of being Technical Editor of 'The Queensland Radio News', a popular magazine which had been in publication since 1925. He continued association with the magazine until 1932 but it ceased publication two years later. In 1931, Eric was Edgar V Hudson's Sales Manager.

Another Manager who joined in the 1930s was Hiram T Sharpe. In 1931, he became involved in the radio business when he took up a position with G J Grice Ltd, Queen Street, Brisbane as Manager of the Radio Department. The company was Queensland distributor of Tasma receivers manufactured in Sydney by Thom and Smith Ltd. In 1933, he left G J Grice to join Edgar V Hudson as Country Representative. By 1937, he was the company Set Sales Manager.

By 1931, STC and Emmco Troubadour receivers had been added to the range of factory assembled receivers. The Troubadour brand included the AC Screen Grid 5, a five valve model and a seven valve screen grid model with push-pull output. They were provided with dynamic loudspeakers.

Included in the STC models, was the Triple-Triple Electric Four employing three screen grid valves in three tuned RF stages and pentode output valve. Other STC models included three, six and seven valve AC powered sets, and five and nine valve battery sets.

By 1934, ten years after Edgar V Hudson began operation in a small building in Charlotte Street the company had acquired an adjoining warehouse and expanded its stock of radio components and accessories and were distributors of such well-known brand names as Mullard, Emmco, Radiokes, Paillard, Magnavox, TCC, Impex, Marquis, Hydry, Ken-Rad, Polymet, Amplion, Westinghouse, Osram, Cossor, Ever-Ready, Diamond, Clyde, Philips and others. Altogether, the company handled 44 lines, being by far the largest Queensland distributor. Staff handling radio items alone comprised 24 people.

By 1937, operations were being conducted from premises at 284–286 Edward Street, Brisbane with representatives in Townsville, Warwick and Cairns. Senior staff included Fred Hoe, Director; Hiram Sharpe, Set Sales Manager; Eric Cantelin, Radio Goods; Fred Hoe, Junior, Communications; and C Knowles, Cinema. By this time the company had added to its radio component and accessory lines, the distribution of complete factory manufactured receivers including the full range of Stromberg-Carlson models and later STC models.

By 1939, the company had, in addition to being wholesalers of STC radios and general radio goods added Duotrac sound on film recordings and mechanisms to its product lines. Manager of the Cinema Department was C Knowles. Country representatives were based at Warwick, Rockhampton and Townsville with these bases covering most of the Queensland country areas. A Service Department had been established as part of the receiver sales business with J Forrester being Manager of this Department.

During the War years, the company located at 172 Adelaide Street, Brisbane, supplied radio receivers for the Services.

Subsequently, Fred Hoe established a similar business and traded as Fred Hoe and Sons in Adelaide Street, Brisbane.

In 1956, Edgar V Hudson Ltd trading from 316 Adelaide Street, Brisbane were still Queensland representative for STC radios and radiograms and Brimar valves. One of the STC releases during that year was the mantel Pixie 5 valve receiver using Brimar valves and being available in moulded shatterproof cabinet. It was available in a range of colours including Chinese red and white, grey and white, pink and white and all-cream with rich gold trims.

* INTERCOLONIAL BORING COMPANY

  Agents for Lewcos connecting and flexible wires used in radio assembly and maintenance work. These included hard drawn copper aerial wire; hard drawn enamelled aerial wire; silk covered indoor aerial wire; ;multiway battery cable; headphone cords; silk covered 'Litz' wire; aerial lead-in flex; hollow copper shielding braid; Stayput connecting wire; Rapid assembly wire; screened gram-radio pick-up flex; single and double cotton and single and double silk coil winding wires; insulating materials including oiled cotton sleeving (spaghetti); Prespalm; Empire Cloth; insulating tapes, etc.

* JOHN LUNN, SANDGATE

  John Lunn was a Chemist and Licensed Radio Dealer who stocked a range of receivers including crystal sets and battery receivers up to five valves. He also stocked radio components and accessories. For some time the radio side of the business was more profitable than dispensing medicine.

  He was one of the first Dealers in Brisbane to stock the RCA UY227 valve when he imported ten from USA late in 1927. The valve filament could be powered from the AC mains and he had two receivers assembled to sell with his receiver stock. Voltage applied to the heater was 2.5 volts AC. One of the receivers was purchased by Sam Castor, a farmer at Brackenridge who had a 110 volt AC home lighting system on his property. The receiver replaced a Marvelo V five valve all battery-powered receiver which Sam had purchased from the shop as a 1925 Christmas present for his wife.

  Included in receiver models sold in the shop were a five valve receiver employing two stages of transformer coupled RF amplification, a detector and two stages of AF amplification; a two valve receiver with reflex circuit using one stage of RF amplification, a fixed crystal detector and two effective stages of AF amplification; and a three valve inverse-duplex circuit.

  John maintained a large range of components with emphasis on variable capacitors and coils. Capacitor brands were Acme, Remler, King Cardwell, Marco, Flewelling, Bremer-Tully, Continental and Mignon while inductors included Pathe, Raven, Superior and Excel variometers and variocouplers; Tricoil, Harkness, Superdyne, Cockaday, Spider Web and Phusiforma coils.

  Kit sets were also a popular stock line with circuits for Reinartz, Erla Reflex, Two valve Harkness Reflex, Cockaday and Phusiforma being catered for at reasonable prices.

* MARTIN WILSON BROS LTD, 299 ADELAIDE STREET, BRISBANE

  The company was well-known for its range of Stewart-Warner receivers made in USA. The USA company which made the receiver had an enormous production line producing 1000 fully assembled receivers a day during 1926–27. Martin Wilson Bros imported many of the models produced with 1929–30 stock including Model 801 Series B, one of the most popular, with many going to country clients. It was an all-electric set designed to be operated with USA mains power but modified by Martin Wilson Bros staff to operate with power supplies as appropriate to the area where the Queensland purchaser lived. The receiver employed seven valves with push-pull output feeding a Model 435A reproducer which was a magnetic cone loudspeaker designed to sit on top of the receiver cabinet.

  Four tuned circuits in three RF stages ensured knife edge selectivity. Tuning was performed by a single illuminated dial. The receiver was designed with built-in aerial with provision for connection of an external system. The all steel cabinet had a beautiful moire finish. The Model 806 was a popular model for country listeners who did not have access to AC mains power. It was identical in appearance to the Model 801 and was provided with 6 volt accumulator as A battery, three 45 volt dry cell B batteries and two C batteries.

  Country clients who purchased the Model 806 as a 1929 Christmas present for their families were two brothers on adjacent properties out from Gatton where they reported good reception of 4QG, 4GR, 2FC, 2UW, 2HD and 5CL.

Alan Arkinstall who purchased one of the receivers moved to Grantham during 1932. The receiver was still fully operational there in 1940 when Alan left the farm to join the Army. It had been to a Radio Serviceman in Toowoomba on only two occasions for servicing during the 11 years that Alan owned the receiver.

* C J MEEHAN, GLENFERN AVENUE, STAFFORD

A Post War small manufacturing radio business producing a range of receivers under the Aeradio brand during 1946–48. They were housed in mantel, table and console cabinets and included a personal portable set.

All AC powered receivers were dual wave types and included Model FK2, a four valve receiver in mantel cabinet; Model WE2, a five valve set in table cabinet; Model WE4, a five valve receiver in polished console cabinet, and an alternative five valve version with high quality veneer piano finish console cabinet; Model WE6, a four valve set in console cabinet; and WE7, a four valve set in console cabinet.

Model JC was a battery-powered portable. A smaller five valve set using 1.4 volt filament valves was also available. All designs employed an IF of 455 kHz.

A feature of the console cabinet models was straight line tuning with a large roll top dial system. Permag type loudspeakers were used.

Brisbane distributors for Aeradio receivers were H G Noble and Co., Perry House, Elizabeth Street.

* NOYES BROS, PERRY HOUSE, ELIZABETH STREET, BRISBANE

Distributors of Seyon receivers; Igranic superheterodyne kits and components including fixed capacitors, Igranic Pacent variable capacitors, fixed and variable grid-leaks, Igranic Pacent battery switches, audio transformers, anti microphonic valve holders, coils, coil holders, vario and fixed couplers, knobs, dials, rheostats, potentiometers, HF transformers, terminals and earthing switches. In September 1930, Noyes Bros relocated to Burton House, 197 Elizabeth Street.

* W E PETERMAN, PERRY HOUSE, ELIZABETH STREET, BRISBANE

The proprietor originally established business at 160 Edward Street, Brisbane shortly after broadcasting began, and stocked a large range of components, many of which were not available from other shops in the city. Stock included a full range of All-American transformers manufactured in USA by All-American Mohawk Corporation. One of the partners was E W Rauland who subsequently left to form his own company Rauland Manufacturing Co. He kept the brand name All-American and continued to produce the designs for many years. They were more expensive than most other brands but had a reputation for high performance and reliability. In 1926, Peterman had the following All-American transformers in stock:

- Audio frequency transformers, R12, 3:1 ratio; R21, 5:1 ratio; R13, 10:1 ratio and R500 Rauland Lyric Trio.
- Push-pull transformers, R30 input and R31 output.
- Radio frequency transformers R199 made to suit type 199 valve; R201A made to suit type 201A valve; R110 intermediate frequency unit; R140 radio frequency coupler; R140 universal radio frequency coupler and R120 filter transformer.

Peterman also had a stock of Trimm loudspeakers and headphones including Entertain, Concert and Home loudspeaker models and Trimm Dependable and Professional headphones.

In 1927, due to the need to provide more space for increasing stock items he shifted to 160 Edward Street where he added Toroid Coil kits, All-American superheterodyne kits, Balkite-Dilecto insulation rods, tubes and sheets; Fanstell-Balkite goods including trickle chargers, A battery chargers, B eliminators, Bull headphones, Casembly four valve kit, Belden Litz wire, loop aerials and many others.

* QUEENSLAND PASTORAL SUPPLIES, BOWEN STREET, BRISBANE

One Queensland business which catered for almost every material need of country people was Queensland Pastoral Supplies which included a Wireless Department in its organisation. The company was sole Queensland agents for English manufactured Burndept Ethophone receivers but also stocked other brands including Astor models. The company had showrooms in Wharf Street where, in 1925, they had on display crystal sets; Burndept Duplex two valve receiver; Hibiscus Special three valve receiver; The Champion four valve receiver; The Champion five valve receiver; Burndept Ethophone Ultra four valve receiver, the same model as supplied to HRH the Prince of Wales in England; Ethovox loudspeakers; seven valve Burndept superheterodyne receiver and others. The seven valve model sold for £125 and was advertised in the showroom as 'A receiver of exceptional quality and performance for those who can afford it'. The company had a list of names of people who purchased this expensive receiver printed on a card and displayed on the showroom wall for all to see. Included in the purchasers were graziers at Dalby, Oakey, Stanthorpe, Emerald, Blackall; company Directors in Toowoomba, Mt Morgan, Gympie and Maryborough; and the owner of a luxury yacht moored in the Brisbane River.

* RADIO MANUFACTURERS LTD, 341 QUEEN STREET, BRISBANE

The company was one of the few radio businesses at the time which specialised in the design and manufacture of receivers for motor cars. It began this operation shortly after 4QG went on air. The company had a strong quality control commitment, selecting only reliable and tested components for receivers because of the harsh environment under which a car receiver operated. They specialised in the installation of receivers for all car models on the road at the time. Most car designers had made no provision for the installation of a radio receiver and not only were there mechanical installation problems to be overcome, but electrical interference was a major problem which had to be solved with each car.

In addition to car receivers, the company put together kit sets for crystal sets; one, two, three, four and five valve receiver designs. Fully assembled crystal sets were marketed under the brand RM and sold well, particularly during 1926–27. It is known that four boys of the Toombul Radio Club assembled crystal sets from kits purchased from Radio Manufacturers Ltd and entered them in a competition held by the Club. Prizes were provided by Arthur Walz who was the proprietor of Walz Radio Equipment Co.

* RADIO PRODUCTS LTD, EWING HOUSE, ADELAIDE STREET, BRISBANE

The business was distributor of Rotorfor receivers including the Rotorfor Five built in a mahogany cabinet with antique finish. A feature of the Rotorfor range of Neutrodyne receivers was incorporation of patented Rotoformers which automatically synchronised all tuning apparatus so that control of the receiver tuning was centred on one dial only.

* RADIO SUPPLIES CO., DENHAM STREET, ROCKHAMPTON

The company were retailers of Supertone receivers, kit sets and components.

* RADIO SUPPLIES UNLIMITED, T&G BUILDING, ALBERT STREET, BRISBANE

In 1927, the main selling lines of the company stock included the Chapin five valve receiver manufactured by Latimers, Sydney. It was sold with a Manhattan Junior loudspeaker. A listener in Bundaberg reported good reception of 4QG and 4GR using one of these receivers with an outside aerial of cage type about 20 metres long and supported by poles 15 metres high.

* HENRY ROBERTS, BRUNSWICK STREET, THE VALLEY

Manufacturer of a range of standard, period and special cabinet designs for radio receivers. Period styles included Jacobean, Queen Anne, Hepplewhite, Chippendale and others.

* RYMOLA RADIO AND ELECTRICAL PTY LTD, 478 QUEEN STREET, BRISBANE

Rymola receivers were popular sets in Brisbane for a period after the Second World War. All designs employed an IF of 453.5 kHz. First models were available in 1946 and by 1948 about 11 designs had been produced. They were all five valve receivers except Model L4B, and AC powered four valve MF band set in mantel cabinet. The only portable produced was Model P5BA, a five valve set. Four of the console models had dual wave band capability.

* THE LAWRENCE AND HANSON ELECTRICAL CO., LTD, 35–37 CHARLOTTE STREET, BRISBANE

In 1925, the company were wholesale distributors of Philips and Sterling products including the full range of Sterling radio receivers and components. Sterling products were manufactured by Sterling Telephone and Electric Co., Ltd, England and receivers stocked by Lawrence and Hanson included crystal set with ebonite panel, variometer tuning and walnut cabinet; Anodion one valve receiver with DER valve; Anodion two valve receiver with DER valves; Threeflex three valve receiver with doors covering the front panel and designed for long distance reception, and the Sterling four valve receiver with compartment under the receiver to accommodate the batteries. The company had one of the Sterling four valve receivers on display in their showrooms before it was purchased by one of the 4QG executives just before Christmas 1925. Sterling components in stock included frame aerials; coils; capacitors; cords; crystals; grid-leaks; headphones; jacks; loudspeakers; potentiometers; rheostats; variometers; HF, LF and power transformers; cat's whiskers and coils of wire.

* THE MUSIC MASTERS RADIO CO., 85–91, STANLEY STREET, SOUTH BRISBANE

The company was founded about 1930 and manufactured a range of receivers under the brand names Beethoven, Chopin, Liszt, Mendelssohn, Mozart and Wagner. They included mains and battery-powered models designed as standard MF band receivers plus dual and triple band types and radiogram units. Cabinets were supplied by Hale and Son, one of Brisbane's premier cabinetmakers.

The year 1945 saw the production of a range of at least 30 models with some of the designs still being released three years later. They were designed for operation with AC, Universal, battery or vibrator/accumulator power supplies and were housed in mantel, console and chairside type cabinets. The Chairside Model A523 was a dual wave five valve receiver. The range included a battery-powered five valve Model C501 receiver.

In 1948, circuit designs employed 1.4 volt filament valves. Receivers produced with this type of valve included Model C503P, a five valve MF band portable receiver; Model C504P, a five valve dual wave band portable receiver; C521, C562 and C563, five valve dual wave band sets in console cabinets.

Six valve receivers manufactured in 1948 included Model A664, a dual wave AC powered console cabinet receiver and Models D662 and D663, dual wave Universal powered sets fitted in console cabinets.

The only seven valve receiver produced was the Beethoven released in 1941. It was an AC powered console cabinet type with triple wave band facility.

Production was scaled down during the early 1950s with the business being sold during the late 1950s. Keith Schleicher one of the receiver assemblers later moved to Tracksons Service Department.

Among the last receivers produced by the company before closure were Music Masters Consolette Radio, a mantel set in a cabinet of rosewood, maple, walnut or ash finishes; Music Masters Automatic Radiogram, a five valve receiver with three speed record player and available in cabinet finishes of camphor laurel, rosewood, maple or walnut; and Music Masters Console Radios with cabinet finishes similar to the Radiogram model.

* THE THOMAS RADIO CO., ADELAIDE STREET, BRISBANE

Thomas Radio Co., were retailers of Pacific Radiophone and Eisemann receivers, and a wide range of components, parts and accessories. The Eisemann receiver was manufactured in the USA by Eisemann Magneto Corporation who began production of radio receivers in 1923 but abandoned the radio part of the business two years later to concentrate on magneto manufacture. Thomas Radio sold many of the three valve models particularly to country customers with three being sent in one consignment to Shultz Brothers, farmers in Esk, just out from Ipswich. The receiver had an RF stage, a detector and an AF stage. They were sold with a Majestic loudspeaker, a large unit made of unbreakable Pyrilin with a 14 inch (350 mm) diameter horn. The loudspeaker was mounted on top of the solid mahogany receiver cabinet.

Thomas Radio provided a free valve and battery testing service which enticed many potential customers into the shop.

* TRACKSON BROS PTY LTD, 157–159 ELIZABETH STREET, BRISBANE

The business operated as Electrical Engineers and Radio Merchants in premises facing the Regent Theatre. It was one of the early Engineering businesses in Brisbane being established in 1883 as a private company. It became a public company about 1936 at which time company Directors were Phil Trackson, J Trackson and A A Ewing with Phil Trackson being Managing Director. Phil was an Associate Member of The Institution of Radio Engineers (Australia) and in 1933 was President, Radio Traders Section of the Electrical Federation of Queensland. During 1934, he was a member of the Electrical Workers Board, Uniform Wiring Rules Committee and Group Apprenticeship Committee. Phil came to Australia in 1894 to join his brother as Electrical Engineer in business.

During 1927, Tracksons released a range of receivers imported from Kodel Manufacturing Co., USA. They included crystal sets, one valve receiver Model 11 with regeneration; two valve receiver Model C12, with single dial tuning; three valve receiver Model C13 employing reflex amplification and four valve receiver Model C14 with battery compartment below the receiver unit.

At the time of the Radio and Electrical Exhibition at Bohemia Theatre, South Brisbane in July 1928, Tracksons mounted a giant Exhibition Radio Sale giving attractive discounts on receivers and components. Included in receivers sold during the sale were crystal sets, one valve Hinkler, Hyatt six valve portable, Trav-Ler five valve portable, FADA five valve Neutrodyne receiver, Apex Super Five valve receiver, Peto Scott five valve Solodyne receiver, Ambarola six valve receiver and World five valve receiver.

Only one Apex Super Five receiver was sold during the period. It was purchased through Mail Order by a grazier at Quorn, north of Port Augusta in South Australia. The owner was a member of the Quorn Radio Society, one of the early Radio Clubs in South Australia when it was formed on 25 August 1924. The receiver was subsequently donated to the radio collection of the Telecommunications Museum, Adelaide.

In 1929, the company was Queensland distributor for Wetless radio products which at the time included well-known lines such as RF chokes, Neutrodyne three coil kits with neutralising capacitors, Reinartz tuner, rotor tuner, Browning-Drake kit with neutralising capacitor, double rotor tuner, a range of midget variable capacitors and A and B series fixed mica capacitors.

In 1930, the kit set for the Simplicity Three receiver was one of Tracksons popular lines. It was available as parts only, mounted on chassis but not wired, or as completely wired chassis. A cabinet was available as a separate item. The set was designed and manufactured by Evans Electrical Co., Ipswich.

Company policy was to provide friendly and helpful service, particularly to young radio enthusiasts who may have required assistance in their hobby. Two well-known counter staff were Bob Yorston and Jack Edgar both popular in Brisbane radio circles. Jack worked for Tracksons for some 46 years. Keith Schleicher in charge of the Service Department for some 11 years was also a well-known employee.

* THE PONTYNEN RADIO MANUFACTURING CO., REGENT STREET, SOUTH BRISBANE

The company manufactured a range of receivers in the late 1920s with the Pontynen Three and the Pontynen Screen Grid

Four being the most popular as far as sales figures were concerned during 1927.

Receivers incorporated a tuning unit developed by the company to provide high selectivity enabling Sydney stations to be heard in Brisbane without interference from the local A Class station and Amateur broadcasters. The tuning unit was sold as an independent unit to other manufacturers for incorporation in their models. Experts who tested the unit reported that it made a TRF receiver as selective and sensitive as a superheterodyne receiver.

* UNITED DISTRIBUTORS LTD, 343 QUEEN STREET, BRISBANE

The company were distributors of Udisco receivers manufactured by the company factory in Sydney, Signal receiver kit sets and a large stock of components, particularly Frost and Signal brands. In 1927, the Udisco Eight Super-neut was one of the best lines sold to country clients. One was sold to the Postmaster at Barcaldine in Central Queensland in December 1927. In a letter to the Brisbane Manager of United Distributors, the Postmaster advised that he had received every one of the 20 Australian broadcasting stations licensed at the time.

The aerial was erected by the district Telephone Linesman using old telephone poles about 10 m high supporting an inverted L type aerial.

* WIRELESS CENTRE, ADELAIDE STREET, BRISBANE

One of the major lines of Wireless Centre during 1926–27 was the Elliott Three, a receiver with outstanding performance characteristics designed by Tom Elliott one of Brisbane's foremost Amateur broadcasters and television experimenter at the time with his station OA4CM. During the Christmas trading period of 1926, more than 100 Elliott Three receivers were sold with the majority being purchased by country listeners as far west as Quilpie and as far north as Thursday Island. The workshop where the receivers were assembled was located opposite the Normal School and the company claimed that it was the largest radio workshop in the State. Tom Elliott was in charge of the facility.

* WIRELESS HOUSE LTD, CITY BUILDINGS, EDWARD STREET, BRISBANE

The company advertised itself as the 'Queensland Pioneer Radio House'. It was originally established in a small shop next to Finneys in Adelaide Street by John Price on 7 November 1922, three years before the first A Class station 4QG was commissioned. During 1924, the business was moved further along Adelaide Street to premises opposite the Normal School. In December of that year, it became a Limited company.

During the first week in September 1926, the business was relocated to City Buildings, Edward Street.

During the 1925 Election, the company received considerable publicity when it set up a Dulcephone Three receiver feeding a power amplifier to enable a huge crowd estimated to be in excess of 5000 who thronged the city to hear a broadcast of the progress in counting of the votes. Three large loudspeakers were mounted on the balcony of The Daily Mail office and the receiver tuned to 4QG which provided a program of music from the studio in between comments on the results of counting. The demonstration began at 7 pm on 14 November and went until 1 am the following morning with the volume and clarity being praised by the people.

The company stocked a full range of Dulcephone brand receivers with all the valve models being housed in polished rosewood cabinets. The range included Boys Own crystal sets with slide or variometer tuning; a De Luxe crystal set in a leatherette case; one valve receiver; two valve receiver with detector and AF amplifier stages; three valve receiver capable of receiving Sydney stations at loudspeaker strength; four valve receiver constructer with Browning-Drake circuit and designed for the country listener, and a five valve De Luxe receiver with a specially designed three stage amplifier producing high fidelity performance. A wide selection of components was stocked and included Mello, Scientific, Brandes and Trimm Dependable headphones; Neutron, Hertzite, NHM galena and Ajax crystals; phosphor bronze, silver, gold and steel cat's whiskers; Newey, Tunup and New York variable capacitors and others.

The larger premises available in City Buildings, enabled the company to stock other brands of receivers and components. These included Crosley and RCA receivers, both of USA manufacture, and Igranic Superheterodyne kit set. The Igranic kit set, a six valve receiver, was also sold in a fully assembled form.

The RCA models included the Model 20 a five valve balanced TRF receiver with the additional feature of variable regeneration in the detector circuit; Model 25 a six valve model featuring the second harmonic six valve superheterodyne circuit equipped with Radiotron UX120 dry cell valves, and the Model 28 an eight valve superheterodyne desk model supplied with loop aerial mounted on top of the cabinet. This latter model was employed as a demonstration model on the shop counter for about a year until presented as a gift to one of the female staff who left to be married.

John Price who founded the company went to England after completing schooling in Brisbane to study Electrical Engineering at the City and Guilds College, London. On return to Australia, he took up an appointment with the Postmaster General's Department where he worked for 15 years occupying a number of important positions, including Assistant Engineer Telephone Equipment, from 1913 until 1922 when he left to set up his own business.

As no parts were available locally, he travelled to Sydney to purchase stock to set up the business.

He subsequently left Wireless House Ltd and in 1929, began business in Perry House, Elizabeth Street trading as J C Price. He was Queensland Sales representative for New System products, Acme B battery eliminators, Operadio loudspeakers and distributor for Burgess batteries and Philips products. The business was still in operation in the mid 1930s.

In order to improve their share of the large radio trade, a group of radio, electrical and musical firms and a magazine publisher, sponsored an hour long musical session broadcast by station 4BK Brisbane. The scheme was an initiative of the management of Edgar V Hudson Ltd and King and King joint proprietors of 4BK, and themselves engaged in the radio and musical industries respectively.

In September 1931, the firms sponsoring the program were:

Clyde Engineering Co., Ltd, Clyde and Simplex batteries, Albert Street; Evans Electrical Co., Electrical and Radio Merchants, Brisbane Street, Ipswich; Exide Battery Service Co., Radio and car batteries, Adelaide Street; J R Foster, Radio Trader, Elizabeth Street; J T Greenlees and Co., 'Queen' radio receivers; Harringtons Ltd, Radio dealers and merchants, Queen Street; A Hall and Co., 'Aerola' receivers, Adelaide Street; E A Holt, Electrical and Radio Store, Stanley Street; Edgar V Hudson Ltd, Radio Merchants, Charlotte Street; King and King Ltd, Musical Warehouse, Queen Street; National Radio Corp., Radio Merchants, Adelaide Street; Noyes Bros, Electrical and Radio Merchants, Elizabeth Street; W H Paling and Co., Ltd, Musical Warehouse, Queen Street; W E Peterman, Electrical and Radio Merchant, Edward Street; Philips Lamps (A/Asia) Ltd, Radio valves, receivers and components, Elizabeth Street; Queensland Motors Ltd, 'JCA' radio receivers, Adelaide Street; Radio Supplies Unlimited, Radio Sales and Service, Albert Street; Read Press 'Queensland Radio News', Adelaide Street; The Lawrence and Hanson Electric Co., Ltd, Electrical and Radio Merchants, Elizabeth Street; Vocalian (Aust.) Ltd, Gramophone and Record Merchants, Edward Street.

By about 1936, many early established organisations had ceased operation in Queensland while others entered the radio business as radio dealers, traders or receiver servicing operations. Members of Radio Traders Section of the Electrical and Radio Federation (Qld) included:

Air-Master Radio Co.; Australian General Electric Ltd; W O Barber; Bush and Co.; J B Chandler and Co.; Crammond Radio Manufacturing Co.; Eclipse Radio Co., Ltd; J R Foster; J T Greenlees and Co.; G J Grice Ltd; A E Harrold; Edgar V Hudson Ltd; Irvine Radio and Electrical Co.; King and King; W A Malloy; Music Masters Radio Co.; National Radio Corp.; Noyes Bros Ltd; Radio Corporation Ltd; The Lawrence and Hanson Electric Co. (Qld), Ltd; F Tritton Pty Ltd; and Vesta Battery Co., Ltd.

Other prominent traders of the period included:

Fields Radio and Cycles, Mackay; E A Holt; Hopper Bros; J C Price; Rogers and King, Goondiwindi; R Rose, Longreach; Rosentengels Pty Ltd, Toowoomba; Rymola Radio and Electrical Pty Ltd and others.

Country towns still had their fair share of radio Retailers and Servicemen after the War years particularly during the 1950–60s.

Maryborough is typical where well-known businesses associated with the broadcasting industry included:

* Andersen's Music Store, 148 Adelaide Street — Breville, STC.
* Bruce Small, 166 Adelaide Street — Kriesler, Breville, Astor.
* Arch Caswell, 276 Kent Street — Astor, Tasma.
* Chandler-Wynne, Adelaide and Kent Streets — Radiola, Kriesler.
* Denradio Industries, Adelaide Street — Denradio, Kriesler.
* Keers Radio Service, Adelaide Street — Philips, Kriesler.
* Geo King, Kent Street — Kriesler.
* Ray Nelmes, 158 Adelaide Street — Kriesler.
* R G Sprake and Co., 92 Ellena Street — Paling Victor.
* Wests Radio Service, Richmond Street — Kriesler.
* W H Wilcox, Kent Street — STC.

Included among the many well-known individuals associated with Radio Dealership or Servicing operations were: Eric Ashlin in charge of Rosentengels Furniture Store, Toowoomba until he joined the RAAF as Signals Officer during the Second World War; Frank Barraclough employed in Radio Service Department of Palings Music House, Brisbane before Second World War; Sid Baxter in charge of Trittons Radio Service Department until he established his own radio and TV business at Carina; Patrick Golden, Salesman at Trackson Bros, and tireless worker with the Wynnum Manly Radio Club established in 1926; Cliff Couchman employed as Technician at NBS 10 kW station 4QS Dalby until he left to establish his own electrical and radio business in Dalby; Jack Heine employed by Eclipse Radio and after War service worked in the Radio Service Department of Bush and Co., Brisbane; Vince Jeffs worked for Crammond Radio Manufacturing Co., on design and service duties during the War and later setting up his own business, Jeffs Radio in The Valley; Bob Meadows employed as Radio Serviceman with Pems Radio, Rockhampton until the War, after which he moved to Sydney to become Technical Editor of a well-known electrical magazine; Arthur Minchin a former Chief Engineer of 4RO Rockhampton and proprietor of Minchins Radio Service, Rockhampton from 1937; Bill Petersen and Dave Ainstey, partners in Advance Radio Sales and Service, Stones Corner with Bill later establishing Wynnum Radio Repairs, a Radio Service business at the bayside suburb of Wynnum; Merv Wratten Manager Radio Section of Cribb and Foote, Ipswich and later, Manager and owner of Avon Theatre.

* TASMANIA

For its size, Tasmania was well served by broadcasting stations to the end of the 1930s. Stations on air included 7ZL Hobart, 1924; 7HO Hobart, 1930; 7LA Launceston, 1930; 7UV Ulverstone, 1932; 7NT Kelso, 1935; 7BU Burnie, 1935; 7HT Hobart, 1937; 7QT Queenstown, 1937; 7EX Launceston, 1938; 7DY Derby, 1938 and 7ZR Hobart, 1938. Listeners licences just prior to the outbreak of the Second World War in 1939 numbered 12800 in the Metropolitan area, and 25900 in the country areas. Overall 71% of the population possessed licences and many outlets for sale and servicing the receivers were in operation. A small number of businesses manufactured or assembled receivers locally, but the majority relied on imports from the mainland.

Early radio businesses in Tasmania included:

* AMPLION (AUST.) LTD
  Amplion loudspeakers.
* C C BOAG BATTERIES
  Breville receivers, batteries and a range of components.
* WILLIAM BUCKLAND PTY LTD
  Airmaster and Celebrity receivers, components and accessories.
* BRITISH GENERAL ELECTRIC CO.
  Genalex, Gecophone receivers and battery chargers.
* BURROWS AND MEEK PTY LTD
  Wholesalers of a range of radio receivers and components. The firm operated a radio service outlet with Chief Mechanic R H Drake and Assistant H Burke.
* EASTERN TRADING CO., LTD
  Ken Rad valves, electrolytic capacitors and a wide range of components and accessories.
* FINDLAY BROS
  Distributors of Audiola, Radiola and Stromberg-Carlson receivers, components and accessories.
* W AND G GENDERS PTY LTD
  The company was based in Launceston with a branch in Hobart. Main stock included STC receivers; Rola loudspeakers; Crown Radio products; Vesta batteries; Chancery, Chanex, Dylytic, Jubilee and IRC components; and many other brands of components and accessories. Managing Director was E B Genders, and Manager of the Radio and Electrical Department was H W Hallet.
* HARRINGTONS LTD
  Raycophone, Impera and Gilfillan receivers; AWA products; Radiotron valves; Columbia batteries; Grodan products; Amplion loudspeakers; kit sets for battery receivers and crystal sets; Philips valves, loudspeakers and transformers; Warren and Front headphones; All-American AF transformers.
* HOWARD RADIO PTY LTD
  Howard and Mullard receivers, Diamond batteries, Garrard products, components and accessories.
* CHARLES IRVINE
  Healing receivers, components and accessories.
* LOVETTS RADIO
  Proprietor Leonard Lovett, was one of the first to establish a radio business in Hobart, having set up an Electrical business in Bathurst Street, Hobart in 1920. The firm stocked a range of receivers, an extensive range of components and accessories, and also provided a Radio Service group for servicing receivers throughout the State.
* MCCANN BROS
  New System Telephone receivers.
* V MCDONALD-BRAME
  Marquis moulded radio products.
* MEDHURST AND SONS PTY LTD
  Airzone receivers, components and accessories.
* NOYES BROS
  Tasma, Seyon, STC and Slade receivers; Calstan meters and test instruments, Igranic kit sets and components; Philips valves.
* PETERS BROS
  Eclipse products, Scientific variable capacitors, Kenyon AF transformers, Kelford cushion valve sockets, Parker Aeolus valve sockets.
* RADIO CORPORATION PTY LTD
  Astor, Monarch, Mickey Mouse receivers; car receivers; component parts and accessories.
* J SMITH
  Hotpoint receivers, accessories.
* THE LAWRENCE AND HANSON ELECTRICAL CO., LTD
  Lekmek and Philips receivers; Philips valves and AF transformers; Paton instruments; Melovox and other Sterling loudspeakers, headphones; components.
* W G WATSON AND CO., LTD
  Lekmek receivers and kit sets; Cossor and Philips valves; components and accessories.

* WILLS AND CO., PTY LTD
Audiola and Stromberg-Carlson receivers; kit sets; Amplion and other brands of loudspeakers; Radiotron and Philips valves; Diamond batteries.

MORE RECENT ORGANISATIONS

Many of the early organisations no longer exist, their place being taken by others in subsequent years to meet the demands of an active broadcasting market.

In the manufacture of a broadcast transmitter, even the large firms were dependent upon many outside organisations for the supply of components, parts or services. As an example, when Commonwealth Electronics Pty Ltd manufactured their 2.5 kW transmitter type MFT8/2500 during 1965, suppliers who provided components and materials included the following:

* COMMONWEALTH ELECTRONICS PTY LTD, BAULKHAM HILLS.
Capacitors, modulation coupling filters, feed and tuning inductors, aerial changeover contactor, sockets, RF line current meter, valves.
* A E ACKLAND PTY LTD, SYDNEY.
Remote control locks.
* AERONAUTICAL PTY LTD, SYDNEY.
Connectors.
* AMALGAMATED WIRELESS (A/ASIA) LTD, SYDNEY.
Frequency determining crystals.
* AMALGAMATED WIRELESS VALVE CO., PTY LTD, RYDALMERE.
Silicon transistors, valves.
* AUSTRALIAN ELECTRICAL INDUSTRIES PTY LTD, SYDNEY.
Components.
* A W BARRS PTY LTD, SYDNEY.
Components.
* BELLING AND LEE (AUST.) PTY LTD, BURWOOD.
Cartridge fuses, fuse holders.
* F W BRIMSMEAD PTY LTD, MARRICKVILLE.
Fans.
* BRITISH GENERAL ELECTRIC CO., PTY LTD, SYDNEY.
Fuses.
* BRITISH MERCHANDISING PTY LTD, SYDNEY.
Trimming capacitors.
* CANNON PLUGS PTY LTD, MASCOT.
Semi-conductor rectifiers, panel jacks.
* CARR FASTENER CO., OF AUSTRALIA LTD, PETERSHAM.
Fasteners.
* CLIFF & BUNTING PTY LTD, MELBOURNE.
Trimax AF transformers.
* COULTER B W AND CO., SYDNEY.
Contactors.
* R H CUNNINGHAM PTY LTD, CHATSWOOD.
Indicator lampholders.
* W G CROSSLE AND CO., PTY LTD, SYDNEY.
Air blowers.
* DUCON CONDENSER PTY LTD, VILLAWOOD.
Filter, bypass, coupling, feedback, compensation and tuning capacitors, wirewound vitreous resistors, wirewound variable resistors.
* ELECTRICAL EQUIPMENT OF AUSTRALIA PTY LTD, SYDNEY.
Door and interlock switches.
* ELECTRONIC TRANSFORMERS PTY LTD, BROOKVALE.
AF transformers.
* ELEMENT SPECIALIST AND MANUFACTURING CO., GUILDFORD.
Starting resistors, artificial aerial resistor cards.
* ENGLISH ELECTRIC CO., LTD, SYDNEY.
Fuse holders.
* L M ERICCSON PTY LTD, NORTH COBURG.
Impedance matching transformers.
* FERGUSON TRANSFORMERS PTY LTD, CHATSWOOD.
Transformers.
* GENERAL ELECTRONIC SERVICES PTY LTD, LIDCOMBE.
Semi-conductor bias rectifier.
* HAROLD J GILBERT, CONCORD.
Airflow interlock.
* HONEYWELL PTY LTD, SYDNEY.
Switches.
* INTERNATIONAL RESISTANCE CO. (A/ASIA), PTY LTD, KINGSGROVE.
Primary surge damper, wirewound resistors, bleed resistors, dividers, multiple resistors.
* JACOBY MITCHELL AND CO., PTY LTD, SYDNEY.
Instruments and components.
* LAVENDER ENGINEERING PTY LTD, GUILDFORD.
HRC and cartridge fuses.
* LAWRENCE AND HANSON ELECTRICAL PTY LTD, ZETLAND.
Insulated wire.
* LORIMER CONTACTS PTY LTD, TURRELLA.
Relay contacts.
* MANUFACTURERS SPECIAL PRODUCTS PTY LTD, SYDNEY.
Toggle switches.
* MASTER INSTRUMENTS PTY LTD, MARRICKVILLE.
Meters, multiplier resistors.
* MINIWATT (DIVISION OF PHILIPS ELECTRICAL INDUSTRIES), ARTARMON.
Capacitors, carbon resistors.
* MORGANITE AUST. PTY LTD, ALEXANDRIA.
Variable carbon resistors, fixed carbon resistors.
* MULLARD – AUSTRALIA PTY LTD, SYDNEY.
Permeability tuner, silicon diode, transistors, valves, voltage supply stabilisers.
* W J MCLELLAN AND CO., PTY LTD, KINGSGROVE.
Lamp indicators.
* NATIONAL AUTOMOTIVE SERVICE, DANDENONG.
Germanium transistors.
* NATIONAL TRANSFORMERS PTY LTD, KINGSGROVE.
Transformers.
* R K OLIVER PTY LTD, WEST DEE WHY.
Power filter inductors, power supply transformers, modulation transformer and reactor, filament transformers.
* PAINTON AUST. PTY LTD, CHATSWOOD.
Components.
* PATON ELECTRICAL PTY LTD, ASHFIELD.
Meter switches, meters, crystal selector switches.
* PHILIPS INDUSTRIES PTY LTD, SYDNEY.
Relays, indicators.
* PIONEER AERIALS PTY LTD, RUSHCUTTERS BAY.
Coaxial switch.
* PYE PTY LTD, CLAYTON.
Plugs and sockets.
* RELAYS PTY LTD, FIVEDOCK.
Relays.
* E S RUBIN AND CO., PTY LTD, ARTARMON.
Lampholders, push button switches.
* GEO. H SAMPLE AND SON PTY LTD, CHIPPENDALE.
Meters.
* SIEMENS HALSKE, SIEMENS SCHUCKERT (A/ASIA) PTY LTD, NORTH SYDNEY.
Elapsed time register, contactors.
* SINTER PTY LTD, SYDNEY.
Components.
* S SMITH AND SONS (AUST.) PTY LTD, GRANVILLE.
* STABILOC PTY LTD, KINGSGROVE.
Filament regulators.
* STANDARD TELEPHONES AND CABLES PTY LTD, ALEXANDRIA.
Silicon controlled rectifiers, relays, silicon unijunction transistors.
* TELECON AUSTRALIA PTY LTD, ALEXANDRIA.
Cables.
* TELEPHONE AND ELECTRICAL INDUSTRIES PTY LTD, MEADOWBANK.
Relays.

* TELEPHONE MANUFACTURING CO., PTY LTD, ANNANDALE.
  Telephone equipment.
* TEXAS INSTRUMENTS AUSTRALIA LTD, ELIZABETH.
  Connectors.
* TRANSMISSION PRODUCTS PTY LTD, NORTH SYDNEY.
  AF monitor.
* UNITED CAPACITOR CO., PTY LTD, BELFIELD.
  Capacitors.
* VOKES AUSTRALIA PTY LTD, ROCKDALE.
  Air filter.
* WARBURTON FRANKI LTD, SYDNEY.
  Circuit breakers.
* WATKIN WYNNE PTY LTD, CROWS NEST.
* WELWYN ELECTRIC CO., MASCOT.
  Metal oxide resistors, wirewound resistors.
* WESTINGHOUSE ROSEBERY PTY LTD, WATERLOO.
  Circuit breakers.

With the large industry associated with the design, development, manufacture, distribution and sale of broadcast transmitters, receivers and components for many years, now only a memory to many people, requirements of today's broadcasters and the public are in the hands of a great many organisations specialising in the marketing of systems, equipment and components, the majority of which are of overseas origin.

In 1997, organisations included:

* TRANSMITTERS AND STUDIO EQUIPMENT
  Advanced Automation Australia; Amber Technology Pty Ltd; Amtec Australia; AR Audio Engineering Pty Ltd; AFRC Pty Ltd; Australian Broadcasting Services; AV Communications; Broadcast Services Australia; Comsyst Pty Ltd; Innes Corporation Pty Ltd; Intertan Australia Pty Ltd; IRT Electronics Pty Ltd; Jands Electronics Pty Ltd; JNS Electronics Industries; NEC Australia Pty Ltd; Philips BTS; QASAR Communications Pty Ltd; Syntec International Pty Ltd; Techtronix Australia; Thomson CSF; Yamaha Music Australia and many others.
* RECEIVERS INCLUDING HI-FI SYSTEMS
  Akai Pty; Bang and Olufsen (Aust.) Pty Ltd; Bose Pty Ltd; Breville Australia Pty Ltd; Kenwood Electronics Aust., Pty Ltd; Mitsubishi Australia Pty Ltd; Panasonic Australia Pty Ltd; Pioneer Electronics Australia Pty Ltd; Samsung Electronics Australia Pty Ltd; Sanyo Australia Pty Ltd; Sharp Corporation Australia Pty Ltd; Sony (Aust.) Ltd; Strathfield Car Radios Pty Ltd; TEAC Australia Pty Ltd and many others.
* COMPONENTS
  Altronics Distributors Pty Ltd; AWA Distribution; Dick Smith Electronics Ltd; Eveready Australia Pty Ltd; Philips Electronics Australia Ltd; Plessey-Ducon; RCS Radio Pty Ltd, Tandy Electronics, and many others.

COMPONENT MANUFACTURE

Nearly every item of radio equipment is built up of components with some items requiring only a few components while large complex units may involve thousands. The power handling capacity of a particular component might range from microwatts for receivers to megawatts for transmitters.

Even before the advent of broadcasting, there was a high demand for experimenters and others for radio components, and although many experimenters made their own, specialist factories were established overseas to meet the worldwide demand. Australia was also in the production field with Amalgamated Wireless (A/Asia) Ltd, being the major supplier not only to meet its own internal requirements, but to supply the public. By 1937, the company was manufacturing some 60 million parts and components for receivers.

Components incorporating resistance, inductance and capacitance had been developed well before wireless. Telegraphy, telephony and electric power all needed components with such characteristics. Carbon composition resistors had been produced overseas as early as 1885 and the first inductor for radio purposes in 1887 by Hertz when he carried out his famous experiments.

Even before the First World War, Australian industry became involved in the manufacture of wireless components when the Reverend Father Shaw and another partner established the Maritime Wireless Company in Sydney to manufacture equipment for the establishment of a network of Coast Radio Stations.

However, it was the First World War which marked the real starting point in the development of radio components assuming roughly the form that we know them today. Having satisfied the needs of the Military during the War years, manufacturers worldwide began to direct their effort to meet the expanding needs of experimenters, particularly discharged Servicemen who had been trained in Wireless Technology, and the emerging broadcasting industry.

With the establishment of broadcasting in Great Britain and the USA in the early 1920s, many component manufacturers began to specialise in individual components for the home constructor.

Catalogues began to flood the market with one British catalogue comprising 308 pages. There was a bewildering range of components offered. For example, in coils alone, the range included basket, plug-in, formers, changing unit, holders, basket holder, mounts, plugs, socket switch, tapped anode, tuned, slider coils, loose coupled coils, variometer, gimbal mounted coils, magnum coil, duo-lateral coil, double layer tapped coil, capstan coil holder, resistance coils and many others.

The most widely employed components in their various forms can be classified under the headings Resistors, Capacitors and Inductors.

• RESISTORS

Resistors are the most widely employed component in transmitters and receivers, but until about 1930, the fixed resistor in particular, occupied a position of unimportance in radio work. The types employed were mostly of the carbon coated paper and the metallised types. Their most important applications was as grid-leaks and anode loads. In 1925, typical brands listed in Australian catalogues included Aerovox, Amsco, Bradley, Carter, Dubilier, Electrad, Firth, Magnus, Ohmite, Watmel and others.

By 1930, a number of small companies which specialised in the manufacture of fixed resistors were in operation. Two brands were Renrade resistors manufactured by R W Reynolds Ltd, Chalmers Street, Sydney, and Radion resistors made by George Habel of Hyde Park, Adelaide. The resistive film on early resistors was extremely thin and had to be protected against damage by handling and moisture absorption. Both these organisations tackled the problem by enclosing the element in a glass ceramic tube and sealing the ends by soldering or with a suitable compound. In these resistors, the element comprised carbon deposited on the inner of a glass tube with the carbon film thickness determining the resistance value.

Another technique was to pass each tube past a nozzle that automatically sprayed the element mixture onto the glass. The resistor was baked in an oven to ensure constancy of the element and after cooling, bands and pigtails were attached. Final treatment was to dip the element in a ceramic mixture and bake it, followed by value identification colour.

Over the next 20 years, carbon resistors were produced as either insulated or non-insulated types, while the resistance material was either composition or cracked carbon for high stability. The material was in the form of solid rod or as a film. Wire wound types used nichrome, constantan, manganin or eureka wire.

Typical carbon resistors comprised a ceramic tube on which a special carbon mixture was deposited by either an evaporating process or immersion.

The carbon coated tubes were baked in an oven then sorted into groups of specified resistance values. A fine emery wheel was used to cut a spiral shaped groove in the carbon coating in order to match each resistor to a standard. Pigtails were then fitted to both ends of the resistor body and a coating of lacquer applied. Typical power ratings were ¼ W, ½ W, 1 W and 3 W.

By about the mid 1950s, carbon resistors were manufactured in a standard range of values. A feature of the range was that each successive value of resistance was about 10% higher than the preceding one.

The principal means of indicating resistance value was by means of a colour code or numbers followed by letters. Philips resistors employed the latter system.

By the mid 1930s, there were at least 70 companies in Australia involved in the manufacture or distribution of fixed and variable resistors or rheostats. The major Australian manufacturers included Crown Radio Manufacturing Co.; Ducon Condenser Pty Ltd; Wm J McLellan; R W Reynolds Ltd and RCS Radio.

An unusual resistor of the early 1930s, was the spaghetti resistor. It was a flexible type consisting of a core of asbestos string, round which was wound resistance wire. The ends of the winding were clamped to connecting lugs and the winding covered with insulating sleeving. Harris Scarfe Ltd of Adelaide was one store which carried stocks of this type in their Radio Department.

With the advent of AC/DC receivers there was a requirement for a resistors which had a high negative temperature coefficient in order to limit the initial current surge in the filament circuit. It was common practice to connect the filaments and dial lamp in series, sometimes with an additional resistor. Because the valve filament resistance to the initial current was only about one seventh to one tenth that at the normal operating temperature the current surge often resulted in burn-out of the dial lamp.

To overcome the problem, a Negative Temperature Coefficient (NTC) resistor was connected in series with the filament circuit. Its resistance characteristic was the reverse of the filament behaviour, with a typical resistance being a value of about 3000 ohms at average room temperature (20°C) and dropping to about 200 ohms when warm (120–150°C).

Variable resistances in the form of rheostats and potentiometers were available in a wide range of resistance values, power ratings and construction arrangements.

Rheostats found their greatest application for controlling the filament voltages applied to valves in battery receivers. Typical types available from Radio Shops in the mid 1920s included Acme filament rheostat featuring a roller contact with spring arm, available as 15 ohm and 30 ohm units; Peerless dual rheostat designed to provide for both bright and dull emitter valves, employed two windings, one of a resistance of 6 ohms and a continuation of this to a 30 ohm winding wound on a hard fibre strip; Gambrell rheostat designed with contact fixed, and the resistance element, which was wound on a porcelain block, moveable; General Radio compression rheostat, a stepless, noiseless unit which provided a smooth working micrometer adjustment; Interchangeable rheostat using replacement resistance cartridge elements to provide any value 6–10 or 30 ohms; Oojah, a graphite pile rheostat variable from 0.15 to 40 ohms providing almost infinite adjustment between these values; Lissen made patterns of 7 ohms, 35 ohms and dual, fitted with combined knob and pointer and photo engraved dial plate; Ellanpee vernier rheostat with resistance value 6.5 ohms and current capacity 0.75 amperes; MH filament rheostat produced as single, dual and triple type units with the resistance element being supported on the circumference; Cosmos with resistance wire wound on porcelain bobbin and obtainable as single or dual units to enable use with bright or dull emitter valves; Sterling interchangeable rheostat consisting of rotary switch holder and two cartridge type resistances covering requirements of bright and dull emitter valves; Woodhall vernier rheostat, a cylindrical type wound with an enamelled resistance wire on an ebonite former and employing a combined plunger and rotary movement to provide push-pull movement for coarse setting, and rotary for vernier.

Other brands of rheostats in use at the time and available from Adelaide Radio Company Ltd, Mackenzie and Maddern and Harringtons Ltd in Adelaide, included Advance, Bretwood, CAV, Ashdown, Atlas, Ericsson, RI, Climax, Chakophone, De Forest, EMC, Fortevox, Frost, Fullers, Gecophone, Gilfillan, Goldtone, H&B, Igranic, Magnus, Mastastat, Mullard, Nutmeg, Ormond, Polar, Pye, Seaford, Service, Un-X-Ld, Wates and others.

Potentiometers during the 1920s were used for controlling grid bias in many receiver designs. Values ranged from 300 ohms to about 40000 ohms for typical units. Brands included Centralab, Climax, EMC, Gecophone, Igranic, Marconiphone, Lissen, HH, Penton, Powertest, Silvertown, Sterling and others.

By the mid 1930s, with the introduction of more advanced receiver circuit technology, the term 'volume control' became more widely applied with typical units embodying a graphite resistance element on a smooth surface over which a contact arm was made to glide to produce minimum noise and ensuring a flowing, stepless gradation of effective volume control. A long metal arm was often provided, and this was cut to the appropriate length to suit chassis/cabinet requirement. Some incorporated an on/off power switch. Popular brands of the period included Bradleymeter, CRL, Ferranti, IRC, Marquis, M&M, Microhm, Radiokes, Saxon, Yaxley and others.

Today, potentiometers usually referred to as 'pots' are available in a range of types and sizes with emphasis on miniaturisation to meet the needs of solid state technology designs. They include single gang rotary, single gang with switch, dual gang rotary, special function, vertical format, trim pots, horizontal trim pots, slider pot and others. Rotary pots are available in both linear and logarithmic formats in typical values of 10k, 20k, 50k, 100k, 500k and 1M ohms.

Resistors make up a considerable percentage of components in a broadcast transmitter. In a typical 2.5 kW MF transmitter manufactured in Australia in the mid 1960s, over 200 resistors were employed. Power handling capability ranged up to 1000 watts and resistance values varied from a few ohms to several megohms. Types included wire wound on cylinders, wire wound on cards, wire wound vitreous, fixed carbon, variable carbon, variable wire wound, metal oxide, metallised and others.

With wire wound resistors, a resistance wire was wound on an insulating form which could take many forms. In ceramic types, grooved formers were usually employed. The wire was coated with a material such as vitreous enamel, a protective silicone coating, cement or other insulating sealant.

Housed wire wound resistors were a comparatively recent development. The resistive element was moulded in a finned anodised aluminium housing which acted as a heat sink giving complete environmental protection and high stability under load. They were usually screw mounted to the chassis for additional heat sink effect.

For circuit board application, individual chip resistors could be produced using thick film technology. Thick film networks competed with the cheapest film resistors and had the advantage that all resistors in the network were printed on one substrate and therefore shared a common environment.

• CAPACITORS

Capacitors (or condensers as they were originally called) were available in a wide range of types and included fixed, electrolytic, neutrodyne, variable and vernier. Within these types there were compression, grid-leak CR combination, straight line capacity, straight line wavelength, straight line frequency, midget variable, padder, trimmer, ganged variable, semi-circular variable, variable tubular, bracket, spiral cam and others.

Capacitors perform a variety of functions in broadcast equipment. These include circuit tuning, bypassing, filtering, DC blocking and in the case of some large early transmitting stations, as power factor correction devices.

For many years, types known as paper capacitors were widely employed. They used various waxes and oils in their construction including paraffin wax, petroleum jelly, castor oil and mineral oil. They were usually sealed in metal cans to keep out moisture. It was not unusual for capacitors of different values to be enclosed in a single metal container with multiple terminals to cater for the various capacitance values.

Types with mica sheets as dielectric were also used being employed in the early wireless telegraphy era. They were more efficient and reliable than paper types but were more expensive. Moulded types became available in the 1920s and were an improvement on the unprotected sandwich types by preventing moisture from entering the unit.

The invention of the mica dielectric capacitor about 1915 by William Dubilier in the USA was a milestone in Radio Technology. Dubilier was a pioneer in high voltage capacitors employing mica as the dielectric for use in spark transmitters and later, valve transmitters during the First World War. Capacitors produced by his company were referred to as the 'Rolls Royce' in their field, and replaced the cumbersome Leyden glass jars in transmitters.

So successful were his mica capacitors, that the British Government encouraged him to establish a factory in England to manufacture capacitors for home receivers and transmitters. The Dubilier Condenser Co., Ltd was established in 1921 in England, and the Radio Department of Harris Scarfe Ltd in Adelaide was one of the early Radio Shops in Australia to import Dubilier capacitors from the English factory.

Included in the stock were:

- Types 600 and 600A designed for use in receivers. The type 600 was provided with soldering tags and fitted with or without clips for grid-leak. The type 600A was designed to mount in a vertical position.
- Types 610 and 620, replicas of types 600 and 600A but with improved moulded insulating cases. Both types were available in capacitances between 0.0001 MFD and 0.015 MFD with a ± 15% accuracy.
- Type 577 Universal capacitor suitable for both reception and low power transmitting application where voltage did not exceed 2000 volt DC or in which the low frequency voltage did not exceed 1000 volts AC.

They were available in capacitances 0.0001 MFD to 0.01 MFD. The larger capacitors could carry RF currents up to 1 ampere provided the RF voltage did not exceed 500 volts. Although more expensive than most other brands, Harris Scarfe Ltd found a steady demand from Amateur experimenters and home receiver constructors during the mid 1920s. Alick Clark was in charge of the firm's Radio Department at the time.

One of the important capacitor developments for broadcasting application was the wet electrolytic capacitor. Although its principle of operation had been known since the early 1800s and various attempts made to use it in telegraph work, and later, as line surge arrestors in DC power lines, it was the introduction of mains powered broadcast receivers and the need to filter hum from the power unit that spurred Engineers on to develop an efficient and reliable unit of high capacitance and capable of working at high voltage.

Components used in their manufacture varied slightly from company to company, especially where there were patent problems to overcome, but by the late 1930s, materials employed in manufacture included extruded aluminium can which formed the cathode of the capacitor; aluminium foil for the anode structure; rubber bush and liner; metal and insulating washer; and various acids and chemicals required for etching foil and cleaning the assembly, in forming the solution and electrolyte, and distilled water for washing, forming and filling solution.

In addition to electrolytic capacitors made overseas and imported into Australia, there were a number of active manufacturers in Australia producing large quantities to meet the demand.

At the World Radio Convention held in Sydney during 1938 by The Institution of Radio Engineers (Australia), Clifford Vaughan of Eastern Trading Co., Ltd (ETC) presented a paper 'A Brief Survey of "Wet" Electrolytic Condensers and their Manufacture in Australia'. He had joined ETC in July 1934 following indenture as Apprentice Electrical Fitter with O'Donnell, Griffen and Co., in 1921, rising to Assistant to the Works Manager before transferring to Don Electrical Co., as Manager in 1930.

Well-known brands of metal-cased electrolytic capacitors available in Australian Radio Shops during the 1930s included Aerovox, Ducon, Dulytic, ETC, Lomil, Mershon, Powertone, Solar, Sprague, TCC and others.

The Mershon designs included an 8 MFD model manufactured with a copper container and provided with a coarse thread at the base. It was screwed into a brass socket fixed to the receiver chassis. The positive lead terminated in a bolt with a solder lug on the top of the unit. The company also produced models with a non screw flat type base. In addition to a single 8 MFD model designated S8 type, others available in this capacity included D8, a double 8 MFD unit; T8, a triple 8 MFD unit and Q32, a quad 8 MFD unit. Oliver J Nilsen and Co., Adelaide stocked a complete range of Mershon capacitors.

Most manufacturers had standardised on a can size of about 30 mm diameter and about 130 mm tall with a capacitance 8–10 MFD, and rated at 450 volts working.

Subsequent development work, resulted in smaller physical size, higher capacity, higher working voltage and improved reliability.

A later development was the so-called 'dry' electrolytic capacitor. In this construction, the electrolyte was contained in an absorbent layer between the electrodes. One major advantage of this type of construction was that it could be mounted in a horizontal position under the chassis whereas the wet type had to be mounted vertically requiring a hole to be punched in the chassis for mounting each capacitor. The dry electrolytic had a number of other advantages, even though it did not possess the same self-healing characteristics of the wet type, and it eventually replaced the wet type in receiver construction practice. The dry type was available as multiple section units providing two and sometimes three capacitor outlets of the same or different capacitance values.

In addition to cylindrical design of dry types they were available as flat mounting units. Two mounting flanges were part of the box, adapting it for flat mounting. Separate terminals were brought out from each section. They were available in values 4, 6, 8, 10 and 12 MFD with a DC working voltage of 500 volts.

Today, electrolytic capacitors are available in large values of capacitance and a range of different shapes and sizes. With the exception of bipolar types, they are polarised and must be connected into the circuit correctly. The bipolar types are designed for employment where the voltage across them changes, such as speaker crossover networks.

The typical variable air capacitor consisted of a number of metal plates usually of approximately semi-circular shape and so placed that a second set of plates could intermesh between the first plates. The fixed plates were called stator plates while the moving plates were called rotor plates.

Two of the most widely employed types in tuning circuits were the straight line capacitor and the square law capacitor.

With the straight line capacitor, the shape of the plates was such that the capacity depended upon the overlapping area and was therefore proportional to the angle of rotation of the moveable plates. When plotted on graph paper, capacity versus dial setting produced a straight line.

With the square law capacitor, the shape of the plates was such that when graphed, the wavelength curve was a straight line directly proportional to the angle through which the dial turned.

Capacitors were also made so that the frequency curve was nearly a straight line, varying roughly as the angle of rotation of the plates.

In addition to intermeshing rotor designs, others included:

- Variation of capacitance by varying the distance between two plates by means of a threaded rod.
- A screw type in which the rotor plates were cast as a continuous corkscrew.
- A set of moving plates which moved along grooves into the fixed plates.
- One tube telescoping over another.

- Book leaf type using two hinged plates with space being varied by opening or closing the free ends.
- Compression type in which a plate in the shape of a dome or curved leaf was acted on by a screw to vary the spacing between the fixed and moveable plates.

A major problem faced by designers of early variable or allocating capacitors was in the design of the rotor and stator supports, and in insulating them from each other. One approach was to make the frame a part of the stator system and insulating the rotor by means of a metal bushing set in an end plate of insulation.

The effect of hand capacity on operation of a tuning capacitor was an important consideration in the mechanical design. Many early designs in which the stator was grounded were failures as the capacity of the operator's hand was carried to the dial by the rotor shaft, even with many shielded designs. The most successful design grounded the rotor rather than the stator. This meant that the stator was insulated from the frame. The frame could then be fixed to the panel and by grounding, was not influenced by hand capacity.

However, the technique required a good deal of development work to provide a good and reliable electrical contact with the moving rotor. Where construction provided for friction contact, the amount of bearing surface was small and contaminated bearing grease or dust often resulted in a high resistance contact.

Methods of overcoming the problem included a flexible strap or pressure spring or sleeve.

To overcome bearing wear factors and sloppy movement with some designs, a counterweight system was provided on the rotor so that adjustment would not be altered due to the effect of gravity. Another design employed two-sided construction dividing half the rotor and half the stator plates in opposite sides of the tuning shaft. The most economical and widely employed design was to use a slotted pressure sleeve on the rotor shaft. This ensured even and permanent pressure so preventing slippage of the plates from gravity effect.

The most widely used material for plates was sheet aluminium, although many seen in vintage radio collections were made from sheet brass often nickel plated or copper with some silver plated. A number of designs using cast rotor and cast stator sections can also be seen in collections.

Rotor shafts were mainly made from high grade case hardened steel with end bearings being brass or bronze. Pigtail connections for rotor were generally manufactured from braided copper wire, phosphor bronze or shim brass wound like a watch spring.

Designers of early variable capacitors had considerable difficulty with receiver drift due to changes in capacitance of the tuning capacitor as a result of physical changes because of changes in ambient temperature.

This was a particular problem with early AC powered receivers where the valves and power unit produced considerable localised heat.

The design of a stable variable capacitor was somewhat complicated. The dimensions and temperature coefficients of all the various component parts used in the assembled unit had to be such that any unavoidable changes in dimensions with temperature did not result in change of shape.

If this objective was not met, the relative shape and spacing of plates would change resulting in a change of capacitance, so detuning the receiver.

In some high quality capacitors a very low temperature coefficient was secured by constructing the capacitor with an aluminium frame and stator, and a rotor made partly from aluminium and partly from invar.

Brands of variable capacitors available from Radio Shops in the 1920–30s included:

Acme, Advance, AJS, Amsco, Ashdown, Atlas, AWA, Bretwood, Bowyer-Lowe, BTH, Burndept, Colvern, Curtis, David Grimes, De Forest, De Jur, Dubilier, Ediswan, Emmco, Ericsson, Erla, Federal, Formo, Fortevox, Gecophone, General Radio, Gilfillan, Goldtone, Hammarlund, Hava, H&B, Igranic, JB, King-Hunners, Lissen, Magnus, Marconi, Montrose, Murdoch, Nelslide, Neutron, N&S, Ormond, Pacent, Panel, Pausin, Peerless, Penton, Pilot, Quam, Radiax, Radiovox, RVG, Saba, Service, Southworth, Sterling, Success, SW, Tunup, Utility, Vercon, Wootophone and others.

The Nelson manufactured Nelslide which appeared in the shops in 1925, was an unusual design. Because of in-built gear action, it was in effect a 2:1 vernier. Plates moved in a horizontal plane in accurately milled grooves rather than in a rotary motion, the end plate was heavy rolled brass with bright nickel finish, contact spring was nickel silver with self-cleaning action ensuring minimum series resistance, the rack had helical cut teeth pivoted on one end only, pinion and shaft were one piece with helical cut teeth to provide smooth and noiseless operation, and a tension spring of phosphor bronze to provide for zero backlash.

The Radiovox was another novel design. It was a low loss vaneless type employing a winding strip format in a moulded case of high dielectric strength. The unit had a maximum capacitance of 0.001 MFD and a very low minimum, giving a wide range of wavelength with any given inductance. Vernier tuning was possible over the whole range with the engraved knob making two complete revolutions. The capacitor was available in Adelaide from Mackenzie and Maddern, Grenfell Street and was used in a receiver entered in the Radio Trade Exhibition held in Adelaide in June 1926.

The Success was typical of the most widely employed variable capacitors. It was of rugged construction, had skeleton end plates, skeleton insulation plate, sprung end plates to compensate for wear on bearings, pigtail connection to moving vanes, copper vanes, fixed vanes secured to bottom end plate only, very small dielectric, loss, no backlash and no external vernier. It had a 4:1 gear which transferred motion to the moving vanes. To minimise hand capacity effect, the master gear wheel was made of hard vulcanised fibre. Dielectric losses were kept to a minimum by employing a skeleton design of best quality ebonite or mahoganite.

Variable capacitors were also available for Neutrodyne circuits. Brands included Success, Bowyer-Lowe, Magnum, Gambrell, Igranic, Lissen, MH, Polar, Service, Goldtone and others. Some units such as the vertically mounted Gambrell 'Neutrovernier' stabilising capacitor were masterpieces of the turning and fitting trade at the time.

Fixed types included:

Bradley, Chanex, Dubilier-Mansbridge, Dubilier moulded, Dubilier ruby mica, Ducon, Electrad, Federal, Ferranti, Flechtheim, HCR, Lissen, Magnus, Marconiphone, Met-Vick, N&S, Ormond, Pilot, Powertest, Renrade mica, Renrade canvas, Renrade bakelite, Sangamo, Simplex, Sprague, TCC, and others.

Some fixed capacitors were provided with mounts designed for specified application such as RC coupling unit, grid-leak/capacitor unit and others.

An examination of modern day scrap boxes among vintage radio collections, reveals dozens of unbranded types which were on the market in the 1920s. Some cheap imported types used untreated brown paper as dielectric.

There were also types known as 'transmitting condensers, which in the 1920–30s were made with strips or sheets of tinfoil interleaved with either paraffin coated paper, ebonite, mica, impregnated veneer wood or glass sheets. Oil filled types were made of strips of tinfoil between glass plates immersed in paraffin oil or transformer oil contained in an iron or brass case.

Even before the establishment of broadcast transmitters, large capacitors were manufactured for wireless telegraphy transmitters. As early as 1904, the transmitter designed by Lee de Forest for the St Louis World Exposition in USA, the spark gap capacitor consisted of six liquid tight tanks each 7 ft by 2 ft by 2 ft (2100 mm by 600 mm by 600 mm) and weighed more than a tonne. Plates were made of thick glass covered on both sides with tin foil. The dielectric was kerosene. Voltage across the capacitor bank was 60 kV provided by a transformer 2100 mm high.

On several occasions the bank of capacitors exploded during lightning storms and sprayed broken glass and kerosene throughout the shack. Operators described the odour of ozone mixed with kerosene as 'quite pleasant'.

In more recent times, a synthetic liquid dielectric used in some transmitting type capacitors was polychlorbiphenol (PCB). Although it had some merit as a dielectric, it was not acceptable on environmental grounds and is no longer used.

Considerable development work was undertaken during the late 1930s to meet the specific capacitor demands of receiver designs employing superheterodyne circuits and mains voltages. By the late 1950s, types available included:

- Fixed capacitors using paper dielectric, mounted in rectangular or tubular cases.
- Fixed capacitors using mica dielectric, and provided with metallised or moulded case, including wax protected types.
- Fixed capacitors using ceramic dielectric of the cup and disc types, including temperature compensating types.
- Fixed electrolytic capacitors in tubular metal cases.
- Variable capacitors including air dielectric rotary, air spaced ganged miniature, air dielectric miniature trimmer, air dielectric trimmer with locking device, air dielectric concentric trimmer and air spaced miniature vane type trimmer.

Today, there is a vast array available with many being developed specifically for employment with low voltage solid state equipment. Types available include aluminium electrolyte, solid tantalum, ceramic, paper, polyester, polycarbonate, polystyrene, polypropylene and a range of film capacitor types.

About 1990, market share was approximately plastic 28%, aluminium electrolyte 27%, multilayer ceramic 12%, dry solid tantalum 10%, single layer ceramic 10%, wet tantalum 6%, paper 4% and mica 3%.

One of the interesting developments in ceramic technology has been the production of chip monolithic ceramic capacitors. Their continued size reduction, improvements in dimensional precision, lower voltages due to the use of materials with finer particles, high capacitance due to thinner dielectric layers and cost reduction, all make it evident that they will be in considerable demand for many years.

Until about 1985, the most commonly used size of chip capacitor was 3.2 by 1.6 mm but within a short time, the size of one popular type had been reduced to 2.0 mm by 1.25 mm. By 1990, chip size of 1.6 by 0.8 mm was not uncommon with application in television and short wave receivers and other radio areas.

The size of electrolytic capacitors has also fallen with some brands being 60 to 70% smaller than those manufactured in the 1970s. Greater life expectancy — up to eight times greater — and greater reliability have also resulted from extensive development work and research.

• INDUCTORS

Whereas resistor and capacitor performance were, and still are, relatively independent of the frequency employed in broadcast equipment, except for some wire wound resistor types, the inductor design was frequency sensitive and special designs had to be prepared for the power supply, audio, intermediate and radio frequencies.

Inductors designed to operate at low frequencies of power and audio frequencies employed ferrous cores whereas those designed to operate at intermediate and radio frequencies employed air cores or special low-loss powdered iron cores.

The two basic uses of inductors were as transformers or chokes. Included among the wide range of radio frequency inductors or coils employed with early receivers were single layer, bankwound, honeycomb, narrow basket weave, loose basket weave, radial basket weave, solenoid, dual range, astatic, magnum, toroid and others. There were also many overseas manufactured coils known by the name of their designer or manufacturer. These included Aerocoil, All-American, Brandes, Bruno, Burndept, Coast Coil, Dubilier, Erla, Freshman, Gambrell, Gen-Win, Goldtone, Hammarlund, Insulex, Lorenz, Marco, Met-Vick, Na-Ald, Naxon, O'Keefe, Orbit, Pathe, Polar, Powertest, Quadroformer, Sickles, Summitt, Sterling, Stradio, Turney, Wallace and others. Metropolitan Vickers produced the ANP (Astatic Non Parasitic) coil for high frequency application while Polar manufactured a combined aerial/reaction coil unit with variable reaction coil.

Audio frequency transformers were also available in a very wide range with models being manufactured in Australia, USA, Great Britain, and Europe being stocked in local Radio Shops. Transformers with such names as the following can be seen today in vintage radio collections and museums:

Acme, Airad, Airzone, AJS, All-American, Atlas, AWA, Brandes, Bretwood, Brownie, Brunet, BTH, CAV, Cavalier, Chakophone, Climax, Compton, Cossor, Croix, Crosley, Daisy, Dubilier, Eclipse, Ediswan, Efesca, Emmco, Energo, Ericsson, Ferranti, Formo, Fullers, Gambrell, Gecophone, General Radio, Golden Voice, Grand Opera, GRC, Healing, HTC, Igranic, Jackson, Jefferson, Kaynite, Kelford, Kellogg, Kenyon, Lekmek, Magnus, Marconiphone, Marle, Max-Amp, MH, Midget, Mignon, ML, Mullard, Neutron, Ormond, Peerless, Pep Punch, Philips, Pilot, Pival, Polar, Powerquip, Puratone, Pye, Radiax, Remler, Salonola, Sampson, Sangamo, Saxon, Sensifone, Signal, Silver Marshall, Silverton, Star, Stella, Sterling, Success, Superman, Sutra, Tangent, Telsen, Thordason, Trimax, United, Viking, Western Electric, Woodhill and many others. Many unbranded types can also be seen in collections.

Unfortunately, the interstage transformer proved to be one of the major causes of the high failure rate of early receivers.

In order to reduce space and cost, the designers employed very fine copper wire. The wire was enamelled for insulation purposes and each layer was separated by kraft paper. The transformer usually failed as a result of corrosion of the wire bringing about an open circuit condition. The corrosion started through a small pinhole in the enamel. Chemicals in the interleaving paper or the atmosphere, reacted on the bare copper producing a green deposit referred to as verdigris and consisting of basic copper carbonate or sulphate of variable composition. The problem was more evident with the primary winding which carried a DC current in the anode circuit.

Although various methods were tried to prevent the problem, including dipping the transformer in hot wax to keep out moisture laden air, it was only partially successful. Other methods adopted included connecting the transformer iron core to the HT supply and sealing the unit with pitch in a metal can, sectionalising the windings into vertical pies, and employing wire other than copper wire.

An example of the latter arrangement, was the Philips 4003 transformer. The primary was wound with silver wire and the secondary with nickel wire. A special alloy core was used and the manufacturer claimed that it was immune to saturation, even with the largest power valves then available for receivers. Philips data sheets showed the transformer as having a reasonably flat frequency response over the range 200 to 10000 Hz. Many Philips transformers have stood the test of time, and they can be seen working today, in vintage radio receivers.

Many of the early AF transformers were cheap, badly designed, unreliable and gave poor performance in terms of frequency response and distortion. The cheap models sold for $1.25 to $2.50 (in today's currency) but the top class imported models such as UK Ferranti sold in Radio Shops for $8 to $10 each. Top quality models imported from USA were even more expensive. Ameritran and Sangamo models were priced at $20 to $30 in some shops.

The low quality models disappeared from the market when circuits employing resistance-capacitance coupling replaced the earlier transformer coupled circuits. However, high quality audio transformers still had their place with push-pull amplifiers and for mixing and matching in studio equipment.

Among the high fidelity AF transformers produced in Australia in the late 1930s, were Trimax transformers made by Cliff and

Bunting Pty Ltd, Melbourne. In the 1940s, Trimax transformers had about 60% of the market for studio equipment. Applications included mixing (line to line) transformers; mixing (line to line) multishielded transformers; input (bridging) transformers; input (line to grid) transformers; input (line to grid) multishielded transformers; interstage transformers and output (anode to line) transformers.

Features of these transformers included low insertion loss, uniform frequency response, low waveform distortion, freedom from intermodulation effects, and high reliability. When employed at low levels, additional features included freedom from electromagnetic and electrostatic pick-up; effective shielding against longitudinal currents; balanced windings and consistent performance.

In the mid 1940s, there were at least 25 different types available. Typical frequency response was ± 1 dB over the range 30 Hz to 10 kHz; electromagnetic shielding was provided by an astatic hum balancing structure with two separate sections enclosed in cases of mild steel or high conductivity non-ferrous metal; a high conductivity non-ferrous case guarded against electrostatic interference; high conductivity shields between primary and secondary windings attenuated transfer of longitudinal currents and also improved balance to ground on the windings; coils were layer wound with high quality paper interlayer insulation; interwinding insulation was a plastic material of low moisture absorption characteristics; after winding, coils were vacuum impregnated with micro crystalline wax; the complete transformer was sealed in the case with a bitumen compound and cores were constructed of high permeability heart treated nickel-iron alloy laminations.

During the 1930s, Australian engineers made major contributions to the development of RF coils employed in receiver construction. Two engineers prominent in this area were Philip Parker, Works Manager at Airzone (1931) Ltd and John Briton, Chief Engineer of Briton Electrical and Radio Pty Ltd. Both delivered papers related to their work at the World Radio Convention organised by the Institution of Radio Engineers (Australia) in Sydney in 1938.

With the rapid expansion in receiver manufacturing, and the need to produce coils of the highest efficiency, coupled with simplicity of manufacture and low cost, designers were under constant pressure to improve coil performance by the application of new technology and new materials, to ensure high stability under a wide range of climatic and operating conditions and also to provide improved methods of speedy mass production.

The problem was complicated, because of the large number of different designs required in a typical receiver. Radio frequency coils included aerial, bandpass, oscillator, intermediate frequency coils and RF chokes; audio frequency coils included AF transformers, AF chokes, and loudspeaker input transformers, while power supply equipment included power transformers, filter chokes and loudspeaker field coils.

Further important developments in improving the efficiency and performance of inductors took place during the years of the Second World War. Howard Love, founder of Kingsley Radio Pty Ltd, Melbourne played a leading role in the application of ferro-magnetic technology.

The company decided to apply the knowledge obtained about the manufacture of iron dust cores to the production of better radio parts. The Permaclad, Permacore and Ferrotune lines became part of the product line.

Kingsley Engineers had spent considerable effort in the application of iron dust cores to coils for receiver designs. The Permaclad types employed an encasing pot which in combination with the adjustable core employed just the correct amount of wire to provide a given 'L' at the frequency of operation. The result was a range of coils with high Q.

The company had contracts with Defence for the manufacture of equipment including radio accessories, crystal calibrators, iron dust cores and the AR7 model communications receiver of which over 3000 were produced.

Permaclad components including aerial, RF and IF coils were used with the receiver.

In late 1945, when Defence commitments had declined, the company released coil units for the domestic market and also a pre-aligned Ferrotune front end which gave straight line tuning over the full MF broadcast band. Each revolution of the tuning knob covered a 100 kHz range.

The company also produced a range of broadcast receivers in which the Ferrotune assembly was employed. However, all company production activities ceased in 1948 with closure of the factory following the death of its founder Howard Love.

Staff associated with the company development, design and production activities included George Neilson, John Bremner, Jack Kling, Laurie Fitzgerald, Lay Cranch and others.

Layman Cranch who became an Associate Member of The Institution of Radio Engineers (Australia) in 1939 and was licensed operator of VK2XC became Managing Editor of the monthly publication 'Australian Radio and Electronics' incorporating 'Australian Radio World' after leaving Kingsley Radio. The magazine published by the proprietors of Radio and Electronics (Aust.) Pty Ltd had as its objective, 'Advancement of Radio and Electronic knowledge'.

Many types of windings were employed in the 1930s, with the majority of those used during the early 1920s being no longer employed by the major coil winding organisations. Most manufacturers had standardised, and for radio frequency application were using crosswound, solenoid and bank coils. Paper section and form wound types were employed for audio frequency and power supply components.

Standard enamelled copper wire of appropriate gauge was widely used for coil manufacture but many designers preferred Litzendraht wire for RF coils. It consisted of multiple strands of enamelled wire covered with either one or two coverings of silk or cotton. The smallest possible diameter of single wire was selected in order to reduce losses resulting from eddy currents.

By about the early 1950s, the most widely employed methods of coil winding for receiver application included:

- The progressive duolateral winding. In appearance the winding somewhat resembled the early honeycomb coil. In format it was a broadly wound coil of few layers.
- The spiral or cylindrical winding. Turns were wound next to each other on the former.
- The duolateral winding. It resembled the old basket weave format.

Iron dust cores or slugs found wide application, particularly for IF and RF coils in receivers. Iron cores simplified the problem of obtaining high Q windings. Core shapes available included H, Cross, Roller, Pill Box, Screwed Pug and Cylindrical Plug. An advantage of using iron cores in oscillator circuits was that it gave increased coupling between primary and secondary circuits compared with air core types. When used in IF circuits, they enabled smaller coil sizes to be made, they increased the Q of the winding and facilitated adjustment of the tuned circuit to resonance. From about 1960, ferrite pot cores replaced earlier types. The core was usually in halves which were cemented together after placement of the coil in the core halves.

Metal screening cans were provided over coils to prevent undesirable coupling between other coils on the receiver chassis. However, it was difficult to manufacture coils with exactly similar characteristics due to a number of factors, so it was usual to provide a method of adjusting self-inductance before the coils were passed to the receiver assembly line. Adjustment methods included the provision of a moveable iron slug, or swaging the coil can by making a groove in the coil can at the height of the coil. In some earlier designs, a small copper disc or plate was fitted inside the can. The adjustment rod attached to the disc was locked in place, usually by lacquer, when the correct value of self-inductance was obtained.

Screening cans were fitted to the chassis in various ways, with the most popular methods being by means of a lip cut out of the chassis steel sheet, by clamp and screw, or by means of a clip squeezed into place by a tool.

Considerable advancement has been made in the miniaturisation of inductors, especially in the field of components for surface mounting technique.

One series of chip inductors available in the early 1980s consisted of a square shaped ceramic or ferrite coil former wound with a single copper wire layer. The winding ends were welded to the contact elements at the front end.

These chip inductors had a number of important advantages which included, very small size, could be used on standard circuit boards, excellent performance at radio frequencies, high reliability, consistent reproducibility during production, and could be used with most soldering methods in use.

Chips found application as tuners in car radios, short wave receivers, tape recorders, television receivers and many others.

Resistors, capacitors and inductors, of course, are only three of the many components used in broadcasting equipment. Others, some of which are no longer employed, include such items as accumulators; accumulator charging equipment; aerial and earth accessories; aerial interference filters; metal chassis; A, B and C batteries; ammeters; anti capacity tuning handles and knobs; loudspeaker and transformer bobbins, nuts and bolts; panel and baseboard brackets; bulbs; buzzers; cabinets; coil cans; coil formers; coil plugs; coil winding machines; battery, speaker and headphones cords; dials; crystal detector; earth clips; A, B and C battery eliminators; generators; vibrators; grommets; headphones; hydrometers; insulators; lightning arresters; lugs; fuses; meters; plugs and jacks; shields and screens; sockets; speaker switches; terminal connectors and tags; valves; valve windows; voltmeters; wave traps and many others.

With the introduction of broadcast receivers powered from the mains, the 'do-it-yourself-enthusiasts' decreased in number rapidly because of the danger in working with high voltages and the greater complexity of circuits based mainly around the superheterodyne circuit. This lead to the gradual decrease in the number of Radio Shops selling components to hobbyists.

Receiver manufacturers formed close relationships with specialist component makers to meet their particular requirements. However, there were very few specifications applicable to component tolerances, ratings etc.

It was not until the outbreak of the Second World War in 1939 when there arose a sudden demand for large quantities of components that rationalisation was introduced.

In order to meet the demand from all branches of the Defence Forces for radio equipment, the Munitions Department of the Commonwealth Government created the Directorate of Radio and Signal Supplies in June 1942 and vested in it the responsibility for directing all future production. By the end of the War, more than 12000 radio transmitter, 9000 radio receivers and nearly 19000 transceivers had been produced involving millions of components. Nearly 600 separate firms were engaged in some aspects of production, either as contractors, distributors, or suppliers of specialised materials.

All this work resulted in improved components for incorporation in Services equipment and was the basis for standards which continued after the War. Today, components bear little resemblance to their earlier counterparts, being smaller, lighter, more stable and capable of operation over wider extremes of temperature and other climatic conditions. Even so, requirements for broadcast equipment components are demanding higher standards with the advent of solid state equipment and still more miniaturisation.

After the War when the manufacturing industry was changing over from production of equipment and components for the Services to civilian needs, many of the pre War brand names were absent from Radio Shops stocks. Well-known pre War brand component names included Advance, Aegis, AWA, Colonial, Crown, Ducon, Eclipse, Efco, Emmco, IRC, Philips, Radiokes, RCS Radio, Saxon, Simplex, Technico and Wetless. However, very few of these names reappeared on components in post War years.

Workshop Production Facilities

At the outbreak of the Second World War in 1939, public broadcasting had been in service for only 16 years but the radio manufacturing industry had undergone incredible development and change.

Although AWA, the major Radio Engineering organisation in the nation had been well-placed to meet the challenge of broadcasting as a result of its involvement in the establishment and operation of radio communication services, even before the First World War, it was some years before other organisations were geared up for mass production, particularly of home radio receivers. However, there were hundreds of small organisations, some comprising one or a few employees making many of the parts by hand, assembling and testing each receiver one at a time.

For the first few years, quantity production techniques had not become part of the radio industry. Also, the state of the technology was such that Radio Engineering was regarded as being too specialised and too technically intricate for automatic or mass production practices to be introduced.

By 1926, when AWA began to scale up the production of domestic receivers, the workshop at the Radio Electric Works in Knox Street, Sydney was well-equipped to produce everything from very small parts and large components to meet the needs for receiver and transmitter manufacture. Facilities included automatic turret lathes, screw cutting machines, milling machines, multiple drills, grinders, power presses, guillotines, diecasting facilities as well as machines to meet the specialist needs of Radio Engineering such as coil winding, capacitor and resistor manufacture, loudspeakers, glass valves etc.

In 1924, the factory output included high power broadcast transmitters for A Class stations and some 200 domestic receivers. By 1937, it was under great pressure to meet the demand for Commercial station transmitters and the enormous public demand for receivers. In that year, 50000 receivers comprising 17 models were produced. A single receiver required more than 1200 piece parts, with the company producing most of these in its factory. By the late 1930s, AWA was joined by large manufacturing organisations in Sydney, Melbourne and Adelaide and smaller ones in the other capitals. Most concentrated on the production of domestic receivers but a few such as Transmission Products, STC and Colville Wireless Equipment manufactured transmitters for the National and Commercial services. Some of the firms grew from tiny workshop one person outfits in the 1920s, into large mass production enterprises employing hundreds of people in the 1930s. Whereas in the 1920s, their receiver brand was known to only a handful of people, by the 1930s it was a well-known household name.

The techniques employed in the mass production of domestic receivers followed the practice in many overseas factories which, particularly in the USA, had adopted the practice used in the motor car industry whereby the raw materials were routed through definite manufacturing and assembly cycles. As each part passed inspection and testing procedures it was delayed until arrival of the next part required in the receiver assembly. As the chassis progressed along the assembly line, various completed parts and wiring were added until it reached the final testing point.

The success of the major companies was due mainly to continued technical development of equipment and components produced under precision manufacturing methods coupled with rigid quality control. A well-equipped laboratory was an essential requirement to carry out development work, to improve current models and to design new models taking into account the latest scientific discoveries.

A tool room staffed by qualified Tradesmen was a key facility in a large mass production company. The tool room staff developed and produced special tools, dies, moulds etc, required for stamping, screw cutting, moulding and other operations for production of transformer cases, dial escutcheon plates, capacitor and valve shields, coil cans, rheostat wipers and cases, dial assemblies, moulds for knobs etc.

Toolmaking was really the first stage in the production of a new product or component. It was very expensive, requiring skilled staff, the preparation of detailed drawings and specifications, and considerable development work. At a large factory, toolmaking was an ongoing operation to meet the needs for new products and to modify and upgrade existing plant and components. One tool room Engineer of the 1950s was Eric Burgess who came to Australia from England in the late 1920s, and worked for AWA for many years.

Screw making Machine Operators were kept busy turning out thousands of small parts such as thumb nuts, metal and wood screws of various sizes and patterns, capacitor and rheostat shafts, terminal posts, dial bearings, terminal lugs etc. The type of small metal screws used in receiver assembly was usually limited to the British Association (BA) pattern which had eleven sizes from 0 BA to 10 BA. If bigger screws were required, Whitworth screws were generally used. Whilst some screw types were available from commercial sources, many special patterns were not readily available off-the-shelf, and were manufactured locally in the machine shop.

Most of the large screw machines were automatic in operation with one operator often handling several machines. Long rods of steel, brass etc, were fed into one end of the machine which automatically formed, threaded, tapped and cut off the part it was tooled up to make.

Electroplating facilities were essential in any large factory for such work as barrel plating of small parts like nuts, bolts, screws etc, anodising, and a number of other processes usually carried out in small vats, such as silver, nickel, chromium, gold and rhodium plating.

In the 1960s, AWA had one of the largest plating shops in Australia. The main room was some 70 metres in length and contained an automatic cadmium plating machine designed and built by AWA staff. A large zinc plating machine was designed in UK but with the exception of the automatic overhead conveyor mechanism, was made by AWA staff to the UK specifications and drawings.

Punch presses had wide application punching out small parts such as valve socket prongs and holders, variable capacitor plates, transformer laminations, transformers covers, valve shields, coil cans, potentiometer cases, chassis and many others.

Although some presses were small in size many were massive, requiring very large concrete bases to support the machines. Typical large presses in the AWA factory were 60 tonne, 80 tonne and 150 tonne in weight. The large presses were supplemented by many smaller presses used in various departments throughout the factory.

Many factories could not justify the cost of massive presses and carried out punching operations with medium size units. Many were automatic in operation and capable of stamping out rapidly and cleanly thousands of transformer laminations, variable capacitor plates and other metal parts from long strips of steel, brass or aluminium.

The production of transformer laminations was a little different from stamping out other metal parts. Sheet steel with specified metallurgical content, magnetic flux density, permeability and low hysteresis losses was purchased to ensure the assembled transformer met desired electrical and performance characteristics.

After being punched out, the laminations were placed in a rotating barrel containing sawdust to remove oil and lubrication used with the press. They were then transferred to another tumbling barrel to round off the corners and remove scale.

Bakelite parts were produced in large quantities in the moulding section of those factories which had moulding equipment installed. Expensive mechanical or hydraulic presses produced dials, knobs, dial drums, panels, tubing, plug-in coil formers, transformer and capacitor cases, and plain sheets.

In producing bakelite parts, some factories used a method of pouring bakelite powder into each mould separately, while others moulded small parts from the bakelite powder made into the form of pills with each pill containing just sufficient powder to mould one piece.

Machines employed for the winding of paper and metal foil sheets for bypass and filter capacitors, were frequently separated from other machines to ensure the air was free of dust and other contaminants which could result in capacitor breakdown on the application of working voltage. Heated paraffin storage tanks and impregnating ovens were an integral part of capacitor manufacture.

Many factory Engineers built elaborate capacitor winding machines, but their principle of operation was very simple. In a typical design, the machine comprised a series of spindles which supported rolls of specially prepared paper and aluminium foil. After loading the machine, the ends of the rolls were brought out through slits and secured to a spindle in front of an operator. The operator controlled the motor driven spindle by a foot switch. A counter on the spindle indicated the correct number of turns for a particular capacitance value. Small pieces of tinned copper were placed against the foil before application of the last few turns to serve as connection lugs. They were held in position by the tightness of the winding. After pasting down the end of the outermost paper, the capacitor was removed from the spindle and squeezed flat. High grade paper about 0.0004 inch thick and free of carbon and dust was critical to ensuring a reliable capacitor. The aluminium foil was about 0.00025 inch thick. Both foil and paper were purchased in various widths for a range of capacitance values.

After winding the capacitor, it was heated in an oven and impregnated with wax. Final work was to carry out electrical tests and assemble the unit in a metal can filled with paraffin. Further electrical tests were carried out before passing the unit to store.

Audio frequency transformers, power transformers, radio frequency chokes, power supply filter chokes, intermediate frequency transformers, oscillator and aerial coils, resistance coils etc, were wound by automatic machines. The machines were designed to ensure an even tension of the wire while the coil was being wound. In the days of the gimbal mounted coils such as honeycomb, basket, spider and other similar types, various patterns of coil winding machines and devices were developed. For example, the Lokap coil winding machine was one of the popular models used to enable duolateral and other forms of basket weave coils to be easily wound. For small production lots, the machine was hand operated but for mass production, the mechanism was driven by a small electric motor.

Audio frequency transformerS were the most troublesome component in early receivers — even more so than valves. Many receivers imported from the USA in 1923—24 to meet the demand when broadcasting commenced here, failed within a few hours of application of battery power. Even the most expensive receivers were not immune. The problem was finally traced to the fine wire used in the transformer secondary. During manufacture of the wire, it was passed through an acid bath before the application of the insulating enamel. Investigations showed that the acid had not been completely removed resulting in eventual corrosion, causing short and open circuits. The problem was an expensive lesson for American manufacturers with thousands of receivers being returned to manufacturers. For a time, receivers made in the USA were not popular with Australian receiver owners and Radio Shops. One Adelaide dealer had a notice in the window, 'No American receivers sold here'.

When Australian manufacturers began the production of AF transformers, the American experience of the high failure rate was taken into account. One of the early Australian companies involved in large scale production of these units was the Electricity Meter Manufacturing Co., in Sydney. It produced AF transformers initially under the brand names Signal and Emmco in 1925-26. Other brand names followed in subsequent years. Of a total staff of 500, about 24 girls were employed in the coil winding section and operated high speed winding machinery. The number of turns were automatically calculated by an adaptor attached to the machine with the regularity of the winding being controlled by a sliding arm through which the wire passed from the spool. Each layer of wire was insulated by specially prepared insulation paper. After winding the primary and secondary coils, they were tested for continuity and then placed in a drying oven for 12 hours. Later, the coil was wound with cotton tape, dipped in varnish and dried in an oven for at least 12 hours. The next operation was to fit the windings inside the laminations, fit lugs to the wires and fit the unit into the case. Following a further drying operation, each coil was subjected to insulation and amplification tests before being labelled and packaged.

Manufactured components requiring assembly of a number of separate parts e.g. variable capacitors, rheostats, potentiometers, valve sockets, loudspeakers etc were put together in a general assembly area from parts which had been fabricated or produced by various machines throughout the workshops. The assembly benches were laid out so that work passed from one worker to the next without excessive handling.

Every assembled component manufactured on the premises was put through a series of appropriate tests and visual examinations to confirm that it met specifications laid down by the design Engineer before being passed for use in the receiver assembly lines.

The various machines of the 1920s were driven by a complicated network of overhead shafts, pulleys and belts linked to individual machines on the floor. However, by the 1930s the system had been replaced by a system of separate electric motors for each machine. It provided a safer, cleaner and quieter environment for the workers.

The mass production techniques of the 1920s varied from firm to firm and the receiver model being produced. At the time, operating controls were fixed to a front vertical panel and components attached to a wooden baseboard, with battery, aerial and earth terminals at the rear. Later, metal chassis punched to suit component mounting were introduced.

The front panels were machined to the desired dimensions, sanded and then subjected to finishing which in many models produced a pleasing flat wood grain like finish. Other finishes included imitation marble and gloss brown or black bakelite. The panels were then passed to drilling machines where all holes were drilled with the aid of templates. The next operation was engraving where designations and the receiver name or type were engraved.

The panel assembly procedure varied from model to model but for a typical battery-powered four valve model, one worker would mount the filament rheostat, the next would fit the binding posts, and so the mounting work would proceed down the assembly line, passing from one worker to the next. Hook-up or wiring would then proceed with each assembler having only a few wires to attach. If square busbar type wiring was being used it would be supplied to the assembler cut to size and already bent to the correct shape to facilitate connection. At the end of the assembly operations, the receiver would be placed on wagon racks and later taken to the Inspection and Test areas.

At the start of the 1930 decade, a major change in mass production assembly arrangements took place. It was the time when the screen grid valve was designed into circuits requiring consideration of shielding aspects for valves, coils and wiring. It was also the start of the superheterodyne era when nearly every major manufacturer introduced at least one receiver using a superheterodyne circuit.

Its outstanding performance and the introduction of new valves to suit soon led to the disappearance of those circuits which had dominated the radio receiver scene during the 1920s. The all-mains receiver also appeared on the production line, and although the unit required extra components including an extra valve, compared with battery receivers, the advantages of operating from the mains soon overcame the problem of additional cost. The high voltage involved as a result of mains operation required a re-examination of insulation and safety factors in receiver design and layout. Shielding of components and particularly wiring layout to prevent the introduction of hum into the output had to be addressed.

In the early 1930s, slowly moving conveyor belts were a feature of receiver mass production in many factories. Receiver chassis were mounted on frames to give greater rigidity and to facilitate mounting of components and wiring. They passed slowly from operator to operator at fixed intervals with each operator usually being equipped with soldering iron, automatic spanners and screwdrivers and at some positions, a spot welder.

At the end of the assembly line, each completed chassis was subjected to a number of tests including assessment of quality of reproduction, accuracy of calibration, correct operation of controls etc. It would also be inspected for dry solder joints and excess flux removed from soldering operations.

If the chassis passed the factory specifications, it would be moved to another section to be fitted into a cabinet. Large firms manufactured their own cabinets but small firms purchased their requirements from firms who specialised in this work. Although some wooden and wood veneer cabinets were hand French polished, the majority had the finish sprayed on. The finish of wooden cabinets in the 1920s was usually matt or stain finish but in the 1930s it was piano or high gloss finish to take advantage of the in-laid veneer work popular at the time. After the War, wooden cabinets gradually gave way to moulded plastic designs and the large floor mounted consoles disappeared from the showrooms by the 1960s.

Mass production was facilitated by the manufacture of a small number of standard chassis. A firm marketing up to 25 models might generally employ only 4 or 5 different chassis.

A Development Laboratory was essential for survival. The release of new models with features which could be emphasised by the marketing people was part of the cut and thrust approach to ensure a fair share of the highly competitive market There was also the need to update current models to take account of feedback from Radio Servicemen in the field. Environmental problems became a problem when the broadcasting stations opened in tropical Queensland. Receiver failure due to the high humidity conditions was common and manufacturers realised that tropic proofing of components was essential if they were to continue to market their products in these areas.

In addition to the manufacturing process, the major organisations produced brochures and leaflets with circuit diagrams for the benefit of Servicemen who had to maintain their products after they had been sold. They also carried out an extensive advertising campaign on radio and in the press to ensure high exposure of their product.

A key person in all manufacturing plants was the Inspector. In a very small organisation employing up to about 20 people, one Inspector would generally suffice but for a very large factory producing many hundreds of different parts, components and full assemblies such as domestic receivers, many Inspectors would be employed. It was essential that every operation be inspected from the time it started until the product was shipped from the premises to sales outlets or distributors. A typical five valve receiver may have required 80–90 inspections at various stages before shipment.

For the very large organisations which may have operated with a number of departments, the Engineering Department would have been the key department which set the standards and tolerances, and the Inspectorial Group would have been part of that Department.

The inspection process, like production, was progressive so that at any defined point or stage of manufacture, the product or receiver had reached a predefined specification. In this way, there was no final inspection which might require major surgery to correct defects.

With an efficient inspection procedure, most of the Australian receiver manufacturers were able to ensure that very few sets which left the factory were defective and any defects which may have slipped through the system were of such a minor nature that they could be corrected quickly and easily by the dealer or distributor. The aim was to ensure that no set had to be returned to the factory.

Factories and small workshops producing radio test instruments were just as particular in ensuring component reliability. At the Paton Electrical Instrument Company at Ashfield where large quantities of meter movements were produced in mid 1930s, each meter was subjected to an eight hour 'to and fro' exercise before the instrument was passed for either use in the company's own instruments or despatched to Radio Shops for sale.

Very seldom was material which was rejected by Inspectors returned to the production workers. For a critical item it was often directed to a group where it may be repaired, the reason for rejection analysed, and the Production Department advised.

Frequently, parts were inspected by people who had experience in their production, but assemblies and complete units were inspected by people who possessed practical and theoretical knowledge in Radio Engineering. To this end, many organisations encouraged staff to attend evening classes to obtain formal qualifications in some field of Radio Engineering.

Inspectors were seldom received with enthusiasm by production staff. The aim of the Production Department was to make as many units as possible while the Inspector's role was to ensure the upkeep of quality.

During the War, most of the major manufacturers were fully occupied in meeting the demands of the Services and very few new domestic receivers were produced.

However, the Government recognised the importance of radio sets for the civilian population and Radio Servicemen were kept supplied with spare parts to keep home receivers operational. Firms like A S Radio Parts, Elizabeth Street, Melbourne, were typical of wholesale suppliers. Full replacement parts were not available for every type of model of receiver, but in the main, alternative parts could often be used with a little modification. Transmitter operators often helped other station operators during an emergency to keep transmissions going when there was a staff shortage or some vital equipment component was required.

After the War, many of the major pre War companies began manufacture of transmitters, receivers and components to satisfy demand. However, a number of factors had ensured that the heady days of the 1930s decade would not return after the War.

Even in 1939, at the end of the decade, there was a strong indication that receiver sales, the mainstay of the broadcast manufacturing industry, had declined greatly. In fact, there was an atmosphere of gloom among the Radio Retailers and many had already taken steps to stock electrical merchandise additional to radio receivers. Such things as refrigerators, electric washing machines, toasters and other appliances began to occupy large areas of floor and shelf space previously set aside for a wide range of radio receivers and components.

The mortality rate in the ranks of receiver manufacturers was distinctly noticeable and it was freely predicted in the trade in 1938, that within two years, there would be only about six manufacturers in business supplying the whole of the Australian broadcast receiver market.

One reason for reduced sales was that advances in technology had resulted in increased reliability of domestic receivers. Whereas the life of a receiver was about five years in the early 1930s, it had risen to about ten years by the late 1930s. Also, the rush to buy dual wave receivers in 1930 and 1934 to listen to the cricket Test Matches being played in England did not eventuate with the 1938 tour. As tension in world events in Europe increased, the radio trade had a rapid downturn in activity.

Another factor was that the design and manufacture of domestic receivers was becoming more technically complex and wages were rising sharply under Industrial Codes. Typical of designations employed in a large factory with backup servicing facilities in the late 1930s were Serviceman, Repairer, Chassis Maker, Tester, Wirer, Installer, Fitter, Transformer Winder, Assembler, Coil Winder and Cabinet Maker. A Serviceman was a person who maintained and repaired radio sets outside of the employers place of business. A Repairer was a person who maintained and repaired radio sets inside the employers place of business, while a Tester was a person who tested receivers under working conditions with valves and sockets. The Serviceman designation was the highest paid of the group with a marginal difference twice that of a Repairer and 10 times that of a Coil Winder.

The outbreak of the War saved many manufacturers from closing down. They expanded to meet large orders for Service requirements, with some manufacturing materials and components outside their pre War broadcast field, such as hand grenade casings, aircraft carburettors, oil-less bearings, magnetic chucks and the like.

There was another honeymoon period for a few years immediately after the cessation of hostilities, but from about the mid 1950s until the early 1960s the broadcast equipment market showed an increasing decline

By the 1960s, the impact of the transistor was such as to require a complete retooling of factories, and the injection of considerable capital funds. The new technology saw the introduction of circuit boards, miniaturisation on a scale not envisaged a few years earlier and manufacturing techniques vastly different from those previously practised. The low voltage requirement of the transistor, and later the integrated circuit, resulted in an upsurge in the demand for personal portables with miniaturisation being taken to the point where a radio could be worn on the wrist.

Notwithstanding the efforts of some factories to modernise, they could not compete with the flood of low price receivers coming into the country in enormous quantities from overseas sources. Some organisations saw the challenge as too much, and closed their doors. Others were taken over by bigger manufacturers, desperate to survive in a rapidly falling sales environment. One by one they ceased production, and today, the domestic radio manufacturing industry in Australia is history.

Even the transmitter giants, AWA and STC who provided so much of the transmitting stations' equipment and components for well over half a century have had to take a back seat in the market with the importation of solid state transmitters from Canada, USA, Japan and other sources since about 1983.

AUSTRALIAN RADIO TECHNICAL SERVICES AND PATENTS COMPANY LTD

Patents have played an important role in the broadcasting industry. In 1927, the Australian Government entered into an agreement with Amalgamated Wireless (A/Asia) Ltd, whereby the company received a payment based on threepence per listener's licence per month for the use of all patents owned and controlled by AWA. This money came out of the licence fee paid by listeners and collected by the Government.

Although AWA controlled a large number of patents, there were important patents held by other companies, and in 1933 the Government gave 12 months notice of cancellation of the agreement.

Another company with a large interest in patents was Standard Telephones and Cables Pty Ltd (now Alcatel Australia). It had a Patents Department which co-ordinated all patent activities.

One of the company's most important patents was Australian Patent No 16552/20 associated with the superheterodyne receiver. Originally filed in Paris in 1917, it was later assigned to Western Electric Company, London and to Standard Telephones and Cables Pty Ltd, Sydney in 1926. The company received considerable royalty payments on receivers manufactured in Australia up to 1930 when the patent expired.

Many patents were granted for inventions associated with radio transmitters manufactured in Australia for use in Australia and overseas.

Over some 75 years, the company filed an estimated 8000 patents with more than 170 employees being nominated as the inventor.

In the early 1930s, a group of major radio traders formed Radio Interests Ltd to protect their radio patent interests by Neutrodyne

Pty Ltd, a Melbourne-based company which owned the Australian rights to the US Hazeltine radio patents, was not a member and separately licensed a number of companies to use its patents. Chairman of Directors of Radio Interests Ltd was Richard Kennell, Chief Engineer and Manager, James Manufacturing Company and Chief Engineer, New System Telephones Pty Ltd. He was also a Councillor of The Institution of Radio Engineers (Australia). Manager/Secretary was Reg Burchell a former member of the Commonwealth Parliament for 10 years.

Although the Neutrodyne organisation at first declined to join the group, agreement was reached and in December 1933 a new organisation known as Australian Radio Technical Services and Patents Ltd (ARTS & P) was formed. The objective was to have a single body to administer licensing arrangements and to take legal action to protect patents. The major patent holders of the group were Philips, AWA and STC.

The group mounted their first court action in 1934 against Stromberg-Carlson (A/Asia) Ltd with respect to a patent controlled by STC.

A manufacturer using patents held by members of the group was required to pay a basic annual charge determined by the number and types of valves, excluding rectifier, used in each receiver. Each receiver so licensed carried a stick-on transfer with a letter which identified the year it was licensed and these labels are now a valuable reference for collectors of vintage receivers in identifying the year in which a particular receiver was licensed.

Manufacturers paid a royalty based on the number of valves. The rate per valve excluding the rectifier varied from three shillings and sixpence up to 2000 valves decreasing to three shillings up to 18000 valves and falling to two shillings where the total number of valves exceeded 443000.

The organisation fulfilled its function for many years to the period when major local manufacture of radio receivers ceased about the 1960s. Its activities were terminated in the 1970s.

The Company published a number of Bulletins, with the first appearing on 9 August 1934 and the last during 1960.

Technical Bulletins issued during 1942 are typical of subjects covered by the Bulletins. They included:

- No 117, The Design of High Pass Filters for Bass Tone Control.
- No 118, Parallel–T RC System.
- No 119, Design, Construction and Performance Characteristics of a Miniature Four valve Superheterodyne Receiver.
- No 120, Noise Suppression.
- No 121, Factors Affecting Design of the Detector System for FM Receivers.

In addition to the Australian Radio Technical Services and Patents Co., Ltd, another group known as the Australian Radio Manufacturers Patents Association Ltd was active in the 1930s. The objects of the Association were to promote the manufacturing interests of its members and to mould the general body of Radio Manufacturers into a cohesive and single-minded association. In particular, it rendered a service to members by giving them a complete knowledge of patents and to form a buying pool for securing overseas patents direct.

In 1937, the President was L P R Bean of Stromberg-Carlson (A/Asia) Ltd and the Technical Committee comprised:

C H Norville, Chief Engineer, Breville Radio Pty Ltd;
W A Syme, Proprietor, W A Syme and Co.;
N H Buchanan, Chief Engineer, Sterling Radio;
J N Briton, Chief Engineer, Briton Electrical and Radio Pty Ltd;
C Slade, Proprietor, Slade Radio and Test Equipment;
H A Warby;
A W Scott, Chief Engineer, Stromberg-Carlson (A/Asia) Ltd.

TECHNICAL PUBLICATIONS

The birth of the radio press was almost coincident with the commencement of public demand for radio apparatus. Magazines were published with a range of titles, with the majority originating in Great Britain frequently employing the word 'wireless', while those of USA origin preferred 'radio'.

It is understood that 'radio' was first used at the 1903 protocol in Berlin when the Germans pushed it forward because the British and Americans had adopted the word 'wireless'.

Even before the end of 1923 when broadcasting officially commenced in Australia, there were shops which sold radio parts — mostly imported — with Amateur station operators and hobbyists being the main customers. Magazines were also imported to meet the demand of the growing army of radio enthusiasts eager to learn more of the latest overseas developments in the new science. Typical of magazines imported from Great Britain were 'The Wireless World', 'Popular Wireless', 'The Broadcaster', 'Amateur Wireless', 'Practical Wireless', and 'Wireless Engineer' while USA magazines included 'Radio', 'Radio News', 'Radio Craft', 'FM & Television', 'C Q' and 'Q S T'.

Early Australian publishers showed no particular preference for titles of their magazines, some using the word 'radio', while others used 'wireless'. With the advent of broadcasting, articles on Broadcasting Technology and the station programs became a feature of many of the publications. They catered for a wide cross-section of the community, including the technical expert, experimenter, hobbyist, the novice and the listener. Some were devoted exclusively to Amateur station work.

Magazines published in Australia and in circulation in the 1920s, and the year of their first issue include:

- 'Sea, Land and Air' – 1918.
- 'The Wireless Weekly' – 1922.
- 'The Australasian Wireless Review '– 1923.
- 'Western Wireless' – 1923.
- 'Radio in Australia and New Zealand' – 1923.
- 'Radio Experimenter' – 1923.
- 'The Boy's Wireless News' – 1924.
- 'Experimental Radio Broadcast News' – 1924.
- 'The South Australian Wireless (Monthly) and Radio Magazine' – 1924. (Changed to 'South Australian Wireless and Radio Weekly' – 1925.)
- 'The Homecraft Magazine' – 1925.
- 'The Listener-In' – 1925.
- 'Radio Broadcast' – 1925.
- 'The Queensland Radio News' – 1925.
- 'Popular Radio Weekly' – 1925.
- 'Radio' – 1927.
- 'CQ' – 1927.
- 'QTC' – 1927 and others.

Many of the publications started with, or later changed to, other titles. Some ceased publication less than a year after first publication.

During the 1930s, more than 35 new titles published in Australia appeared on the scene.

Just prior to the Second World War, there were at least 200 magazines and journals from various countries available for reference purposes to people interested in the technical side of Radio Engineering.

Some of those of Australian origin include 'Radio Trade Annual of Australia', an annual publication of the radio industry – 1933; 'Radio Review of Australia', a monthly technical publication incorporating the Proceedings of The Institution of Radio Engineers (Australia) – 1931; 'Radio Retailer of Australia', a weekly trade journal covering the radio industry – 1930; 'Broadcasting Business Year Book', containing a wide cross-section of reference material relevant to the business of broadcasting – 1935; 'Broadcasting Business', a weekly business paper for Commercial broadcasting activities – 1934; 'ERDA', the official organ of the Electrical and Radio Association of NSW – 1930; 'Radio Review of Australia' – 1931; 'Listeners Weekly and Screen News', covering radio programs, topical radio and screen articles – 1935; 'Radio Pictorial of Australia', a radio pictorial of broadcasting activities for listeners – 1935; 'The Broadcaster', a weekly magazine containing programs, technical features and general radio information - 1934; 'Australasian Radio World', a monthly technical magazine - 1936; 'Australian Radio News', a weekly journal containing program details and technical articles - 1933; 'Teleradio', a weekly publication containing program and technical aspects of broadcasting - 1933; 'The Queensland Electrical and Radio World', a trade publication with financial, trade and technical articles - 1936; 'The Wireless Weekly', now one of the longest running radio periodicals in the world. The first edition of 'The Wireless Weekly' comprising 12 pages, appeared on 4 August 1922; the title was changed to 'Radio and Hobbies Australia' in April 1939; to 'Radio, Television and Hobbies' in February 1955; to 'Electronics Australia' in April 1965, and to 'Electronics Australia with ETI', in 1990. First Editor of 'The Wireless Weekly' was William Maclardy. He was followed by Arthur Watt.

Australian Radio Publications Ltd with Head Office at 30 Carrington Street, Sydney and Branch Office, Mingay Publishing Company, 422 Little Collins Street, Melbourne were the major contributors to the great range of publications which became available to the broadcasting industry beginning in the 1930s. In 1936, they were publishers of 'Broadcasting Business', 'Broadcasting Business Year Book', 'Radio Retailer of Australia', 'Radio Review' and 'Radio Trade Annual'.

Managing Director was Oswald Mingay; Technical Editor, James Edwards; Assistant Editor, K H M Denny; with Interstate Representatives being C R Porter, Brisbane; Ronand Catt, Adelaide; Walter Coxon, Perth; and R T Sparks, Melbourne.

Over the years there have also been many publications produced at irregular intervals, with some not being available to the public, including: 'AWA Technical Review'; 'Philips Technical Communications'; 'Philips Technical Review'; 'Proceedings of The Institution of Engineers, Australia'; 'Philips Research Report'; 'Proceedings of The Institution of Radio and Electronics Engineers, Australia'; 'Proceedings of The Institution of Radio Engineers (Australia)'; 'Radiotronics'; 'The Telecommunications Journal of Australia'. There were also publications by Amalgamated Wireless (A/Asia) Ltd; Australian Broadcasting Authority; Australian Broadcasting Control Board; Australian Broadcasting Commission; Australian Broadcasting Company; Australian Broadcasting Corporation; Australian Broadcasting Tribunal; Australian Post Office; Department of Communications; Department of Transport and Communications; Greater Publications Pty Ltd; 'Broadcasting and Television Year Book'; National Transmission Agency; Postal Electrical Society of Victoria; Radio Section, PMG's Department; Research Laboratories, PMG's Department; Telecom Broadcasting; Telecommunications Museum and Engineering Historical Committee; The Radio Research Board and many others.

The Reed Business Publishing monthly magazine 'Broadcast Engineering News' with a 1996 circulation of 3650 copies has for many years been a valuable source of technical information and news for technical staff in the broadcasting industry. Regular features include Radio station technology, Pro studio news, Field production, Equipment Updates and others. In 1998, Editor was Phil Sandberg and Assistant Editor was Ross Gow.

The many catalogues, handbooks, brochures, instruction and data sheets published by many firms have also, over the years, been a source of valuable information to those Engineers, Technicians and other workers responsible for the design and operation of broadcasting equipment as well as to domestic receiver Servicemen and hobbyists.

A large item of equipment, such as a transmitter, was as a general rule, provided with one or more handbooks describing in detail the circuitry, design aspects, installation procedure, maintenance requirements, valve and component details and other appropriate details. Studio equipment was usually catered for by a collection of small handbooks, brochures etc, of the various major items such as amplifiers, control desk, microphones, turntables, pick-ups, test equipment, power supplies etc.

Most manufacturers of domestic receivers provided Radio Service Manuals, Data Sheets, Service Bulletins or News Sheets concerning their products. These publications usually included circuit diagrams, design features, component details, voltages at various points on the chassis and other details to assist the Serviceman in maintaining the facility. Some also provided Technical Data Sheets describing typical faults found in the equipment as reported from various sources.

The hobbyist from earliest times, had a wide range of catalogues from which to choose components or fully assembled receivers. Typical of catalogues issued in the 1920s and 1930s were those prepared by Adelaide Radio Company; Amalgamated Wireless (A/Asia) Ltd; Australian General Electric Co., Ltd; L P R Bean and Co.; Bloch and Gerber Ltd; Burgin Electric Co.; Colville Moore Wireless Supplies; Commonwealth Moulding and Electric Co.; Eastern Trading Co.; Eclipse Radio Pty Ltd; Efco Manufacturing Co., Ltd; Electricity House; Fox and Macgillycuddy Ltd; Grace Bros, Ltd; Hardy's Radio Stores; Hartleys; Harringtons Ltd; Alfred Harvey Pty Ltd; A G Healing Ltd; Homecraft Pty Ltd; International Radio Co., Ltd; David Jones Ltd; Kriesler Radio Co., Ltd; Lekmek Radio Laboratories; Levenson's Radio; Louis Coen Wireless Pty Ltd; Martin de Launay Ltd; Wm J McLellan; Morris and Co., Radio; Norris and Skelly Wireless Pty Ltd; Murdochs Ltd; Noyes Bros, Ltd; Peto and Radford; Philips Lamps (A/Asia) Ltd; Price's Radio; Radio Corporation Pty Ltd; Radiokes; Ramsay and Sharp Co., Ltd; RCS Radio; R W Reynolds Ltd; A Robotham Pty Ltd; Rola Co. (Aust.), Pty Ltd; South Australian Radio Co.; Stromberg-Carlson; Speakers (A/Asia) Ltd; The Leviathan; The Wireless Shop; Thom and Smith; Tracksons; United Distributors Ltd; Universal Electric Co.; Veals; Wills and Paton Pty Ltd and others.

Some of these publications contained much more information than a list of components. For instance, the 1934 catalogue issued by Levenson's Radio, 226 Pitt Street, Sydney comprised 224 pages and was profusely illustrated. It contained Easiway Home Assembly Construction Charts for battery and mains powered receivers, including a range of short wave, console, portable, midget and crystal receivers; wave traps; battery eliminators; noise and line filters, and a series of charts for fault-finding in receivers.

The Levensons Radio Circuit Portfolio with construction details of 16 radio sets including crystal set and battery receivers from one to five valve models, short wave adapters, wave trap, add-on RF and AF stages, was another of their publications.

Another very popular publication was 'The Homecraft Magazine' published by the House of Homecrafts which had been founded at the turn of the century by Mr P H McElroy. The business grew rapidly and by the early 1920s the headquarters building comprising a basement and three floors at 211 Swanston Street, Melbourne, was a hive of activity supplying the needs of experimenters and hobbyists throughout the Commonwealth. To encourage hobbyists, McElroy decided to publish a magazine to cover a wide range of scientific subjects but with emphasis on radio.

The first of 'The Homecraft Magazine' was published on 1 June 1925 with Technical Expert being Stan Hosken. Stan was a major contributor of technical articles on Radio Engineering topics and also conducted the Questions and Answers column where he provided answers on a wide range of technical problems sent in by readers. He had been associated with wireless since 1908 and in later years played a major role in Broadcast Engineering in the National Broadcasting Service controlled by the Postmaster General's Department. He entered the Department's Engineering Branch in 1914 and was subsequently involved in the construction of the short wave transmitter VLR Lyndhurst and the 10 kW water cooled MF transmitter installed for 6WF in 1924. He later served as Officer-in-Charge at 3WV Dooen and 3LO/3AR Sydenham. He retired from the Department in 1954.

One early publication of particular interest is the 'Universal Radio Guide and Encyclopedia' for 1933–34. It was Edited by A Mackenzie and published by the Radio Publications Department of F J Palmer and Son Ltd, Sydney. In the Foreword, the Publisher commented as follows:

'This Journal has been compiled with the object of providing as much information as possible upon the subjects of broadcasting stations and popular technical matter as considered advisable.'

It included contributions by well-known people on a wide range of subjects related to radio with emphasis on broadcasting. Contributors included Norm Gilmour, Harry Brown, Oswald Anderson, Ernest Fisk, James Millen, George Grammer, Emil Voigt, H A Warby, Y B F Groeneveld and A Mackenzie.

In more recent times, the Federal Publishing Company has produced a number of interesting Electronics Australia publications dealing with historical aspects of Broadcasting Technology. They include:

- 'The Best of Australia's Wireless Weekly in 1927', published 1985.
- 'Discovering Vintage Radio', by Peter Lankshear, 1992.
- 'The Dawn of Australia's Radio Broadcasting', by Philip Geeves, 1993.

Although the market is well supplied with books, as distinct from magazine type publications, detailing broadcasting in Australia they are in the main, heavily biased towards the programming side of broadcasting; the people behind the microphone; the social implications of broadcasting; criticisms of broadcasting managers; station histories etc. They include:

- 'Let's Look at Radio', Federation of Australian Broadcasters, Sydney, 1948.
- 'Broadcasting in Australia', Ian Mackay, Melbourne University Press, Melbourne, 1957.
- 'Life Has Been Wonderful', George H Patterson, Ure Smith, Sydney, 1956.
- 'The Magic Spark', R R Walker, Hawthorn Press, Melbourne, 1973.
- 'Inside the ABC — A Piece of Australian History', Frank Dixon, Hawthorn Press, Melbourne, 1975.
- 'Life with Aunty — 40 Years with the ABC', Ellis Blain, Methuen of Australia, Sydney, 1977.
- 'Broadcast and Be Damned — The ABC's First Two Decades', Alan Thomas, Globe Press, Fitzroy, 1980.
- '3YB — Pioneer of Country Broadcasting in Victoria, 1931–1981', Hugh Adams, 1981.
- 'Sounds Real — Radio in Everyday Life', C S Higgins and P D Moss, University of Queensland Press, St Lucia, 1982.
- 'Out of the Bakelite Box — The Heyday of Australian Radio', Jacqueline Kent, Angus and Robertson, Sydney, 1983.
- 'Wonderful Wireless — Reminiscence of the stars of Australia's live radio', Nancy Bridges, Methuen Australia, North Ryde, 1983.
- 'Something in the Air — A History of Radio in Australia', Colin Jones, Kangaroo Press Ltd, Kenthurst, 1995.
- 'Great Company — The Story of 1260 3SR', Bill Morvell, Associated Broadcast Services Ltd, Ballarat, 1986.
- 'This is the ABC — The Australian Broadcasting Commission 1932–1983', K S Inglis, Melbourne University Press, Melbourne, 1983.
- 'The First Sixty Years 1924–84', David J Towler, 5DN Macquarie, North Adelaide, 1984.
- 'Dial 1179 — The 3KZ Story', R R Walker, Lloyd O'Neil, South Yarra, 1984.
- 'From Wireless to Radio — The 3DB Story', Bill McLaughlin, The Herald and Wireless Weekly Times, Melbourne, 1985;

and many others.

In comparison, books — except those published as Government publications and training texts — published on the technology of broadcasting by Australian authors are few in number.

Without question, the best-known is 'Radiotron Designers Handbook', sold worldwide with an estimated 280000 copies being sold by 1950. There would be very few Engineers and Technicians involved in Radio and Audio Engineering who have not used the book as a reference source particularly in design applications. Author was Fritz Langford-Smith of AWA. The publication first appeared as a booklet in 1932 followed by increasing larger volumes as the Second Edition in 1935 and the Third Edition in 1940. It was in such demand during the years of the Second World War that it was reprinted nine times in Australia as well by companies in USA and UK. In 1952, a massive Fourth Edition comprising nearly 1500 pages appeared. It too, was reprinted, with the last reprinting taking place during 1963. In 1996, Audio Amateur Publications Inc., a USA business reproduced the Fourth Edition in CD-Rom with access via Adobe Acrobat Reader.

Other books by Australian Authors on Broadcast Engineering Technology include:

- 'Wireless', J W Robinson and G Williams, The Read Press Ltd, Brisbane, 1926.
- 'A History of Radio in South Australia, 1897–1977', J F Ross, Adelaide, 1978.
- 'Handbook for Radio Engineering Managers', J F Ross, Butterworths, London, 1980.
- 'Australian Radio, The Technical Story 1923–83', Winston Muscio, Kangaroo Press, Kenthurst, 1984.
- 'The Concise Radio Handbook', R C Humphery, circa 1936.

One of the most widely-known Technical Editors of the 1930s was Don Knock who had been associated with a number of publications at various times.

Don began his career in England as an Apprentice Mechanical Engineer but became interested in radio in 1911 while a schoolboy at Wigan Grammar School. During the War, he joined the Royal Naval Air Service. When it came time to enter the civilian work force upon discharge, he decided to try his luck in the radio field. His first job was with Sterling Telephone and Electric Company Ltd which he joined in 1924. The company was one of the largest in England at the time, manufacturing a wide range of telephone and radio components. It also produced a range of fully assembled receivers under the brand name Anodion in co-operation with the Marconi Wireless Telegraph Company.

After a short period with Sterling he moved to Burndept Wireless Ltd, another large radio manufacturing company producing components and receivers under the brand name Ethophone.

In 1925, he took up a position with the British Broadcasting Company operating transmitting stations at Leeds and Bradford and a studio at Leeds.

Don migrated to Australia in 1926 with his first job being Sales Engineer with Amplion (A/Asia) Ltd, Sydney.

During the period 1928–29, he was Technical Editor of 'Wireless Weekly' and 'Radio in Australia and New Zealand'.

Following involvement in the construction of broadcasting station 2MO Gunnedah which went to air on 16 January 1931 he became foundation Technical Editor in 1932 of 'Radio Monthly'. This was followed by appointment as Technical Editor of 'Australian Radio News', published by the Bulletin Newspaper Co., Ltd, Sydney. 'The Australian Radio News' was a weekly magazine devoted to the interests of the Listener, the Wireless Amateur and the Trade. It was the official organ of the Australian Radio Artists Association, the Australian Flying Corps and the Zero Beat Radio Club.

Don was also a regular broadcaster conducting a session every Tuesday over 2SM Sydney in which he discussed anything concerning radio, either technical or topical, during the session.

He found time to undertake work as a Consultant, particularly in the design of short wave receivers and Amateur transmitters for operators who wanted something special for their rig. He was well-known to the Amateur fraternity through his station VK2NO which he operated regularly since 1927.

At one stage, he was factory representative for Radiovision and even while Technical Editor of 'Australian Radio News', made it known to readers that Radiovision 4/5 and 5/6 valve models could be obtained direct from him at discount price.

He was a contributor to 'Ham Notes' in 'The Australasian Radio World' magazine with his 'Calling CQ' page during the 1940s. Some selected articles he published in 'The Bulletin' were reprinted in 'The Australasian Radio World'.

Don became a Member of The Institution of Radio Engineers (Australia) in 1937 and was still an active member in the 1960s.

A popular Editor of 'Wireless Weekly' and later, 'Radio and Hobbies' for some 30 years was John Moyle who joined the staff of

'Wireless Weekly' in 1932 after moving to Sydney from Melbourne where he had been a journalist and enthusiastic radio Amateur station operator.

Following work as 'Wireless Weekly' Technical Editor and a period as Acting Editor, he transferred to 'Radio and Hobbies' as Technical Editor when 'Wireless Weekly' gave way to 'Radio and Hobbies' in April 1939.

Within 12 months he was appointed to the position of Editor of the magazine.

John played a major role in the design and development of broadcast receivers which could be constructed by the hobbyist. Well-known contributions included Little Jim, a single valve set employing a 6A6 valve as both regenerative detector and audio amplifier; the 4/39, later revamped as the Little General, a four valve AC powered receiver; Pentagrid three; an eight valve Majestic radiogram and many others.

In 1941, he joined the RAAF as a Commissioned Officer rising to the rank of Squadron Leader in the Directorate of Telecommunications and Radar where he was in charge of Technical Administration at Headquarters in Melbourne. He played a major part in the preparation of Radar Manuals and also lectured in Radar at the Officers Staff College.

On discharge from the RAAF, he returned to his former position with 'Radio and Hobbies' where he remained until 1960.

Soon after taking up duty, he became involved in the design and production in collaboration with 'Radio and Hobbies' staff of portable transceivers, hi-fi amplifiers, pick-ups, loudspeakers, and other project works.

John had a long-time interest in recorded music, contributing many articles on the subject and was founder of the Sydney Recorded Music Society.

For many years he played an active role with the NSW Division of the Wireless Institute of Australia serving periods as Councillor and as President. From about 1931, he designed and built a range of transmitters and receivers for use on various bands. He was also an active member of The Institution of Radio Engineers (Australia), being a Senior Member.

'Radio and Hobbies' Technical staff who assisted John in many of his Post War projects included Neville Williams, Ray Howe, Bill Moore, Derrick Williamson, Maurice Findlay and others.

One of the most widely-known Technical Editors of more recent times was W N (Neville) Williams. Neville became interested in radio whilst at school constructing his first crystal set. In 1933, he joined Reliance Radio Co. (A/Asia), which had been established the previous year by N S T Craven at 47 York Street, Sydney, later to become the site of the AWA building and its roof top tower, still a feature of the area in 1998.

Neville gained valuable experience in the assembly, testing and servicing of receivers which in 1933 included seven models with well-known models being the Phoenix and Reliance-York models. The company also produced a range of popular receiver kit sets.

In 1936, he moved to Amalgamated Wireless Valve Company working in the Ashfield Applications Laboratory and later transferring to Head Office where he became involved in the preparation of company Technical documents including valve data sheets, Radiotron bulletins, 'Radiotronics' magazine and the Third Edition of 'The Radiotron Designers Handbook' under Fritz Langford-Smith. He also spent time as a lecturer at the Marconi School of Wireless.

In 1941 when Editor, John Moyle left to join the RAAF, Neville took up appointment as Acting Editor and Technical Editor of 'Radio and Hobbies' and began a career in Technical Journalism that continued for some 42 years. When he retired in 1983, he was Editor-in-Chief with the magazine which by then was known as 'Electronics Australia'. He continued association with the magazine as a freelance writer with one of his most popular contributions being the series 'When I Think Back', first published in February 1989. The articles were an important feature of the magazine being published up to the time of his death in November 1996. Neville had been associated with the magazine for 56 years.

In 1982, he was made a Fellow of The Institution of Radio and Electronics Engineers, Australia having joined The Institution as Associate Member in 1946.

EXHIBITIONS

Radio Exhibitions have been a feature of the radio industry dating back prior to the commencement of broadcasting, and still form an important part of the industry today. The Exhibitions have been wonderful opportunities for manufacturers, agents, Consulting Engineers and representatives to display the latest products of radio technology, and for the public to witness the most recent products of development. Over the years, the Exhibitions have been organised or sponsored by various groups such as Branches of the Wireless Institute of Australia, Royal Shows, Radio Clubs and in more recent times, by The Institution of Radio and Electronics Engineers, Australia in conjunction with its Conventions and The IREE Society.

The first major Radio Exhibition in Australia was held under the auspices of the Sydney Radio Club and with Oswald Mingay, Secretary of the Wireless Institute of Australia playing a major role in its organisation.

The Exhibition was opened on 22 September 1922 in a Church Hall in Pitt Street, Sydney, by His Excellency, Sir Walter Davidson, Governor of New South Wales.

A large crowd of visitors were treated to the wonders of broadcasting by Amateur experimenters together with a large display of radio equipment and components following opening of the Exhibition. The Club President, Mr R C Marsden, an Amateur station operator gave a demonstration of the working of a radio receiver feeding into a public address amplifier which he had built himself.

On 12 December of the same year, the Western Australian branch of the WIA organised an Exhibition in Perth.

In view of mounting public interest at the time concerning the possible establishment of broadcasting in Australia, a number of importers and companies formed an organising group and mounted a comprehensive display of radio receivers, components and other appropriate equipment at the Sydney Royal Show in April 1923. The firms included:

- The Universal Electric Company with a locally assembled three valve Armstrong Super Regenerative receiver demonstrated publically for the first time at the Show by Mr Fry of the Company. Listeners were thrilled to hear a program being broadcast by an Amateur experimental station in far away Melbourne.

  On display were also kit sets for the Armstrong circuit receiver, Radiotron and Cunningham valves, Baldwin headphones, transformers and other components.
- The Home Electric with a Federal two valve receiver and a range of Federal and De Forest components including De Forest valves.
- Anthony Hordern and Sons with a display of radio components and batteries. One feature of the display was the erection of a very large aerial 30 metres high and 80 metres long with an invitation extended to receiver owners to bring in their receivers for a trial with the aerial.

Later in the same year, Ossie Mingay as Director and Major W H Newman a well-known radio experimenter and early member of the New South Wales Division of the Wireless Institute, together with another local identity, organised a very successful Wireless and Electrical Exhibition in the Sydney Town Hall between 3 and 8 December. More than 12000 people paid for admission and not only was it a financial success for the organisers, but it set the pattern for other exhibitions in following years.

At the time of the Exhibition, station 2SB (2BL) had already been commissioned and 2FC was undergoing final tests and went to air on 5 December at the time the Exhibition was in full swing. The official opening of 2FC did not take place until 10 January

1924, but the owners were keen to begin transmissions before the Exhibition closed so that its rival 2SB did not steal the limelight during the Exhibition.

The Postmaster General, the Hon William Gerrard Gibson, who had been Postmaster General since 9 February 1923 and who was closely associated with approving the conditions for the establishment of broadcasting, forwarded a message to the organisers of the Exhibition at Ossie Mingay's suggestion in which he said:

> 'I am hopeful that the advent of Wireless Broadcasting will prove a great boon, especially to the people in the country districts, as its successful development should place them virtually in the position of the city dwellers who obtain their news in the morning and evening. This should go far towards removing the isolation now existing in the outback districts. I hope that all that is expected of wireless will be realised.'

The message with photograph of the Postmaster General was printed as a souvenir leaflet, and distributed to visitors to the Exhibition.

Oswald (Ossie) Mingay commenced his career in the Postmaster General's Department at the Lithgow Post Office as Telegraph Messenger and in 1911 transferred to Sydney where he began work in the Telephone Department obtaining experience in manual and common battery telephone exchanges and subscribers equipment. He participated in the installation of Sydney's first automatic telephone exchange at Newtown which was commissioned in 1915.

Ossie left the Department in 1915 to join the AIF Signals serving in France and Belgium where he became involved in the operation of spark wireless telegraphy equipment and the introduction of the R type valve into receiving equipment. For a time he was Military Wireless Instructor.

After the War, whilst still in England he spent six months with the British Post Office studying their latest radio station equipment and visiting a number of radio manufacturing factories that had been making radio equipment for the Services.

On return to Australia he resumed work with the Post Office. He organised the Military Radio Association and was appointed its founding Secretary. He was a commissioned Wireless Officer in the CMF.

Ossie decided to make a career of commercial radio and left the Post Office in 1922 to take up an appointment as Manager Radio Apparatus and Telephone Department with The Burgin Electric Co., Ltd, 352 Kent Street, Sydney. The company handled Burginphone, Beco and Becolian receivers; and a range of components including Mullard ORA valves; Remler and De Forest products. He was Head of the Burgin Radio College and operated their Amateur station A2WV.

After three years, he left the company planning to make a visit to England to study the latest developments in broadcasting but a strike by Unionists prevented the ship from leaving Sydney so he cancelled arrangements and obtained a position with Harringtons Ltd being responsible for all company manufacturing operations and sales throughout New South Wales.

In 1926, Ossie established Mingay's Wireless Manufacturing Ltd in a new two-storey building in Alma Street, Darlington to manufacture a range of receivers. The Mingay Unique Super Five was one of the most popular models produced. The Sydney Radio Co., Pitt Street was one of the local stores which stocked his receivers. The business closed in 1929.

He organised Australia's first Radio Exhibition in 1922 and while serving as Secretary of the Wireless Institute of Australia, New South Wales Branch, was a driving force in establishment of The Institution of Radio Engineers. In 1930, he founded the Australian Radio College in Sydney and in the same year founded Australian Radio Publications Ltd, being Managing Editor of such publications as 'Radio and Electrical Merchant' (formerly 'The Radio Retailer') which catered for the merchandising side of radio and electrical domestic appliances and service problems; 'Radio Review of Australia' which incorporated the Proceedings of The Institution of Radio Engineers (Australia) and covering advanced technical subjects; and 'Radio Trade Annual of Australia' published for the first time in 1933 covering particulars of broadcasting station activities, Acts and Regulations, patent information, company particulars, a technical section and Who's Who in Radio.

Additionally, Ossie Mingay was Managing Director of Mingay Publishing Co., 1930–64; Radio Printing Press Pty Ltd 1938–64; and Editor Radio Electrical Publications 1930–64. One of his most popular publications was 'Mingay's Weekly'.

During the Second World War, he was a Captain in Australian Army Signals 1940–42 and with the formation of the Radio Division of the Directorate in June 1942, he was released from the Army to become Radio Production Manager under Colonel Jones.

In January 1943, Colonel Jones sent Ossie to USA to investigate a number of supply problems. He returned 12 months later. Shortly after return in early 1944, he asked to be released in order to return to Sydney and to his own business.

Ossie sold his business in 1961 and retired in 1964. He was awarded the MBE in 1966 for 'services to the electrical industry'.

In recognition of his contribution to the industry, The Institution of Radio and Electronics Engineers, Australia, set up the 'Oswald Mingay Award' with the aim to encourage improvement in the ability of members of the profession to make good presentations of technical (and other) matters related to Electronic Engineering and technical audiences.

The Award was for presentation to:

- Students, either Senior Secondary School, a Technical College or proceeding to their first degree at a University or any other Institution of Tertiary Education, or
- More senior members of the profession.

By the time the 1925 Royal Easter Show was held, broadcasting had been well-established in Sydney and Radio Shops were well-stocked with receivers and a large range of components and kit sets. Some organisations had begun full scale manufacture of domestic receivers. Firms which exhibited at the Show included:

- Western Electric (Australia) Ltd, with a display of receivers made by WE in England. They included a crystal set and valve receivers from one valve to five valve models, WE components and two water cooled transmitting valves.
- United Distributors Ltd, display drew large crowds throughout the period of the Show. It featured a large umbrella type cage aerial, a number of receivers manufactured by the firm and an extensive range of components including loudspeakers, headphones, AF and RF transformers, fixed and variable capacitors, grid-leaks, dials, knobs, rheostats, terminal posts, variometers, inductors, coil mounts, valves, valve sockets, plugs, jacks, insulators, switches, amplifier units and the 'Umakit' home construction kits from single to five models designated Simple, Selective, Unidyne and Australian Neutrodyne. The top of the range, the Australian Neutrodyne comprised two stages of RF amplification, detector and two AF stages. Working models of the kit sets were on display and sale of the kits was very brisk. Another of the company designed receivers was the five valve Beard de Luxe using an Australdyne circuit with the entire receiver including loudspeaker and batteries being incorporated in a highly polished walnut cabinet of registered design with a hinged panel to allow easy access to controls.
- Anthony Hordern and Sons Ltd, with receivers manufactured by the company under the brand name Hordernia, with two, four and five valve models on display. One of the four valve models was built into a writing bureau. Included in the display of components were Manhattan and Western Electric loudspeakers, Jefferson and All-American transformers, Weston meters, Remler intermediate transformers for superheterodyne receivers, and others.
- Amalgamated Wireless (A/Asia) Ltd, with a range of locally made and imported receivers. They included Radiola Superheterodyne in a horizontal Sheraton cabinet with a loop aerial on a hinged door; Radiola crystal set; Radiola III, a four

valve receiver; and Radiola IV, similar to Radiola III but with reaction. All were housed in polished maple cabinets. A Marconiphone V2, a two valve receiver noted for long distance reception was one of several imported models on display. A combined 500 watt radio telephone transmitter and communications receiver developed for radiocommunications to remote centres created considerable interest as did a Radiola IV receiver encased in a glass case enabling the components to be viewed with the receiver fully operational.
The display included a full range of Amplion loudspeakers available from the company.

- Colville-Moore Wireless Supplies Ltd, displayed a wide range of locally designed and manufactured Colmovox receivers from one valve to seven valve models in various cabinet styles.
- Wiles Radio and Electric Supplies with a display of locally manufactured receivers of the Wondertone series ranging from single valve to five valve models. The receivers were also available as kit sets with full construction details. The stand also contained a selection of components sold by the company.

The year 1924, was a great year for the radio industry in Melbourne. Stations 3AR and 3LO began transmission, and two Exhibitions were held. The Victorian Division of the Wireless Institute of Australia held a Wireless and Electrical Exhibition in the Melbourne Town Hall over the period 14 May to 19 May.

The Exhibition was such a success that it was followed up the next year by an expanded Exhibition at Wirth's Park. Traders booked out the floor space within a few days of commencement of negotiations. In November 1924, the All-Australian Manufacturers Exhibition was held in Melbourne. Included in the display was a 500 watt broadcast transmitter and studio equipment provided by AWA.

The Council of the Victorian Radio Association became the organising body for Radio Exhibitions held in Melbourne, and in 1934 celebrated its 10th annual show with a magnificent Exhibition. At the time the President was A F Brash who was also Chairman of the Association's Retailers Section. The name Brash has been associated with music house business for some 132 years and with radio retailing since 1927, the year that 3DB became the fourth broadcasting station to be on air in Melbourne. Under the name Brash Holdings Ltd in 1991, the company operated as an electronics goods and music chain through 374 stores. The company founder was Marcus Brash. However, by 1998 the company ceased to be involved in electronics goods.

Following the success of Exhibitions in Sydney and Melbourne, groups in Adelaide and Brisbane announced plans to mount similar displays.

In Adelaide, the Railways Institute Radio Club took the initiative and it was widely supported by traders, broadcasters and experimenters. The Exhibition was opened on Saturday, 12 December 1925 and it was such a success that the organisers extended the display for a further two days. In the Trade Section, Harris Scarfe Ltd, received the Champion Prize for the best display. It comprised a comprehensive range of fully assembled receivers, kit sets, and components of Sterling, Igranic, Brown, Condor, Cardwell and King Radio. The best trade Crystal Set Prize was awarded to Edison, Swan Electric Co., the Two Valve Reflex Receiver Award went to an Ediswan Cabinet set and the Transatlantic Wireless Co., was awarded the Three Valve Prize with a receiver using an Armstrong circuit. The Four Valve Reflexed Receiver Prize went to Wireless Supplies Ltd, while the Four Valve Ordinary Set Prize was awarded to Harringtons Ltd. Andrews Radio Store was also awarded a Prize for its Gilfillan Neutrodyne Receiver. In the Amateur Section, some novel receivers included a crystal set made with two safety pins, a nail detector and a cup with two coils. Visitors were enthralled to hear 5CL clearly with the receiver and a pair of headphones. Another employed a cotton reel coil, a meat skewer and crystal detector. It also impressed the judges with its reception capability.

The extent of confidence in the radio industry was evident by the large amount of radio equipment and components on display. At the time, there were 194 Registered Dealers in South Australia with the majority being located in the Adelaide City business area. Fully assembled receivers on display by various organisations included:

* Harris Scarfe Ltd
  with Sterling, Threeflex, Anodion, Radiola Six, and King Neutrodyne Five models.
* Duncan and Fraser
  with Operadio and locally produced Dunfra valve and crystal receivers.
* Andrews Radio Stores
  with Gilfillan Neutrodyne Five.
* Edison, Swan Electrical Co., Ltd
  with Ediswan crystal set and Ediswan TooVee Radiophone models.
* Newton, McLaren Ltd
  with Stromberg-Carlson Newkrodyne Six, General Radio Superheterodyne Eight and locally produced MAK crystal and valve models.
* Harringtons Ltd
  with Gilfillan Neutrodyne Four.
* Transatlantic Wireless Manufacturing Co.
  with locally produced Newkrodyne three and four valve models.
* Wireless Supplies Ltd
  with locally produced superheterodyne four valve reflex and TRF models.
* James Marshall and Co., Ltd
  with a seven valve receiver and combined gramophone/receiver.
* Millswood Auto and Radio Co.
  with locally produced two valve reflex and four valve TRF receivers.

In 1926, local traders promoted their own Exhibition. It was held in the Adelaide Town Hall which was barely large enough to cater for the 22 stands and the 10000 people who thronged to see it during the five days that it was open to the public. Major exhibitors and some of the receivers displayed included:

* W H Rook and Co.
  with Kellogg Wavemaster models.
* Bullock Cycle and Radio Stores
  with locally produced Reactodyne models.
* Adelaide Radio Company
  with Silver Marshall Six and locally produced Arcoflex models.
* Andrews Radio Store
  with FADA Neutro Junior, Neutrolette and Queen Anne Desk models.
  Duncan and Fraser
  with Operadio and locally produced Dunfra four, five and six valve models.
* Noyes Bros Pty Ltd
  with assembled Igranic superheterodyne kit set receivers.
* Harringtons Ltd
  with Gilfillan Neutrodyne and locally produced Imperia models.
* Louis Coen Wireless (SA) Ltd
  with Pinnacle Superheterodyne Seven and Pinnacle Five models.
* 5CL Radio and Electrical Co.
  with locally produced Demon Neutrodyne models.
* Newton, McLaren Ltd
  with General Radio Superheterodyne Eight, Stromberg-Carlson Neutrodyne Six and a range of locally produced MAK models.
* United Distributors Ltd
  with locally produced Udisco receivers using the Capacidyne circuit.
* Behrens-Thiem Co.
  with locally produced De Luxe Five in a Queen Anne cabinet design.
* Metro-Electrical Radio
  with Gilfillan Neutrodyne Five and Siemens Three models.
* L Whibley
  with locally produced Superheterodyne Eight and TRF Five in Elizabethan period cabinet designs.

* Edison, Swan Electric Co.
  with Compactum Two model.
* A W Dobbie and Co. Ltd
  with King Neutrodyne and locally produced Alphadyne Two, Three and Four models.
* Harland Radio and Electrical Co.
  with locally produced Harland models.

In 1927, the Adelaide traders followed up with their second Exhibition, but this time, it was held in the much larger Exhibition Building to accommodate the large number of people who flocked to these displays to view the latest in Radio Technology. The site proved to be ideal, and was used for many subsequent exhibitions and displays.

Brisbane's effort of mounting a major Radio and Electrical Exhibition in 1926, the year after broadcasting commenced in the city, was a great success. It was held in the Exhibition Concert Hall during Show Week and was opened on 9 August 1926 by the Mayor. The speech was broadcast by 4QG from a demonstration studio on site.

Many local radio distributors, shop owners and manufacturers exhibited at the Exhibition. They included:

* Siemens Aust., Pty Ltd, Perry House, Brisbane.
  In addition to electrical and telephone produces manufactured by the company, radio items included headphones; loudspeakers; lightning arresters; ebonite sheets, rods and tubes; AF transformers; batteries; crystal sets; crystal valve set and multivalve receivers.
* The Edison-Swan Electric Co., Ltd, 156 Creek Street, Brisbane.
  Items on display included Ediswan valves, Dulcivox and Televox loudspeakers, headphones, variometers, A batteries, crystal sets, variable capacitors, AF transformers, Ever-Ready B batteries and others.
  The central feature of the display was an operational radio receiver beautifully in-laid in colour with Chinese motifs. Demonstrations of its performance drew large and appreciative crowds.
* The Lawrence and Hanson Electrical Co., Ltd, Charlotte Street, Brisbane.
  Radio items of interest included Philips valves and battery chargers; Sterling Dinkie and Primax loudspeakers; Hart and Hegeman radio accessories and Colombia B batteries.
* Home Radio Service Ltd, 1st Floor, Courier Building, Brisbane.
  The comprehensive display included Brandes Matched Tone headphones; Brandes Table Talker and Brandola loudspeakers; Argentite and Russell Hertzite crystals; De Forest valves; Tower Scientific loudspeaker; Spitfire loudspeaker and headphones; H and H radio materials; Emmco products; Clyde A and B batteries, Stromberg-Carlson 6 valve Neutrodyne receiver; De Forest F5AL and D17 receivers; Kennedy 3, 4 and 5 valve receivers; Rico-Dyne 5 valve receiver, Splitdorf 5 valve receiver; Crosley 1, 2 and 3 valve receivers, and a Minuet P3, a three valve portable receiver about the size of a camera.
* J B Chandler and Co., 45 Adelaide Street, Brisbane.
  The display comprised a wide range of electrical and radio equipment with radio items including a large selection of components and receivers from the company's large stock. Included was a Gloriola crystal set made in the company workshop, and a Freshman Masterpiece 5 valve receiver in a handsome cabinet of Queensland Maple.
* Amisco (Q) Ltd, Queen Street, Brisbane.
  Major items included Burginphone receivers and Winchester radio batteries.
* Noyes Bros, (Sydney) Ltd, Perry House, Albert Street, Brisbane.
  Items included Igranic radio components; Igranic superheterodyne six valve kit set plus fully assembled and working receiver; Brown loudspeakers, headphones, microphone amplifier; gramophone adaptor; Oldham accumulators; Philips radio products; Ferranti parts.

One of the prize winners for home constructed receivers was George Payne who was awarded First Prize for best three valve receiver.

Another exhibition held in Brisbane was the Radio and Electrical Exhibition held in the Bohemia Theatre, South Brisbane, 16–30 July 1928. The organisers claimed it to be the most successful held in Australia. Originally planned to run for one week, it was extended to two weeks because of public demand for the extension.

More than 22 stands were occupied by major distributors, with displays by Amalgamated Wireless (A/Asia) Ltd, Trackson Bros Ltd, Edgar V Hudson Ltd, Harringtons Ltd, Australian General Electric Co., Noyes Bros (Sydney) Ltd, Mullard-Ferranti and Philips being amongst the most popular.

Edgar V Hudson Ltd who claimed to have the largest stock of radio components in the Commonwealth at the time, mounted a very comprehensive display with brands including Mullard, Ferranti, Radiokes, De Jur, Amperite, Emmco, Deal, Grodan, Racon, Simplex, Marinette, Advance, Mayolian, Luxor, Audiola, Cyldon, Sonochorde, Ormond, Frost, BTH, Majestic, Lotus, Kolster, Belling-Lee, H and H, Collett, Ultra Handy, Fellows, Dayfan, Polar and others.

The Amateur Competition Stall conducted by the 'Queensland Radio News' and 'The Broadcast Bulletin' was a very popular area with the visitors. The 4QG Silver Cup for the best made exhibit was won by Keith Elliott. Of 31 prizes presented, 14 were awarded to members of the Wooloowin Radio Club. Vern Kenna who was placed third in the 'Best Home Made Piece of Apparatus' Section displayed a hot wire ammeter of unusual design. Another item he entered, but which did not win a prize, was a variable grid-leak. The device was later taken up by a manufacturer and produced commercially in a modified form. It comprised a wooden rod about 12 mm diameter and 100 mm long, impregnated with carbon granule dust recovered from a telephone set and impregnated by, what Vern described, as 'a secret process'. A threaded brass rod was mounted above and parallel with the wooden rod and a ball bearing in a groove made contact with the rod as it was moved along by rotating the threaded brass rod. The thread and ball contact provided a fine adjustment which resulted in resistance variation from zero to about 5 megohms.

Capital city exhibitions continued up to the Second World War with the Radio and Electrical Exhibition held in Sydney Town Hall, 26 March to 5 April 1930 being one of the highlights of the 1930s.

On 26 March, while anchored at Genoa in the Mediterranean Sea, Guglielmo Marconi, one of the world's foremost Radio Pioneers, pressed a telegraph key on his yacht 'Elettra' and operated apparatus in Sydney to switch on some 2800 electric lamps at the Exhibition.

Trials involving Marconi and Ernest Fisk of AWA the previous week had indicated the practicability of the exercise. However, ionospheric conditions were far from ideal at the time for a direct link to Sydney, so a series of relays and the beam wireless system were used.

A radiotelephone link was set up and information conveyed to Marconi that everything was in readiness. At that time the Town Hall was dimly lit. When the Chairman of the Committee, Mr P H Pettyfor, advised Marconi to proceed, a signal was transmitted from a 500 watt transmitter on board the 'Elettra'.

The signal was picked up by a Marconi station at Dorchester in England and relayed from there to the beam wireless station at Grimsby where it was transmitted and then received by the beam receiving station at Rockbank in Victoria. From Rockbank the signal was sent over the Post Office landline system to the Sydney Town Hall. The receiving station at La Perouse near Sydney was used as a backup signal source. AWA Engineer, Murray Johnson was responsible for setting up the technical facilities in Australia.

The signal on arrival at the Town Hall, operated a relay which caused the electric lamps to be switched on, signifying the official opening of the Red Seal Scheme featured as a portion of the Exhibition.

Marconi never visited Australia, but the charisma of his name lent magic to any occasion. One observer commented that many of those in attendance at the Hall 'became intensely emotional, sensing the presence of an invisible hand'.

Marconi sent the following message to the organisers of the Exhibition:

'It affords me great pleasure to perform the ceremony of officially lighting the symbol of the Red Seal Scheme inaugurated by the Electrical and Radio Development Association in New South Wales. It is no more than 30 years since I transmitted the first faint wireless signals across the Atlantic ocean, and today we demonstrate that it is possible by wireless to bring powerful currents into operation at the other ends of the earth. I heartily congratulate Australia on the strides made there during recent years in world-wide wireless communication.'

The range of exhibits was wider than at any Exhibition previously mounted in Sydney. Radio equipment and components displayed included:

* Colville-Moore Wireless Supplies Ltd.
  A display of receivers comprising All-Electric Two and Three valve sets, radiogram combination, battery-operated short wave receiver, several console models and a two valve short wave adaptor.
* Reg Rose and Co., Ltd.
  Jensen electrodynamic loudspeakers, Thordason amplifiers and a selection of receivers imported from USA.
* Australian General Electric Industries Ltd.
  An RCA 'Sun' radio phonograph combination in a handsome cabinet and embodying many new control features; Range of RCA receivers including Models 60, 44, 21 and 22; electrodynamic loudspeaker Models 106 and 100B; a full range of Radiotron receiving valves; a car radio receiver with dashboard control unit; and a recently diagnosed battery-operated receiver employing screen grid valves.
* Mullard Radio Co. (Aust.), Ltd.
  A 4 kW Mullard silica transmitting valve as employed at 7ZR Hobart, Ferranti set analyser and other test instruments, Ferranti transformers, Mullard type loudspeaker, Ferranti AC receiver, Mullard receiving valves including recently introduced AC filament types.
* Amplion (Aust.) Ltd.
  Astor Aladdin and Little Astor receivers; a six valve receiver employing screen grid valves; the new AB6 Amplion loudspeaker; and a display of other models.
* Amalgamated Wireless (A/Asia) Ltd.
  A range of domestic receivers designed and manufactured by the company.
* Stromberg-Carlson (A/Asia) Ltd.
  A three valve AC powered locally produced receiver, a four valve receiver with screen grid valve, Jewel instruments and meters, a range of cabinets and components for home constructors.
* Noyes Bros (Sydney) Pty Ltd.
  Seyon, Igranic and Philips Radioplayer receivers; Jensen, Amplion and Philips loudspeakers; Columbia batteries; Oldham accumulators; and radio parts. The Igranic receiver was a Neutrosonic Seven model, very popular with country listeners.
* Standard Telephones and Cables (A/Asia) Ltd.
  A range of STC radio receivers and a selection of various cabinet styles employed with STC receivers.
* W Harry Wiles.
  Steinite receivers including eight valve radio-gram combination, console and table models.
* S Hoffnung and Co., Ltd.
  A full range of Ever-Ready batteries used for radio purposes.
* Electricity Meter Manufacturing Co., Ltd.
  A selection of radio receivers and radio components manufactured by the company together with a special display showing the various stages of production of audio and power transformers.
* Philips Lamps (A/Asia) Ltd.
  A range of Philips Radioplayer receivers including Models 2510, 2516 and 2802 together with loudspeakers, valves, battery eliminators and other radio components.

The Exhibition was an outstanding success with the involvement of Marconi having a lot to do with the excitement surrounding the event. It was estimated that some 3000 people attended the light ceremony.

On 12 October 1980, just 50 years after the historic event, Marconi's daughter participated in a re-enactment of the 1930 event. However, the 'Elettra' was no longer in service. After Marconi's death in 1937, the Italian Government purchased the vessel and kept it as a museum piece. In 1944, during a bombing raid, it was hit and sunk in the port of Zara. Subsequently, parts of the hull were salvaged and erected on shore as a commemorative monument.

At 8.50 pm on 12 October, Marconi's daughter at a ceremony, caused a signal to be transmitted from the monument at Bologna. The signal switched on lights on the Sydney Harbour Bridge and in the Opera House, and triggered a fireworks display.

On 30 March 1995, the re-enactment was repeated as part of celebrations to commemorate 100 years of radio. On this occasion, the most modern technology was employed. From a yacht in Genoa Harbour, Italian President Scalfaro sent a signal via satellite to active a laser display on the Opera House roof. A video link was established between the Sydney Town Hall and the yacht in Genoa Harbour with Sydney Lord Mayor Frank Sartor making a speech.

Even though the nation was in a state of economic difficulty in the early 1930s, Exhibitions drew large crowds and new models of broadcast receivers resulted in many enquiries as to availability. In the Radio and Electrical Exhibition held in Sydney in early 1933, nearly 60000 people attended compared to 27000 the previous year. Similar Exhibitions were held in Melbourne and Adelaide resulting in attendances of 35000 and 30000 visitors respectively. Two Exhibitions were held in Perth during 1933 and both were well attended.

The 1934 Sydney Exhibition was an even greater success with more than 70000 people attending. During the year, the Electrical and Radio Association held the Electrical and Radio Ball, the first of its kind organised by the Electrical and Radio Industry in Australia. It was an outstanding success with about 2000 being in attendance. Those responsible for organising the Ball were Bill Wing, AWA; E P Bennett, Hecla Electrics; W Wright, STC and R P Godfrey, Godfrey Ltd.

The 1934 exhibitors who displayed the latest in radio receivers and components included:

* Noyes Bros (Sydney) Ltd.
  The firm displayed a range of receivers including Stromberg-Carlson models with push-pull output, visual tuning, AVC and sound focussing technology, and AWA models featuring the newly released A and B audio system of amplification and Rotorvision tuning dial which provided instant sight tuning on a finely graduated dial.
* Westcott Hazell and Co., Ltd.
  Claimed to be the largest distributor of STC receivers, the company exhibited the full range of recently released models. Also exhibited was an RCA Victor Auto radio receiver which was said to have picked up a New Zealand station when the car was travelling down Parramatta Road, Sydney at 35 miles per hour.
* E F Wilks and Co., Ltd.
  The stand featured four newly released Gulbransen superheterodyne receivers including five valve Junior Model 54, six valve Model 64, seven valve Model 74, and 10 valve De Luxe. Model 74 featured a Revolving Cabinet which enabled the loudspeaker to project sound to any part of the listening room.
* British General Electric Co.
  The display comprised a range of recently released Genalex receivers fitted with Osram Catkin all metal valves. Included were Dapper5 and Bureaudio, a five valve superheterodyne receiver with the cabinet accommodating the receiver plus a fold-up writing shelf. Other items on display were GEC Home

Broadcaster carbon microphone and an automatic record changer which could be loaded with eight records.

* Smith, Sons, and Rees Ltd.
  The stand housed a selection of Radio Corporation Pty Ltd receivers including Astor Mickey Mouse, Caliph and Sultan models.
* Standard Telephone and Cables (A/Asia) Ltd.
  The company exhibited the complete range of 1934 models including five and six valve receivers and an eight valve all-wave radiogram.
* Anthony Horderns.
  Radio receivers on display comprised the Uni superheterodyne receiver in two models, and a range of Lekmek receivers.
* Hazell and Moore Ltd.
  One of the leaders in the wholesale radio trade, the display comprised a comprehensive range of AWA receivers including an Automobile set for which the company were distributors, full range of Airzone 1934 models, and five and six valve Red Seal superheterodyne receivers.
* David Jones Ltd.
  The company exhibited selections from many manufacturers and included the Olympic seven valve all-wave set, one of the best-selling models in their Radio Department.
* Metropolitan Electric Co., Ltd.
  A range of Radiokes products were on display and included Kit Sets, a company registered trade name and assembled receivers made up from the Kit Set range including the International All Wave Seven, AC and battery-powered versions, the Super-Superhet and the 1933 Standard AC and battery-powered models.
* Amalgamated Wireless (A/Asia) Ltd.
  The company exhibited eight new receiver models including the Fisk Radiola Grand, an all-wave receiver with automatic record changing gramophone unit; the Fisk Radiola 140, a seven valve set; the Fisk Radiola 138, a six valve battery-powered set; and four Radiolette models, one of which employed a five valve reflex superheterodyne circuit.
* C Winkworth and Son.
  The display comprised the recently released Essex All Wave Seven, which was housed in a Patrician cabinet of Queensland walnut and a five valve Karn superheterodyne set, Model N2.
* Harringtons Ltd.
  The display was prepared with the assistance of Raycophone staff and comprised a complete range of Raycophone receivers from five to eight valve versions in mantel and console cabinets. At the previous Exhibition, the Harringtons Ltd display of Raycophone products won the company the 'Radio Retailer of Australia' Silver Cup.

Other companies and organisations which displayed goods associated with the broadcasting industry included Ever-Ready Co. (Great Britain), Ltd, batteries; Electricity Meter Mfg Co., receivers and components; Elvy and Co., Ltd, receivers; The Lawrence and Hanson Electrical Co., Ltd, Lekmek receivers; Beale and Co., receivers and cabinets; Philips Lamps (A/Asia) Ltd, transmitting and receiving components; Speakers (A/Asia) Ltd, Amplion loudspeakers, microphones and batteries; W Harry Wiles, receivers; W G Watson and Co., Ltd, receivers and test equipment; Australian Radio News, magazines; Postmaster General's Department, portion of one of seven new broadcast transmitters made by STC for the National Broadcasting Service; Wireless Weekly, magazines and portraits of radio personalities; Nock and Kirby Ltd, Bel-a-Tone receivers; and Grace Bros, Ltd, receivers.

Included among more recent Exhibitions of interest to Radio Engineers and Technical staff were the IREECON 91 International Exhibition held at the Sydney Convention and Exhibition Centre in July 1991, and the Sydney section of the Society of Motion Picture and Television Engineers (SMPTE) Conference and Exhibition held at Sydney's Darling Harbour 31 August–3 September 1992.

A total of 76 organisations and firms were represented at the IREECON 91 Exhibition. Although sound broadcasting technology was well represented, it was outnumbered by equipment displays related to television, space communications, software packages, electronic security and optical fibre technology.

More than 80 exhibitors displayed a wide range of hardware at the SMPTE Exhibition. One organisation which participated for the first time was the Australian Film, Television and Radio School.

TECHNICAL MANAGERS

A feature of the Australian manufacturing industry was that many of the firms were started up, or managed by people who had a technical background in Radio Engineering. They included Professional Engineers, Radio Mechanics, Radio Servicemen, Amateur radio station operators, former Ship's Operators and even 'well-to-do' hobbyists who had been 'bitten by the radio bug'.

Most were able to combine Technical expertise with Management expertise and were very successful in running the enterprise. A few found management of the business, particularly Sales and Accountancy too much to handle, and the ventures were short lived. Partnerships of two people were very common, with in some cases, both partners being technically trained, while others were partnerships of a Technical Expert and a Management Expert, usually an Accountant.

Included among well-known radio manufacturing, assembly or large service businesses formed or headed by Technically Trained people are:

* Ace Amplifiers Ltd
  Ernest Beard.
* Adelaide Radio Company
  Lance Jones.
* Advance Radio Products
  Fred Clarke.
* Airzone (1931) Ltd
  Claude Plowman.
* Alan S Duke Pty Ltd
  Alan Duke.
* Amalgamated Wireless (A/Asia) Ltd
  Ernest Fisk.
* Baty C S and Co.
  Stan Baty.
* Bland Radio Ltd
  William Bland.
* Block and Gerber
  Eugene Gerber.
* Borthwick, Everitt and Co.
  Kevin Borthwick and Arthur Everitt.
* Breville Radio Pty Ltd
  Charles Norville and William O'Brien.
* Briton Electrical and Radio Co
  John Briton.
* Brunswick Amplifiers
  Alfred Garth.
* Buckerfield and Jervois-Draysey
  Roy Buckerfield.
* Clubb, A M and Co.
  Alex Clubb.
* Condenser Speciality Co.
  Keith Davison.
* Conlon Radio Co.
  Samuel Conlon.
* Colville Wireless Equipment Co., Pty Ltd
  Sydney Colville.
* Crown Manufacturing Co.
  J B Phillips.
* Edgar V Hudson Pty Ltd
  Frederick Hoe.
* Efco Manufacturing Co., Ltd
  Richard Facer.

* ECM Co., Ltd
  Oliver Turner.
* Essanay Pty Ltd
  Walter Sweeney and Ernest Austin.
* Fox and MacGillicuddy Ltd
  Albert Fox.
* Grand Opera Radio
  Leslie Yelland.
* Hardy W R and Co.
  Walter Hardy.
* Harris D and Co.
  David Harris.
* Hartleys Teleray
  Harold Hartley.
* Henry G Small and Co.
  Henry Small.
* Howard Radio Pty Ltd
  Frederick Henderson.
* Huckell Radio
  Edward Huckell.
* International Radio Co., Ltd
  Charles Forrest.
* Irvine Radio and Electrical Co.
  David Irvine.
* Kerr and Muir Wireless Pty Ltd
  William Kerr.
* Keystone Radio
  Clarence Maddern.
* Kriesler (A/Asia) Pty Ltd
  Rae Weingott.
* Lekmek (A/Asia) Ltd
  Norman Gilmour.
* Limberts Ltd
  Charles Limbert.
* Lovetts Radio
  Leonard Lovett.
* McKenzie and Wallace
  Miss Florence Wallace (Mrs McKenzie).
* Metropolitan Electric Co., Ltd
  (Later Radiokes Ltd)
  Keith Stokes.
* Nomis Radio Co.
  Laurie Simon.
* Paramount Radio Manufacturing Co.
  Donald Maskall.
* Paton Electrical Instrument Co.
  Frederick Paton.
* Radio Maintenance Pty Ltd
  Charles Martin.
* Radix Power Supplies
  Edgar Dix.
* Raycophone Ltd
  Raymond Allsop.
* RCS Radio
  Ronald Bell.
* Reg Rose and Co., Ltd
  Reg Rose.
* Slades Radio Pty Ltd
  Charles Slade.
* Standardised Products
  Reg Ray.
* Stromberg-Carlson (A/Asia) Pty Ltd
  Leslie Bean.
* Thom and Smith Pty Ltd
  Frederick Thom and John Smith.
* Trackson Bros, Ltd
  Phil Trackson.
* Tree Radio-Electric Co.
  Ernest Tree.
* Unbehaun and Johnstone
  Carl Unbehaun.
* Werring Radio Co.
  Oscar Werring.
* Wetless Electric Manufacturing Co.
  A P J Wetless.
* Whatmuff Radio and Electrical Service Pty Ltd
  Clifton Whatmuff.
* Winter's Wireless
  W F Winter.
* Wireless Tasmania Pty Ltd
  Arthur Warner.

There were also many people with a Radio Technical background who occupied the dual role of Station Manager and Chief Engineer at Commercial broadcasting stations. In some cases they even built the technical plant and undertook regular announcing duties.

They include:

*	2AY	Albury	John Dower
*	2BE	Bega	John Kerr
*	2BH	Broken Hill	Roy Allen
*	2CA	Canberra	Albert John Ryan
*	2CH	Sydney	Hamilton Huntley
*	2GF	Grafton	Reg Fox and Stephen O'Shea
*	2GN	Goulburn	Herbert Lewis
*	2KO	Newcastle	George Hood
*	2KM	Kempsey	Bernard Harte
*	2MO	Gunnedah	Marcus Oliver and Ron Gibson
*	2PK	Parkes	J E Parris
*	2RG	Griffith	Bill Gamble
*	2TM	Tamworth	Tom Whitcomb
*	2WL	Wollongong	Russell Yeldon
*	2XN	Lismore	George Exton
*	3BA	Ballarat	Warne Wilson
*	3BO	Bendigo	J P Banney
*	3HA	Hamilton	Rupert Fitts and Eric Cunningham
*	3HS	Horsham	Arch Hopton
*	3MB	Birchip	Bert Aldridge
*	3TR	Sale	Eric Evans
*	3UL	Warragul	Murray Clyne
*	3YB	Warrnambool	Harry Fuller
*	4CA	Cairns	Frank Basden and Fred Pearce
*	4GR	Toowoomba	Ted Gold
*	4KZ	Innisfail	Al Kirton
*	4LG	Longreach	Russel Nicholson
*	4PM	Port Moresby	Kendall Frank
*	4SB	Kingaroy	Ben Whitnall
*	4TO	Townsville	Arnold Lawrence and Harold Cox
*	4ZR	Roma	A H Buzacott and Cecil Taylor
*	6GE	Geraldton	Herbert Ebrall
*	6KG	Kalgoorlie	Norman Simmons and Henry Taylor
*	7BU	Burnie	Cliff Trethewey and Hugh Parish
*	7DY	Derby	Doug Charlton
*	7HT	Hobart	John Howell and Frank Klein
*	7LA	Launceston	Vivian Brooker
*	7QT	Queenstown	Herb Ebrall
*	7SD	Scottsdale	Bert Scetrine
*	7UV	Ulverstone	Bill Launder-Cridge

Many of those people occupied similar positions at more than one broadcasting station. Some of the station callsigns have since disappeared. It was common practice at many country stations for technical staff to also perform duty as Announcer/Chief Announcer/Programmer/Salesman and other positions.

In recent years with the rapid growth in recording technology and the great demand by broadcasters, the public and others for recorded material, many businesses have been established to meet the demand. Engineers have figured prominently in the formation of these organisations with some occupying the dual role of Studio Manager/Engineer or Producer/Engineer. In the mid 1980s, there were more than 50 technically qualified people occupying these dual roles.

Consulting Engineers have played a major role in the planning, design, installation, commissioning and management of Radio Engineering facilities since the earliest days of broadcasting. Most managed their own businesses, and in many cases, the Engineer was the sole member of the business. In others, the Consultant employed Engineers, Technicians and Administration staff.

Although some Consultants specialised in the design, modification and assembly of domestic radio receivers, particularly during the 1920s, other specialised in the planning and commissioning of complete broadcasting stations including studios, transmitters, aerials and associated facilities. In the case of A Class stations 2FC and 3LO, AWA managed the technical facilities after commissioning.

A recent project which involved a number of consultants was the establishment of a facility to enable rebroadcasting of local AM and FM stations in the Sydney Harbour tunnel for the benefit of motorists with radio equipped cars.

Comsyst (Australia) Pty Ltd was contractor for the design and installation of the system. The company Project Engineer was Michael Woodman.

Basically, the system which was commissioned during 1992, received, combined, and transmitted up to 17 AM/FM services as well as a number of VHF/UHF mobile channels along the 2.4 km carriageway of the tunnel.

The broadcast signals were received off air by aerials designed by Consultant John S Innes and were sited on the top of one of the bridge pylons. The 10 AM aerials were ferrite aerials and each was tied to a 30 dB preamplifier tuned to a single AM frequency. The 7 FM aerials were combined through a multicoupler.

The AM signals were fed to AM stereo Deltek exciters feeding 10 RME locally manufactured 250 watt transmitters whose outputs were fed to an LC combining network.

The FM signals were fed to 7 Harris THE–1 FM 55 watt transmitters and combined via a cavity filter network.

The combined AM/FM signals were fed to crossband couplers and thence to a suspended leaky coaxial transmitting aerial manufactured by RFS. The aerial consisted of a standard coaxial cable with a continuous slot cut in its outer sheath.

In-line amplifiers manufactured by Long Distance Technologies, an Adelaide-based organisation were provided to boost the FM signals but the AM service provided 95 % coverage in the tunnel with only 50 watt output from the 250 watt transmitters due to better than expected coupling performance of the leaky coaxial aerial system.

Others associated with the rebroadcast system development and installation included Consultant Peter Warhurst and Consultants Priestly and Shearman.

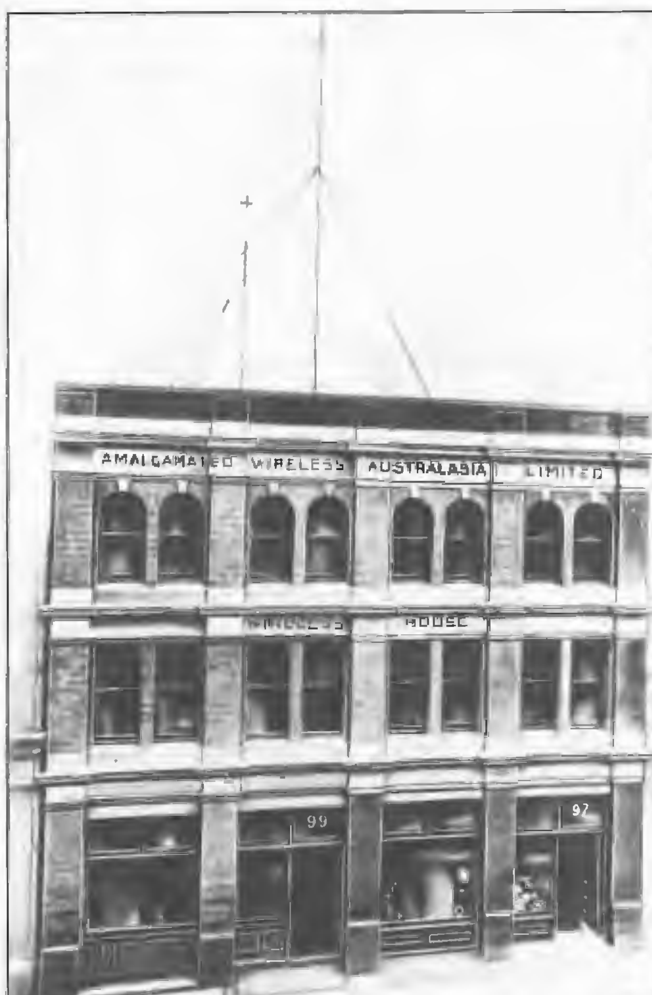
Production workshop of Transatlantic Wireless Co., Adelaide June 1926. In this small workshop staff produced 50 receivers a week under the Newkradyne brand. The receiver employed a Neutrodyne circuit and featured a glass front panel on which controls were mounted. Foreman-in-Charge, Roy Buckerfield.

Radio and Electrical Exhibition, Adelaide 1925. Champion Prize awarded to Messrs Harris Scarfe Ltd for Best Trade Display. Display prepared by Alick Clark, Manager Radio Department for 14 years. Components included Sterling, Igranic, Brown, Condor, Cardwell, King Radio and others.

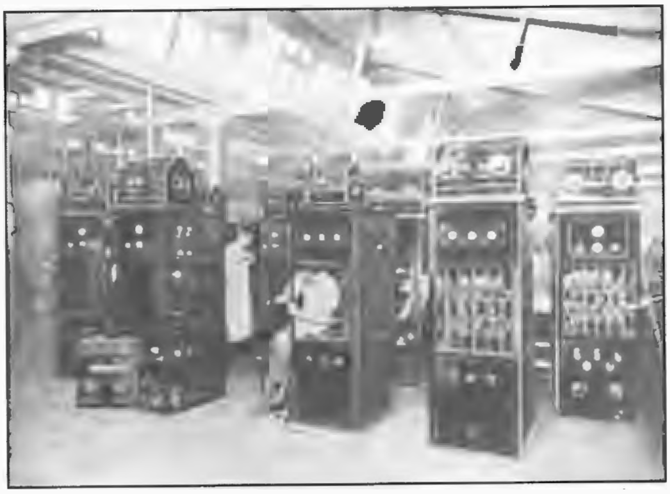
Amalgamated Wireless (A/Asia) Ltd, Radio-Electric Works at Knox Street, Darlington. The premises were occupied in 1922 when it became evident that the Clarence Street premises would not meet the future needs of the company with the introduction of broadcasting being planned by the Government. The Knox Street factory became the key centre in the production of broadcast transmitters, home receivers, ship's wireless apparatus and a multitude of radio components.

Works Manager, Ern Horner who had joined AWA as Electrical Draftsman in 1918.

Display at Radio Traders Association Exhibition, Adelaide June 1926, prepared by W H Rook and Co., agents for Kellogg USA manufactured receivers and components. Included in the display were the top of the line receivers, the Kellogg Wavemaster and Kellogg RFL7.



Wireless House, 97-99 Clarence Street, Sydney, the first headquarters and factory of Amalgamated Wireless (A/Asia) Ltd following formation of the company in 1913. In 1922, production activities were transferred to new premises at Knox Street, Sydney. The multiwire roof-top aerial was employed with the first public demonstration of broadcasting to members of the Royal Society in 1919. Technical Director and General Manager, Ernest Fisk.



Broadcast transmitters, 600 watt (nominal ½ kW) as rated at the time under construction at Amalgamated Wireless (A/Asia) Ltd, Radio-Electric Works, Sydney, early 1924. It was the first time transmitters of this power had been manufactured for broadcast purposes outside Europe and USA factories. Each transmitter comprised three racks — Modulator (AF unit), Oscillator (RF unit) and Rectifier unit. Some were employed as temporary transmitters at A Class stations pending installation by AWA of their 5000 watt transmitters.

One unit was installed at the Marconi School of Wireless, Clarence Street, Sydney. They were also employed at some Coast Radio stations as an interim measure to provide ICW transmissions pending the installation of specially designed transmitters to replace the spark systems.

A party of schoolboys being shown over the Machine Shop of the Amalgamated Wireless (A/Asia) Ltd manufacturing facility. Manufacturing was first undertaken at their Clarence Street premises soon after formation of the company in 1913 and in 1922, transferred to larger premises in Knox Street. Both factories employed overhead shafts and belt-driven machines, the standard practice at the time. Machines included turret lathes, screw cutting machines, power presses, milling and multiple drilling machines and many special purpose machines.

Production Manager, Stan Grimes former Superintendent Electrical Worshops, Sydney Municipal Council.

Amalgamated Wireless (A/Asia) Ltd valve manufacturing facility at Knox Street, Sydney premises during early 1920s. First valves produced by AWA were designated 'Expanse' with production commencing during 1920. In 1923, the Knox Street plant was upgraded and expanded to enable production of AWA type 99 valve. By 1927, many other types had been added with some 60000 valves being manufactured during the year. Production at Knox Street continued until 1931.

First Engineer-in-charge of valve development and production was David Wyles.

Amalgamated Wireless (A/Asia) Ltd, Radio-Electric Works main entrance from Parramatta Road, Ashfield. The Dodge Park facilities were officially opened in March 1931 on a site laid out with lawns and gardens and known as 'The Factory in the Garden'. Over the years, the site area and facilities were greatly expanded to cater for increased output. During the War years, some 5000 people were employed at Ashfield. The facilities were demolished in 1993.

Works Manager, Ern Horner who became Deputy General Manager of AWA in 1956.

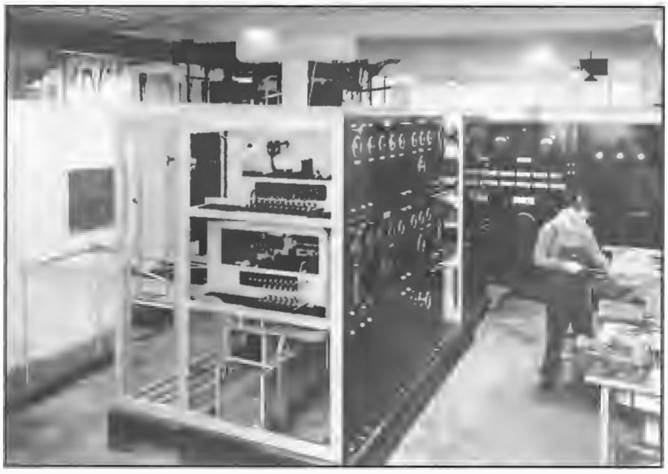
Part of the Machine Shop of the well-equipped workshop at the Amalgamated Wireless (A/Asia) Ltd manufacturing site at Ashfield set up in 1931 with the installation of modern self-powered machines replacing overhead shaft and belt-driven types of earlier years at other sites. The Ashfield works enabled the company to manufacture a wide range of components from raw materials to meet its own needs and those of the radio industry.

Works Production Superintendent, Ern Parkinson who joined AWA in 1929.

During the 1930–33 period, more than 40 transmitters were installed throughout Australia and Amalgamated Wireless (A/Asia) Ltd was well-placed to supply the demand of transmitters of all sizes. This production line shows a popular model comprising two cubicles being assembled. AWA held the licence for Commercial stations 2AY, 4TO, 4CA and 3BO and was shareholder in many others. Most of these stations were provided with AWA transmitters. Hamilton Huntley was one Engineer associated with the network. He joined AWA in 1929 as Cadet Engineer.

Assembly building Amalgamated Wireless(A/Asia) Ltd, Radio-Electric Works, Ashfield circa 1939. In 1924, receiver output by the company at another site was about 200 sets a year but by the late 1930s production reached 50000 sets a year with 20 models. A single receiver required some 1200 piece parts and an uninterrupted supply of components and parts was a major problem in maintaining a high output schedule.

Engineer-in-charge of Broadcast Receiver Development was Albert Martin who joined AWA in 1928.



One of the first MF broadcast transmitters being manufactured by Standard Telephones and Cables Ltd in the Chippendale factory during the mid 1930s. The design was produced for NBS stations 7NT, 2NR, 4QN, 3GI and 6GF. The first station, 7NT Kelso was commissioned in August 1935. The final stage employed 4220B water cooled valves. Director and Transmission Manager, Tim Bore.

MF broadcast transmitter in course of construction at Amalgamated Wireless (A/Asia) Ltd, Radio-Electric Works, Ashfield circa 1939. By end 1939, there were 26 National and 100 Commercial broadcasting stations in operation throughout Australia. Maximum power of National stations was 10 kW, and 2 kW for Commercial stations.

Amalgamated Wireless Valve Co., Pty Ltd valve manufacturing facility at Ashfield in 1950s. The company was formed in 1932 with the first valves being produced in 1933. During 1937, some 750000 valves were produced with octal base types being a major development at the time. In 1956, the Ashfield factory was closed following establishment of a factory at Rydalmere.

Engineer-in-charge in 1932 was Fritz Langford-Smith who later became Chief Applications Engineer.

One of a number of 55 kW MF broadcast transmitters designed and manufactured by Standard Telephones and Cables Ltd in their Liverpool factory during 1950s-60s.

The majority were installed at National Broadcasting Service stations but some were exported to Thailand and Vietnam. The first unit was commissioned at 2NR Lawrence in July 1958. Engineers associated with the design and manufacture of these transmitters included David Abercrombie, Phil Humphries and Clive Pickup.

An STC HF broadcast transmitter employing air blast cooled valves undergoing final acceptance tests at the company's Liverpool factory prior to shipment overseas in mid 1960s. The HF range 3.2-28 MHz was covered in six bands using pneumatically operated switches. Output power was 100 kW.

Company Engineer, Rex Giles was involved in one of the overseas installations.

Workman carrying out alignment and adjustment of high grade STC HF communications type receiver employed with the National Broadcasting Service by the Postmaster General's Department 1960s for reception of ABC programs from HF Inland Service transmitters as alternative program source in the event of failure of the program line. Engineer-in-charge, Winston Muscio.

Chapter Eight

Broadcast Engineering Education and Research Organisations

Broadcast Engineering Education

Pre 1930 Era

Up until about 1920, the only formal education and training in Australia in both the theoretical and practical aspects of wireless, was provided by the Marconi School of Wireless. The School was conducted by Amalgamated Wireless (A/Asia) Ltd with emphasis being on training staff as Ship's Wireless Operators and for the Coast Radio Stations.

Courses were available through some correspondence schools in Australia but were confined to theoretical instruction with limited opportunity to obtain practical experience.

From about 1920, with the establishment of broadcasting under way in some overseas countries, and the possibility of the technology being introduced into Australia, it was evident from public opinion that there was a need to provide instruction in the emerging technology, and in particular, to those people who had expectation of making a career in broadcasting when it became a reality here.

Whilst some individuals and groups, mainly Experimenters or Amateur Operators began to provide tuition, one of the first to publicly advertise the availability of classes was the Radio College, 23 Lang Street, Sydney with Frank Basil Cooke as Principal. In an advertisement in 9 March 1923 issue of 'Wireless Weekly', the College indicated 'Applications are now being received for forming the next class'. Cooke was a well-known experimenter with transmissions being conducted at that time from 'The Manor', Clifton Gardens on 440 metres. Basil Cooke was in charge of David Jones' Radio Department and was official operator of their station A2DJ. When David Jones closed down the station in mid 1924, Cooke removed it to his home and continued to use the A2DJ callsign. In 1926, it was being operated from 'Dachaigh' Namoi Road, Northbridge.

With the commencement of broadcasting in Australia in 1923, there was an immediate demand for technical people capable of designing, installing and operating transmitters and for Mechanics and Servicemen to build, install and maintain the great number of domestic receivers being purchased by listeners.

Although there was a dearth of professionally qualified Radio Engineers, there were many technically competent people who were experienced on wireless telegraphy coast stations, on ship's wireless equipment and in the operation of Experimental or Amateur stations. These latter groups were qualified in the sense that they had to pass examinations to prove their competency. However, people who decided to construct their own receivers did not require any mandatory qualifications by the authorities, and Radio Shops were hard-pressed to meet the demand for components by the do-it-yourself brigade of radio enthusiasts. Radio Clubs and the Wireless Institute conducted lectures and classes to promote the new science and to instruct thousands eager to learn.

Even Universities took up the challenge to explain the new science to the people. On 6 September 1924, two months before 5CL Adelaide was scheduled to commence transmissions, the University of Adelaide conducted a course of twelve lectures with a concurrent course of twelve hours of laboratory experiments.

The one hour long lectures commenced at noon on Saturdays followed by the experimental work. The course was open to all people over 16 years and was fully booked out.

However, those types of lectures and courses were not suitable for training the large numbers of Professional Engineers and Technicians required to meet the rapidly expanding broadcasting service of transmitting stations and studios, plus the industry required to support it.

The Decade of the 1930s

The decade of the 1930s was a period of unprecedented development and growth in Broadcast Engineering. During the period 1930 until the outbreak of the Second World War in 1939, more than 100 additional stations commenced operation, nearly one million listeners licences were issued, new businesses were established to manufacture equipment, particularly broadcast receivers and components, and the education institutions increased the amount of Radio Engineering subjects in their curricula.

At the beginning of the decade, radio training facilities were perhaps the most backward compared with other professions and trades. The reasons are best summarised as follows:

- The inability of teaching institutions to obtain suitably qualified and experienced instructors.
- Radio Engineering had not been credited with a distinct professional status. It was considered to be an appendage of Electrical Engineering.
- Developments in radio science were moving at such a rapid pace throughout the world, that textbooks and equipment became out of date or obsolete, almost overnight.
- There was no body or institution which catered for the specific interests of Professional Radio Engineers.

Operator's Certificates of Proficiency in the various radio disciples could only be obtained after the candidate had passed an appropriate examination conducted by the Postmaster General's Department who administered the Wireless Telegraphy Act and Regulations. The examination was conducted with the object of enabling the candidate to demonstrate his/her knowledge of proficiency for operation of a particular type of station.

In the mid 1930s, examinations were conducted periodically for the following certificates:

- First Class Commercial Operators Certificate of Proficiency in Radiotelegraphy and Radiotelephony.

- Second Class Commercial Operators Certificate of Proficiency in Radiotelegraphy.
- Third Class Certificate of Proficiency in Radiotelegraphy.
- Third Class Certificate of Proficiency in Radiotelephony.
- Broadcast Operators Certificate of Proficiency.
- Amateur Operators Certificate of Proficiency.

Although some candidates were able to pass examination following study from books acquired from bookshops and radio technical magazines, the majority attended instruction in classrooms or by correspondence from schools and colleges which specialised in radio courses.

In more recent times, Government Departments have discontinued involvement in the conduct of examinations and issue of certificates such as Broadcast Operators Certificate of Proficiency (BCOP) and Television Operators Certificate of Proficiency (TVOCP).

From 1 April 1994, responsibility for administration of these two certificates was taken over by a Committee comprising representatives from ABC, SBS, Commercial radio and television industries, Public Sector Union and the relevant Technical Training Institutes.

The Certificates are issued by the Training Institutes with a Central Register of Certificates being maintained by the Committee.

The Royal Melbourne Institute of Technology is one Institute which provides a Correspondence Course for students unable to attend an Institute.

COURSES

Fortunately, the need for specific courses to meet wide ranging demands of the industry was soon realised and many schools, colleges and universities were established to provide courses, or in the case of those already established, new subjects were added to the curricula.

Courses to cover the full needs of Radio Engineering were prepared on the basis of physics and Electrical Engineering with the necessary mathematical background for students to follow the applied calculations. In order to cover the full need of the Broadcast Engineering profession in particular, course administrators concluded that training had to take account of the following groups:

* **RESEARCH**
  There was a limited but definite requirement for training of staff engaged on research activities. Employers with a need for staff in the research field included Radio Research Board, Council for Industrial and Scientific Research, the PMG's Department Research Laboratories, AWA Research Laboratories, and Universities. The appropriate course was considered to be a University Science Degree with specialisation in the final year.
* **DESIGN**
  People engaged in Broadcast Engineering design activities were generally Engineers employed by PMG's Department on the National Broadcasting Service transmitting station and studio activities, together with Engineers and other staff employed in industry on Commercial transmitter design and manufacture, broadcasting studio design, and receiver design and manufacture. General opinion indicated that employers required staff with a Science or Electrical Engineering Degree or alternatively, a Diploma in Radio, Electrical or Communication Engineering.
* **STATION AND STUDIO TECHNICIANS AND OPERATORS**
  Organisations employing transmitter and studio technical staff were guided by the requirements of PMG's Department who dictated the qualifications necessary for staff engaged in that type of broadcasting work. The certified operator concept dated back to the earliest days of wireless telegraphy for ship's operators. The PMG's Department issued eight different types of certificates, but those applicable to broadcasting were the First Class Commercial Operators Certificate (Telegraphy, Telephony and Broadcasting), Second Class Commercial Operators Certificate, and Broadcast Station Operators Certificate. The latter eventually became the most widely obtained certificate by people engaged in broadcasting. There was no telegraphy test but the examination required a very wide knowledge of all phases of Broadcast Engineering principles and practices.
* **RADIO SERVICEMEN AND TESTING TECHNICIANS**
  Servicemen and testing Technicians formed the greatest number of any of the groups. They represented the rank and file of the whole broadcasting industry. A great many Servicemen were self-employed, operating one person businesses.

THE INSTITUTION OF ENGINEERS, AUSTRALIA

The Institution of Engineers, Australia was founded in October 1919 when representatives of separate Engineering organisations met in Sydney and agreed on amalgamation to form The Institution of Engineers, Australia. The Institution was formed as a new body and the separate organisations ceased to function.

Most of the organisations had been in operation for many years, with one having been founded in 1895. They included The Electrical Association of Australia, The Institute of Local Government Engineers of Australasia, The Engineering Association of New South Wales, The Melbourne University Engineering Society, The Northern Engineering Institute of NSW, The Queensland Institute of Engineers, The South Australian Institute of Engineers, The Tasmanian Institute of Engineers and The Western Australian Institution of Engineers.

The first President was Professor William Warren, Challis Professor of Engineering at the University of Sydney. Membership at the time was 1858 and included 124 Members, 1352 Associate Members and 382 non-corporate members. By 1998, The Institution has some 50000 members on its roll including 34000 Professional Engineers with nearly 12000 being in the Electrical Branch. A survey in 1965 indicated that more than half of the members in the Electrical Branch worked in the Communication/Electronics field and included many Broadcast Engineers.

In order to improve the status of the Engineering profession, one of the early actions of the first Council was to form an Examinations Committee together with a second Committee responsible for assessing practical experience of candidates applying for admission to The Institution.

The Institution was granted a Royal Charter in 1938 with the Charter defining the objectives of the organisation and confirming The Institution as the guardian of qualifications and the technical development of the profession in Australia. Membership grades at the time comprised Honorary Members, Members, Associate Members, Graduates, Students and Associates. Honorary Members, Members and Associate Members were known as Corporate Members with the exclusive right to the style 'Chartered Engineer (Australia)'.

The Royal Charter gave the Council power to assess the standard of the theoretical knowledge necessary for admission to the profession. An examination was conducted as part of the assessment process. The first examination was held in 1922 when two candidates were successful at the Associate Membership Examination. The examinations were of a very high standard and candidates needed to be well prepared. Over a 15-year period 1950 to 1965, 1255 candidates sat for the examination but only 479 passed. One of the successful candidates for this Associate Membership Examination was Doug Sanderson who spent 48 years with the Postmaster General's Department, Brisbane working on radiocommunications and broadcasting until retirement as Senior Engineer in 1989. Doug was Author of 'On Air', a history of the National Broadcasting Service in Queensland and Papua New Guinea published in 1988.

From its inception, The Institution has had an important influence on the standard of the many Engineering courses offered by education institutions and also on specific entrance qualifications for students to be accepted for the courses.

The process of accreditation was made clear by a Statement which listed qualifications which satisfied the examination requirements of The Institution. In a 1960 Statement, acceptable qualifications included:

- University Degrees.
  BE and specified B Sc, B Eng Sc,B Tech., degrees issued by University of Sydney, University of New South Wales (formerly NSW University of Technology), The University of Queensland, The University of Adelaide, The University of Tasmania, The University of Melbourne, Monash University and The University of Western Australia.
- College Diplomas.
  Specified Diplomas, Associate Diplomas, Fellowship and Associateship issued by Sydney Technical College, Queensland Institute of Technology (formerly Central Technical College), South Australian Institute of Technology (formerly SA School of Mines and Industries), Education Department of Tasmania Technical Branch, Royal Melbourne Institution of Technology (formerly Royal Melbourne Technical College), Swinburne Technical College, Gordon Institute of Technology, Footscray Technical College and Perth Technical College.
- Departmental Examinations.
  Commonwealth Public Service Examination to enable Cadet Engineers, Postmaster General's Department to qualify for advancement as Engineer, Third Division.
  The Statement also included a list of State Departmental examinations; Overseas' University Degrees, Diplomas and Certificates; and examinations by nominated Engineering Institutions.
  The organisations which formed The Institution in 1920, had been publishing papers written by their members, and this practice was continued by The Institution. First publications were a Quarterly Bulletin and an annual volume of Transactions. From about 1929, a monthly journal replaced both publications. This arrangement continued until 1958 when it began publication of Transactions.
  In more recent times The Institution has been responsible for many publications. In 1997, they included 'Engineers Australia', 'Engineering World', 'Engineering Times', 'College News', and four Transactions with the 'Journal of Electrical and Electronic Engineering' being of particular interest for members in the broadcasting industry.
  Most members are affiliated with one of four Colleges of The Institution established in the late 1980s, with Engineers in the broadcasting industry being members of the College of Electrical Engineers. At end 1997, there were 13386 College affiliates and 2592 College members of whom 1634 were registered in the electrical category of the National Engineers Register. All Colleges have a grade of Emeritus Member for retired Fellows who have provided extensive service to the College or attained a measure of eminence related to service to the profession or achieved prominence within the profession.
  In October/November 1997, a Postal Ballot was conducted on a number of issues and one change related to the governance structure of The Institution effective from early 1998. Changes included a new National Congress and Council.
  The National Congress is a broad representative body with powers to appoint members of the Council; develop and submit to members proposals for changes to the Royal Charter and By-laws; review and approve changes to the Code of Ethics and Disciplinary Regulations; and give advice and counsel to the Council.
  The Council with the exception of the powers of the National Congress is the governing body of The Institution.

THE INSTITUTION OF RADIO AND ELECTRONICS ENGINEERS, AUSTRALIA

The formation of The Institution of Radio Engineers, Australia in 1932, was a milestone in establishing Radio Engineering as a profession in its own right.

It had been registered as The Institute of Radio Engineers, Australia on 6 August 1924 with the Register-General, under the Companies Act of New South Wales with Ernest Fisk as President and Captain Toombs as Secretary.

The original subscribers comprised Sir Thomas Laby, Ernest Fisk, Jim Malone, Frank Cresswell, George Weston, Lionel Hooke, Frank Leverrier, Bill Crawford, John Mulholland, Arthur McDonald, George Apperley, Joe Reed and Samuel Toombs.

In the early 1930s, influential officers of the Wireless Institute of Australia realised that the organisation was no longer a body of purely Amateur experimenters. Membership included many well-known professionals and it was suggested that a change in name of the organisation was appropriate. However, only the NSW Division of the WIA appeared enthusiastic about the proposal, so the local members decided to make the move alone. On 29 February 1932, a Special Meeting was convened and members voted to change the name. On 15 March 1932, a Confirmation Meeting resolved that Council should take steps to form an Institute of Radio Engineers, Australia.

Although the name of the group was taken from the Institute of Radio Engineers founded in USA in 1912 as a successor to the Society of Wireless Telegraph Engineers, the word Institute was later replaced by Institution for the Australian organisation.

Wireless Institute of Australia (NSW Division) did not die. However, it rose again in 1937 following the work of some members, and today represents the Amateur radio enthusiasts of NSW as their official body.

The meeting which set up the IRE resolved that all members of the WIA (NSW Div.) be admitted to the IRE membership and that a Provisional Council be appointed to manage the affairs of the Institute pending a General Meeting. The members of the Provisional Council were Messrs Fisk (President), Mingay (Secretary), Hooke, McDonald, Crawford, Renshaw, Gilmour, Hill, Norville, Tyler, Bean, Emmeldhainz, Turner, Thom and Kennell.

The first activity of the Institute was its inaugural dinner on 30 May 1932 at which 123 members and invited guests attended.

On 20 February 1933, new Articles of Association were registered and Ernest Fisk was elected its first President.

Included among the objects for which The Institution was founded were:

- To promote the science and practice of radio telegraphy and radio telephony in all its branches and the usefulness and efficiency of persons engaged therein.
- To raise the character and status and advance the interests of the profession of radio telegraphy and radio telephony and those engaged therein.
- To increase the confidence of the mercantile and general community in the employment of recognised Engineers and Technical advisers by admitting to The Institution such persons only as shall have satisfied the Council of The Institution that they have a satisfactory knowledge of both the theory and practice of radio telegraphy and radio telephony.
- To encourage the study of radio in all its branches and to improve and elevate the general and technical knowledge of persons engaged or about to be engaged in the profession.
- To conduct examinations, to award prizes, distinctions, certificates, establish scholarships etc.
- To promote honourable practice, to repress malpractice and to settle disputed points of practice and to decide all questions of

professional usage and etiquette among persons engaged in the profession of radio telegraphy and radio telephony.

The Institution elected an Examinations Board under the chairmanship of Stanley Grime with the first examination being held in October 1933. The standard of examination was taken from the Admiralty Handbook of Wireless Telegraphy, 1931.

A Qualifications Committee under the chairmanship of Arthur McDonald was appointed with the function to carefully scrutinise and make the fullest enquiries regarding every application before same was passed on to Council for final determination.

The honour of being the first Fellow of The Institution was accorded to the President, Ernest Fisk at the Annual General Meeting in May 1933.

Divisions of The Institution were soon established in other States.

The Victorian Division was formed on 9 October 1933, just 12 months after formation of The Institution in Sydney. The first committee meeting of the Victorian Division was held in a room at the Melbourne Technical College with the Committee comprising Electrical-Commander Frank Cresswell, Chairman; Jim Malone and John Mulholland, Vice-Chairmen; Ronald Mackay, Hon. Secretary; Clive Evans, Treasurer and Messrs Hayes, Witt, Conry, Martin, Bearup, Draffin, Kauper, Henderson, Dobbyn, Kendall and Wiggins.

Ronald Mackay who was a staff member of the Melbourne Technical College, remained Secretary of the Division until 1952. The initial membership was 19 but by March 1934 it had reached 27. On 24 November 1993, over 80 members celebrated the 60th Anniversary at a function at Ian Clunies Ross Function Centre.

The inaugural Chairman, Electrical-Commander Cresswell had a long and distinguished career in radio. He began work as a Draftsman in the Electrical Engineer's Branch of the Postmaster General's Department in Melbourne in 1900, remaining with the Department until 1911 when he left to join the Navy, becoming Sub-Lieutenant Electrical Duties. From 1912 until 1915, he was RAN Fleet Wireless Officer before being appointed Director of Radio Services of the Commonwealth, a position he occupied until 1921. Subsequent positions included Radio Commander RAN; Electrical-Commander, Director of Signals and Communications RAN; and Defence Member Australian Radio Research Board. He was Author of the publication 'Syntonic Vibratory Hypothesis of Electricity and Construction of Matter'.

The third Division of The Institution to be formed took place in South Australia with a meeting in Adelaide. The inaugural Committee comprised Stan Ackland; Jack Risely; Cliff Moule; Don Gooding; Robert Oakley; Ben Wilson; Wilf Honnor; Professor Kerr-Grant, Chairman; Bert Harrington; and Harry Garth, Secretary/Treasurer. The Division held its first meeting on 1 June 1936, when 72 members attended.

The Chairman, Professor Kerr-Grant was Professor of Physics at the University of Adelaide, having held that position since 1911. He had previously been Lecturer in Physics at the School of Mines, Ballarat and Melbourne University. He took an interest in the local Wireless Institute, lecturing at meetings, providing public lectures in Radio-Physics and was a judge of exhibits at the first Radio and Electrical Exhibition held in Adelaide in 1925. He encouraged his students to gain practical experience in radio by being involved in the operation of the University's Amateur station OA5AW. He was one of the first experimenters to receive radio valves in Adelaide and developed a technique for replacing a burnt out filament and restoring the valve to an operational condition.

By 1938, Divisions had been established in Queensland and Western Australia.

Soon after its formation, The Institution approved the establishment of a Radio Society of Australia. The purpose of the Society was to cater for the interests of the large number of people engaged in radio mechanising, broadcasting, medical technology and other allied radio fields who would not normally meet the technical conditions of entry into The Institution.

The organisation and management of the Society was under the direction of The Institution whose President, Treasurer and Secretary occupied similar positions in the Society. The Society was governed by a Board of Trustees comprising 15 members in number, six of whom were appointed by the Council of the IRE.

In 1934, there were only 18 Radio Society members out of a total IRE membership of 185. By December 1935, the number had increased to 31.

It is not clear whether the Society subsequently attracted sufficient membership for its continuation after the mid 1930s because of the proliferation of radio based organisations, all competing for membership. For example, during 1933–34, groups which catered for people in the radio industry who did not require technical qualifications for their employment, included Radio Interests Ltd, Sydney; Radio Retailers Association of NSW, Sydney; Australian Federation of Broadcasting Stations, Melbourne; Radio Trades Association of WA, Perth; The Electrical and Radio Association of NSW, Sydney; The Radio and Telephone Manufacturers Association, Sydney; Electrical Federation of Queensland (Radio Trades Section), Brisbane; Victorian Radio Association, Melbourne; and Radio Industry Functions (RIF) Clubs in Capital cities.

The Electrical and Radio Association of New South Wales was formed about 1909 to deal with wage claims by electrical workers at the time, and about 1930, included 'Radio' in its title. It included a Development Section called the Electrical and Radio Development Association (ERDA) with function being dissemination of publicity and propaganda as to the advantages of radio and electricity to the population.

The Section published a monthly magazine called ERDA which was distributed to city, suburban, and country radio and electrical dealers; Government Departments; Electricity Supply Authorities; Architects and Builders throughout New South Wales. In 1934, some 2500 copies of the magazine were distributed.

The Association had a number of Sub-Committees to assist in the conduct of its operations. In 1934, the Radio Sub-Committee comprised Messrs Bill Wing, AWA; W Wright, STC; Sam Cook, David Jones Ltd; Ebb Badgery-Parker, Philips Lamps A/Asia Ltd; with R Southwell and Dan Morland, Harringtons Ltd as co-opted Members. One of the tasks of the Sub-Committee during the year was to establish Radio Week held during 28 May to 5 June 1934. ERDA engaged an experienced journalist to 'inspire literary articles in the press regarding the advantage of radio as a home entertainment media and as an advertising medium for businesses'.

In 1970, when ERDA was disbanded, an ERDA Trust Fund was created. It was known as the IREE-ERDA Fund and was administered by The IREE with the aim of fostering acquisition of knowledge in the medical electronics field.

In 1936, the then Governor-General Sir Isaac Isaacs, accepted The Institution's invitation to become The Institution's Patron. Since then, each succeeding Governor-General has honoured the organisation by becoming its Patron. His Excellency Sir William Deane was Patron during 1997–98.

The first 'Proceedings of the IRE (Australia)', Volume 1, Number 1 was published in June 1937. Early local Proceedings were published in 'Radio Review of Australia'.

By 1964, when the publication was known as 'Proceedings of The Institution of Radio and Electronics Engineers, Australia', average monthly copies printed were 2649. At the time, the publication was the only professional journal in the Southern Hemisphere which dealt exclusively with Electronics Engineering subjects. A copy was provided to each of the 2175 members.

The Proceedings was a valuable means of postgraduate education and assisted The Institution to foster its object of advancing science and knowledge.

In 1981, the 'Proceedings of the IREE' was merged with the 'Transactions on Electrical Engineering', published by The Institution of Engineers, Australia to produce a magazine titled 'Journal of Electrical and Electronics Engineering, Australia (JEEEA)'.

Another publication is 'MONITOR'. In mid 1977, the publication was known as 'MONITOR, Proceedings of The Institution of Radio and Electronics Engineer, Australia', with Heather Harriman as Editor.

In January 1980, it was known as 'MONITOR, A Publication of The Institution of Radio and Electronics Engineers, Australia' and became the official magazine of The IREE Australia with the 'Proceedings of The IREE Australia', a technical publication published quarterly from March 1980.

In 1995, 'MONITOR' officially became 'MONITOR, A Publication of The IREE Society', with Cherie Morris as Editor.

In 1996, issue Volume 21, No. 1 was titled 'MONITOR, The I E Australia Magazine for Communications and Information Technology Engineers, A Publication of The IREE Society'. Des Ireland was the new Editor.

Within a few years of establishment of The Institution, members began to consider holding an annual function to commemorate the work of early radio pioneers and in particular, Marconi's historic achievement in being the first radio pioneer to receive wireless signals which had been transmitted across the Atlantic Ocean from his transmitting station in England.

The inaugural Radio Foundation Day function was held on 12 December 1937 at the Hotel Australia, Sydney with a combined function being held in Melbourne, a dinner in Adelaide by the local Institution and a dinner in Brisbane organised by a radio trade group.

The Institution intended the Radio Foundation Day function to be an annual event as a tribute to the pioneers of wireless technology and to be held on or about 12 December, as it was on that day in 1901 that Guglielmo Marconi successfully bridged the Atlantic with wireless signals.

On the occasion of the inaugural function in Sydney, messages were received from Marconi, IRE in USA and Wireless Section of IEE in England.

At the time, the IRE had 314 members including 21 members of the Radio Society.

On 16 November 1951, a Jubilee Radio Foundation Day Commemoration was held in Sydney to mark the 50th Anniversary of Marconi's Atlantic achievement. The Presidential Address was given by John Briton, President and former Partner and Chief Engineer of Briton Electrical and Radio Pty Ltd, manufacturers of Briton brand radio receivers.

With the approaching Centenary on 12 December 2001 of Marconi's successful long-distance experiment, a number of important events have been planned by Radio Engineers.

David Edwards, then Chairman of the Hobart IREE Society Local Area Committee and a Board Member of The IREE Society played a key role in some of the activities.

On 12 December 1995, a combined dinner and technical function was held at the CSIRO Marine Laboratories in Hobart to honour the first trans-Atlantic radio communication by Marconi from a transmitting station in Cornwall to a temporary receiving facility in Newfoundland on 12 December 1901.

The year 1995 was also the centenary of Marconi's first wireless transmission from his laboratory in Italy.

The technical function was a great success, using modern technology comprising satellite and cellular direct dial phone connections and email via internet. This technology was in great contrast with that employed by Marconi 94 years ago when he employed spark wireless telegraphy transmission and coherer receiver.

Over the period 4 to 14 April 1938, The Institution organised a World Radio Convention in Sydney. It was the first World Radio Convention held within the British Empire and did a great deal to enhance the stature of The Institution as a learned body.

The proceedings were opened by His Royal Highness the Duke of Gloucester, speaking over a short wave radio circuit from London. Hundreds thronged the Great Hall of the University of Sydney to hear the speech.

It had been planned to have Guglielmo Marconi at the Convention but, unfortunately, he died on 20 July 1937.

The large number of lectures were held at the University of Sydney. Social events included a Banquet held at Hotel Australia on 4 April; a Civic Reception tendered to overseas and interstate delegates on 5 April at the Sydney Town Hall by the Lord Mayor and Lady Mayoress, Alderman and Mrs Nock; a Ball at the Trocadero on 7 April; a visit to Taronga Park Zoological Gardens; an afternoon Tea Party at the home of Sir Ernest and Lady Fisk at Lindfield; a demonstration of Stereoscopic Sound by Ray Allsop of Raycophone Ltd at Plaza Theatre on 10 April; Official Luncheon at the Trocadero on 12 April; and an Au Revoir Party at Schofield House, Point Piper on 13 April.

The Convention was an unqualified success, this being testified by the many overseas delegates, interstate and local delegates who attended the many sessions and other functions.

Included among the distinguished overseas visitors were Major General Harboard, President of the Radio Corporation of America; John Logie Baird, England; Haraden Pratt, President of The Institute of Radio Engineers (USA); Dr van der Pol, Philips, Holland; F S Hayburn, Director and Foreign Envoy Marconi Company; R Millard Ells, Managing Director Pye Radio Ltd, London; Dr J D McGee, Research Department, Electrical and Musical Industries Ltd, London; J Sanders, Department of Radio and Telegraph Technics, Dutch East Indies, and many others.

The cost of staging the Convention was met by the New South Wales Government, the radio trade and a few individuals. It was one of a number of major activities held to celebrate Australia's 150th Anniversary Celebrations.

During the Convention, 52 papers were presented on many subjects dealing with the various fields of radio technology.

Chairmen for the various sessions of the Convention comprised Sir Ernest Fisk, David Wyles, Len Schultz, Dr Geoffrey Builder, Tom Armstrong, Sid Witt, John Briton, Norm Gilmour, Arthur McDonald, Arthur Dixon and Tom Court.

The papers delivered and/or prepared for the Convention comprised:

- 'Reproducing Lateral Cut Recordings', by R Buring.
- 'Refining Radio Reception', by Y B F J Groeneveld.
- 'Radio in the Flying Doctor Service', by E J T Moore.
- 'Precision Measurements of Small Inductances in Quantity Production', by T P Court.
- 'Maintenance of a Tuning Fork in Vibration by a Valve, Using Electrostatic Drive', by Professor Kerr-Grant and M Iliffe.
- 'Broadcasting in Coastal Waters', by Eileen M Foley.
- 'Measurement of Signal-to-Noise Ratio in Receivers', by E J T Moore.
- 'The Treatment of Disease by UHF Current', by J van Boss.
- 'Equipment for the Measurement of Loudspeaker Response', by J B Rudd.
- 'Loaded Radiators for Broadcasting', by A J McKenzie.
- 'The Research Laboratories of the Postmaster General's Department', by S H Witt.
- 'Vibrator Power Units', by G Hall.
- 'Communication Equipment for Vehicles', by Dr Geoffrey Builder and J D Gilchrist.
- 'Noise, Decrements, Bandwidths and Limiters', by E G Beard.
- 'The Application of Radio to Marine Transport in Australasian and Adjacent Waters', by J L Mulholland.
- 'The Technology of Recording Sound on Disc', by V M Brooker.
- '1913–38 — A Quarter Century of Radio Engineering in Australia', by A S McDonald.
- 'The Trend of Radio Development as Disclosed by a Study of the Inventions for Which Letters Patent Have Been Granted During Recent Years', by E A Burbury.
- 'The Examination of Path Differences in the Acoustic Design of Broadcasting Studios', by E G Bailey and R H Healey.
- 'The Application of Iron in High Frequency Circuits', by J N Briton.
- 'Approach Beacon and Blind Landing', by D L Erben.
- 'Ultra Short Waves in Telephone Communication and

Television, Including a Description of the Eiffel Tower Television Station', by E E Deloraine.
- 'The Relationship Between the Power Output Stage and Loudspeaker', by F Langford-Smith.
- 'Broadcasting in Australia', by H P Brown.
- 'A New Sound Recording System', by S J Rubenstein.
- 'Australian Radio Communication Services', by L A Hooke.
- 'Measuring Instruments for Radio Receiver Development', by L G Dobbie.
- 'Studies in the Propagation of Radio Waves in an Isotropic Ionosphere', by Dr W G Baker.
- 'The Development of High Definition Electronic Television in Great Britain', by Dr J D McGee.
- 'Precision Frequency Control Equipment Using Quartz Crystals', by Dr Geoffrey Builder and J E Benson.
- 'Radio Navigation in three sections — The Application of the Adcock Principle to Direction Finding in Australia', by D G Lindsay.
- 'Radio Navigation Systems for Marine Use', by Dr O O Pulley.
- 'Ultra High Frequency Beacons', by J G Reed.
- 'Beyond Radio', by Dr Balth van der Pol.
- 'A Resume of Soil Conductivity Measurements in Australia', by D McDonald.
- 'The Public Relations Aspect of Radio in America', by E S Colling.
- 'The Problems of the Radio Engineer', by Haraden Pratt.
- 'Education Aspects of the Radio Profession in Australia', by R R Mackay.
- 'A Review of Radio Development as Reflected in Applications in the Australian Patent Office During 1936–37', by S A Mathews, R R Michell, G R Rance and J T Stephenson.
- 'Radio Aids to Air Navigation', by H M Lamb.
- 'The Promise of Radio', by Major General J G Harbord.
- 'Television Problems and Their Practical Solution', by Dr F Schroter.
- 'Thermal and Humidity Effects in Receiver Design', by A W Scott.
- 'Radio Coil Development in Australia', by P S Parker.
- 'Television — A General Survey', by J L Baird.
- 'Short Wave Valves', by K Posthumus.
- 'Illusion and Sound Reproduction', by A L C Webb.
- 'A New Approach to Architectural Acoustic Design in Relation to Radio Broadcasting, Sound Recording and Reproduction', by H Vivian Taylor.
- 'Studio Acoustics', by B Wilkinson.
- 'A Brief Survey of Wet Electrolytic Condensers and Their Manufacture in Australia', by C W Vaughan.
- 'Electron Transit Time in Multigrid Valves', by M J O Strutt.
- 'On the Motion of Electrons in an Alternating Electric Field', by K S Knol, M J O Strutt and A van der Ziel.
- 'Telephony and Programme Distribution by Carrier Current', by T S Skillman.

Sir Ernest Fisk who was at the time President of The Institution, was Chairman of the Convention. Officers and Councillors who assisted in organising and running the Convention included Leslie Bean, Stromberg-Carlson (A/Asia) Pty Ltd; Norman Gilmore, Lekmek (A/Asia) Pty Ltd; Charles Norville, Continental Carbon Resistor Co., Pty Ltd; Philip Parker, Airzone (1931) Ltd; Oswald Mingay, Australian Radio Publications Pty Ltd; Ray Allsop, Raycophone Pty Ltd; John Briton, The Gramophone Co., Ltd; Sydney Colville, Colville Wireless Equipment Co., Pty Ltd; Tom Court, Standard Telephones and Cables (A/Asia) Ltd; Bill Crawford, Postmaster General's Department; Lionel Hooke, Amalgamated Wireless (A/Asia) Ltd; Major Kendall; Richard Kennell, New System Telephones Pty Ltd; Arthur McDonald, Amalgamated Wireless (A/Asia) Ltd; Fred Thom, Thom and Smith Pty Ltd; Charles Tyrrell, Philips Lamps (A/Asia) Pty Ltd, and David Wyles, Briton Electrical and Radio Pty Ltd.

At the time of the Convention, there were 391 members in The Institution. They comprised 1 Fellow, 1 Honorary Life Member, 138 Full Members, 175 Associate Members, 47 Associates and 29 Juniors. Eleven of the members were overseas residents.

The Convention created a lot of interest amongst people in the radio industry who were not members, and the membership rose by 56 within a year. The Institution honoured a number of overseas visitors who participated in the Convention. They included Radio Engineers from USA, England, Java and Holland.

Responsibility for editing the papers produced at the Convention was vested in the Executive Secretary and Editor of the 'Proceedings of the IRE', James Edwards.

During the Second World War, The Institution played a major role in supporting the War effort. Activities included:

- Introduction of the Signals Training Scheme which trained thousands of wireless operators and technicians for the Services. Voluntary members of The Institution produced 50000 copies of technical papers.
- Representation on The War Equipment Committee, Radio Servicing Plan, Registration of Professional Radio Engineers, Technical Mission to study deterioration of telecommunications equipment in the tropics, War Standards Committee, Radio Operators Industrial Committee, IRE Rehabilitation Committee and others.

Some of the wartime activities continued to function for many years after cessation of hostilities.

Many members served with the Services. At 1944, there were more than 1000 members on the role. Ten years later in 1954, the number had increased to 1800.

Shortly after the end of the War, The Institution began planning a convention to be held in Sydney. The Sydney Radio Engineering Convention was held over four days in 1948 with a program of lectures, demonstrations and visits to a number of places of technical interest. The Convention at which about 600 delegates attended was opened by Sir John Madsen, Professor of Electrical Engineering, Sydney University.

This was followed by a Convention in Melbourne 3 to 6 May, 1950 with support from the industry, government instrumentalities and Federal and State Governments. On this occasion, 850 delegates attended.

The success of these two Conventions resulted in The Institution deciding to have a Convention every two years in either Sydney or Melbourne (with one in Canberra).

These Conventions were a feature of The Institution's activities for many years. They incorporated the presentation of technical papers by Engineers, Scientists and Senior Managers, displays of equipment by leading manufacturers and distributors, conducted visits to technical establishments, and a program of social events. The Conventions known as IREECON were reputed to be the largest professional electronics exhibitions and conventions in the Southern Hemisphere. For well over 20 years, the Conventions attracted attendances of about 500 with total Convention attendances including visitors being 4000 to 5000.

In 1962, The Institution established The Dunrossil Memorial Lecture to honour Viscount Dunrossil who died while Governor-General and Patron of The Institution. The plan was for the lecture to be given by an eminent person on a subject akin to the growth of science and technology and matters broadly related to Communications and Electronics Engineering.

His Royal Highness Prince Philip presented the first lecture on 28 December 1964.

In 1964, the name of the organisation was changed to The Institution of Radio and Electronics Engineers, Australia, bringing the organisation in line with kindred bodies in USA and Great Britain which had added 'Electronics' to their titles. Behind the change was the view that Radio Engineering was only a facet of the broader field of electronics which The Institution embraced.

The membership at 31 December 1964 totalled 2175, of which 42 were Fellows. By mid 1990, the membership had increased to 3000.

As at 1964, qualifications which would exempt an applicant from the requirements of its Graduate Examination included degrees in Engineering and Science from recognised Universities, diplomas in Electrical, Electronic and Communication Engineering from a number of approved Technical Institutes and other examinations:

- AUSTRALIAN UNIVERSITY DEGREES
- B E Electrical Engineering, from Universities of Adelaide, New South Wales, Queensland, Sydney, Tasmania and Western Australia.
- B E Mechanical and Electrical Engineering, from Universities of Queensland and Sydney.
- B Sc Tech Electrical Engineering, from Universities of New South Wales and Adelaide.
- B Sc, majoring in Mathematics and Physics, from Universities of Adelaide, Melbourne, New South Wales, Queensland, Tasmania and Western Australia.
- Diplomas of Australian Technical Institutes.
- Fellowship in Electrical or Communication Engineering, from Royal Melbourne Institute of Technology and South Australian Institute of Technology.
- Diplomas in Electrical or Radio Engineering, from Ballarat School of Mines and Industries, Bendigo Technical College, Castlemaine Technical College, Caulfield Technical College, Footscray Technical College, Gordon Institute of Technology, Swinburne Technical College, Sydney Technical College, Technical Branch Education Department of Tasmania.
- Associate Diplomas in Electrical Engineering, Radio Engineering, Communication Engineering or Electronic Engineering, from Central Technical College Brisbane, South Australian Institute of Technology.
- Associateship in Electrical Engineering, Communication Engineering, Radio Engineering or Electronic Engineering, from Perth Technical College, Royal Melbourne Institute of Technology, South Australian Institute of Technology.
- Exemption was also granted for pass in Commonwealth Public Service Examination to enable Cadet Engineers of the Postmaster General's Department to qualify for advancement as Engineer.

From its earliest days, The Institution has been associated with providing technical advice on radio engineering matters for the Royal Flying Doctor Service of Australia (RFDS). The Institution was represented on the council of the RFDS as Technical Adviser. The Very Rev John Flynn called 'Apostle of the Inland and Creator of the Mantle of Safety' was an Honorary Member of The Institution.

During the period 1966 to 1977 when the RFDS planned modernisation of its high frequency communication system to enable single sideband working, the IREE played a major role in the system design, development and implementation.

Many members of The Institution have been advisers to the RFDS over the years and include Walter Coxon, Harry Kauper, Vern Kenna, Ronald Mackay, Clive Pearce, Air Commondore George Pither, Len Schultz, Alf Traeger, David Wyles and others.

On 15 December 1965, The Institution petitioned Her Majesty the Queen for a Royal Charter. Officers submitting the petition were Reginald Boyle, President; Arthur De Courcy-Browne, Deputy President; Ronald Trembath, Immediate Past President; Harold Wilshire, Senior Vice President; Richard Huey, Vice President; Norman Wedgner, Honorary Treasurer; David Wyles, Assistant Honorary Treasurer; Murray Stevenson, Honorary Editor; and Councillors Ronald Aitchison, Ronald Boadle, Edward Coate, Angus Fowler, Graham Hall, David Hutchinson, Vernon Kenna, Samuel Rubenstein, Leonard Schultz, Reginald Southey, Albert Neville Thiele and Herbert Murray Tyle.

Her Majesty granted the Royal Charter on 10 October 1967 with the Charter being presented on 7 December 1967 by Lord Casey, the then Governor-General.

When the petition was prepared, the following Divisions of The Institution were active:

- Adelaide, which provided for members in South Australia; Chairman, Brian Hammond; Honorary Secretary, Tom Govenlock.
- Brisbane, which provided for members in Queensland; Chairman, Roy Wightman; Honorary Secretary, Sydney Grantham.
- Canberra, which provided for members in an area of New South Wales including Young, Wagga Wagga, Cooma, Bega, Nowra and Canberra; Chairman, Brigadier Roseblade; Honorary Secretary, Lt Col Wesley.
- Hobart, which provided for members in Southern Tasmania; Chairman, Neville Brown, Honorary Secretary, John Brodie.
- Launceston, which provided for members in Northern Tasmania; Chairman, Angus Robertson; Honorary Secretary, Ken Briggs.
- Melbourne, which provided for members in Victoria; Chairman, Rudolph Buring; Honorary Secretary, Reginald Crow.
- Newcastle, which provided for members in the Hunter River District of New South Wales; Chairman, Christian Cowan; Honorary Secretary, John Clarke.
- Perth, which provided for members in Western Australia; Chairman, Cyril Fletcher; Honorary Secretary, Solon Mathews.
- Sydney, which provided for members in New South Wales except those covered by the Canberra and Newcastle Divisions; Chairman, Frederick Lackey; Honorary Secretary, Lindsay Allen.

Reg Boyle who was Presidential Signatory to The Institution's Petition to Her Majesty The Queen, had a long association with broadcasting and The Institution, having joined as a Member in 1946 and raised to Fellow in 1965. He was a Councillor for many years and served on many Boards and Committees and periods as General Secretary and Administrator.

After completion of Secondary School education, Reg joined the Postmaster General's Department in Sydney as Cadet Engineer. Following completion of training which included study at Sydney University, he volunteered in 1939, to serve with the AIF/ABC Field Unit in the Middle East to provide an on-the-spot broadcast news facility. Other technical staff of the Unit were G Gallway and W T McFarlane.

He returned to Australia in 1941 and was associated with the installation of radio navigation and radiocommunication systems for the RAAF and USA Army.

After the War, Reg was involved in major radiocommunication survey and construction activities throughout New South Wales.

On 30 June 1947, he presented a paper to the Sydney Division of the IRE 'Engineering Aspects of the National Broadcasting Service'. The paper was later published in the November 1947 issue of 'The Institution's Proceedings'.

Following a visit to Papua New Guinea in 1969 for a World Bank project, he worked on automation and operation of unattended radio broadcasting and TV transmitting stations.

In the early 1970s, Reg was engaged on the Radio Australia Cox Peninsula project and as specialist Assistant to the Superintending Engineer Broadcasting until he retired in 1976.

In 1977, Reg was presented with the IREE's highest award — the Award of Honour.

Initially, membership of The Institution was in four Grades comprising Fellow, Full Member, Associate Member and Junior Member. Additionally, entry could be as a Radio Society Member.

By 1938, at the time The Institution sponsored the World Radio Conference, membership Grades comprised Fellow, Honorary Life Member, Full Member, Associate Member, Associate and Junior.

Since formation in 1932, the standard of qualification for membership to The Institution had been raised as additional courses of training in Electronics Engineering became available.

At the time The Institution petitioned for a Royal Charter, the academic standard required for membership (except for Honorary Members, Companions, Senior Affiliates, Affiliates and Students) was appropriate to the status of a Professional Radio and Electronics Engineer. Corporate members comprised Fellows, Senior Members, Members and Associate Members while Non-Corporate members comprised Honorary, Graduates, Companions, Senior Affiliates, Affiliates and Students.

By early 1975, the Qualifications and Examination Board of The Institution determined entry status for six Grades comprising Fellow, Member, Graduate, Engineering Associate, Affiliate and Student.

- FELLOW
  This was the highest Grade of membership offered by The Institution. The requirements were those required for Member but in addition, the applicant needed to have been engaged for at least 5 years in a position deemed by the Board to be of major responsibility in the design or execution of important or significant electronics or scientific work.
  Examples of positions of major responsibility included Engineer Class 4 in a Government Department; Chief Engineer, Chief Scientist, Technical Director or General Manager in the industrial area; Associate Professor, Reader or Head of School or a College of Advanced Education or comparable position in a Department of Technical Education; Lieutenant Colonel in the Army; Commander in the Navy; Wing Commander in the Air Force; Principal Research Scientist or equivalent in CSIRO and Research Establishments.
- MEMBER
  In addition to specified Academic qualifications such as Degrees or Diplomas, professional experience was a requirement and included, three years professional experience as an Engineer following graduation from a 4-year full-time degree course or its equivalent. The experience could include teaching in courses at professional level.
- GRADUATE
  A Graduate had to meet the requirements for qualifications as required for the Grade of Member but the professional on-the-job experience was not required.
- ENGINEERING ASSOCIATE
  An Engineering Associate was required to be the holder of a Certificate or Diploma specifically named by The Institution for this purpose. They were expected to be employed as Senior Technician, Technical Officer or similar positions.
- AFFILIATE
  An Affiliate was expected to be employed as Technician, Senior Technician or Technical Officer who had advanced beyond the level of tradesman but did not hold one of the Certificates specified for Engineering Associate.

As at 1 September 1997, there were 15 grades of membership namely, Fellow; Senior Member; Member; Associate (Professional); Senior Associate (Professional); Associate (Engineering); Senior Associate (Engineering); Associate (Technical); Senior Associate, (Technical); Companion; Senior Affiliate; Affiliate; Student; Honorary Life Member and Honorary Member. Fellows, Senior Members and Members were known as Corporate Members.

Since 1924, The Institution of Electrical Engineers in the UK had sponsored a Faraday Lecture as an annual event. It presented technological developments in a popular manner to the general public. In 1970, the IREE brought to Australia the 1969 Faraday lecture on Microelectronics and following success of the venture, The Institution decided to sponsor an Australian Faraday Lecture. In 1971, it invited the Australian Post Office to present the inaugural lecture.

Harry Kaye, Assistant Director (Engineering) South Australia and a Fellow of The Institution was selected as the lecturer. The lecture 'Telecommunications — The Nerve Centre of Modern Society', was presented between 23 August and 23 November 1972 at 13 locations throughout Australia to an estimated 30000 people.

Ron Kitchenn provided assistance to Harry in developing the technology for presentation of the lecture.

Harry Kaye was educated at University High School, Melbourne and joined the Postmaster General's Department in Melbourne as Cadet Engineer in 1929.

After completion of training and graduation with Bachelor of Science Degree he was appointed Engineer in 1936 at Headquarters Radio Section. He then spent a period with the Queensland Administration where he supervised establishment of radio stations in Papua and New Guinea. Harry returned to Headquarters in 1940 and for some years co-ordinated radio construction work on behalf of the Armed Services at various sites throughout Australia.

He was promoted Divisional Engineer at Headquarters Radio Section followed by promotion to Assistant Supervising Engineer, being responsible the Radio Capital Works Program.

In 1955, he transferred to the Victorian Administration as Supervising Engineer, Radio being responsible for all broadcasting and radiocommunication activities throughout the State until 1957 when he was appointed to take charge of the Sydney-Melbourne Coaxial Cable Project.

For the visit of Her Majesty the Queen to Australia in 1962, Harry was appointed Commonwealth Communications Officer to co-ordinate Mail; and telephone, telegraph and broadcasting relay services for the Royal Party, Press and Officials. For this work, he received the award of Member of the Royal Victorian Order.

From 1964 to 1967, he was posted to London as the Australian Post Office Representative and on return, took up appointment as Engineer Class 5, Radio Section, Headquarters.

In 1968, Harry was appointed Assistant Director (Engineering) South Australia, followed in 1973 by appointment as Director of Posts and Telegraphs for South Australia, and in 1975 as State Manager, Telecom Australia for South Australia and Northern Territory. He retired on 19 September 1975 after 46 years service.

Ron Kitchenn joined the Australian Post Office in 1951 after having worked with the British Post Office since 1936. While serving with the BPO he obtained a Bachelor of Science (Engineering) Degree and was awarded the British Institution of Radio Engineers 1951 Premium for the most outstanding paper in the field of broadcasting published in 'The Institution's Journal'.

Ron joined the Radio Section of the NSW Administration and was associated with transmitters and studios of the National Broadcasting Service as well as inspection of Commercial stations on behalf of the Australian Broadcasting Control Board.

About 1955, he moved to Headquarters to take up a position as Divisional Engineer, Planning and Standards, in the Radio Section. Three years later, he transferred to Systems Planning Section as Sectional Engineer, Trunk Networks. After formation of Headquarters Planning Branch, Ron became responsible for the determination of transmission objectives and planning rules for the APO network.

For 13 years, Ron was General Secretary of the Telecommunications Society of Australia. He retired from the position in 1972.

On 1 April 1975, Keith Finney was appointed General Secretary of The Institution. Keith had been associated with the Wireless Institute of Australia for some years having served as President and was admitted as Associate of The Institution in 1961. For 15 years he had occupied a number of senior executive positions with AWA in Engineering and Engineering Commercial capacities.

By 1977, there were approximately 2500 members served from the administrative Head Office at 157 Gloucester Street, Sydney, with Divisions in Adelaide, Brisbane, Canberra, Hobart, Melbourne, Perth and Sydney plus a Group in Townsville and a Chapter in Singapore. Most of the Divisions held monthly lecture meetings.

Over the years, The Institution has sponsored and administered a number of Prizes and Awards. They include:

- IREE Fisk Prize established in 1946, in recognition of the work of the Foundation President of The Institution, Sir Ernest Fisk. The Prize was awarded annually to a student attending an Engineering Degree or Diploma Course in Communications or Electronics and who attained best results.
  One of the recipients of the Fisk Prize was Robin Blair. He began his career with the Australian Post Office in 1961 as Cadet Engineer. In 1964, he graduated from University of Queensland with Bachelor of Engineering Degree with First Class Honours and was awarded the Fisk Prize. He later obtained a Master of Engineering Science Degree.

During 1966–69, he worked in the Queensland Radio Section on the installation and maintenance of television transmitting stations and then transferred to Post Office Research Laboratories being involved with various aspects of digital transmission by radio.

In 1973, he transferred to the Broadcasting Branch and worked on the conversion of TV transmitting plant to colour. With the establishment of the Broadcasting Directorate, he was Assistant Director Broadcasting Development Branch. He subsequently left Telecom to take up a position as Consultant with RFS Pty Ltd.

- Norman W V Hayes Memorial Medal awarded in memory of Norman W V Hayes who died in 1950 during his term of office as President of The Institution and while Chief Engineer of the Postmaster General's Department. The Medal is awarded to the author of the paper published in the Proceedings during the year which showed the greatest merit in originality, importance, extent of content and style of presentation. The Award commenced in 1951 and is in the form of a mounted bronze medallion.

  Norm Hayes joined the Postmaster General's Department in Adelaide in 1907 becoming Junior Assistant Engineer in 1909. He transferred to New South Wales in 1917 and was appointed State Sectional Engineer in 1918.

  Norm took a keen interest in broadcasting from the time the Department took over the A Class stations to form the National Broadcasting Service in 1929. He was a foundation member of the Victorian Division of The Institution of Radio Engineers (Australia) when that Division was formed in October 1933.

  In 1940, at the invitation of the Council, Norm became a Fellow of The Institution.

  While Superintending Engineer Victoria, he gave evidence to the Joint Committee of Wireless Broadcasting in 1942.

  He later served as Chairman of the Victorian Division and as Federal President 1949–50.

  At the time of his death in 1950, Norm Hayes was Acting Assistant Director-General (Engineering Services) and Engineer-in-Chief.
- Oswald Mingy Award provided to encourage merit in writing, compilation and preparation of papers and to stimulate members of The Institution to produce and deliver suitably prepared papers. Mr Mingy was a Foundation Member of The Institution, General Secretary for many years and the publisher of books and magazines related to radio.
- Norman S Gilmour Award established to commemorate the work of Norman S Gilmour as President and General Secretary of The Institution. The Award was made to final year students in the PMG's Department Technician-in-training course with the object of encouraging continuation of studies leading to selection as Trainee Engineer. Mr Gilmour was a former Engineer in the PMG's Department 1915–22, and left to enter private enterprise in radio engineering.
- IREE Macquarie Award sponsored by Macquarie Broadcasting Service Pty Ltd for the best paper published in the Proceedings on a subject of interest and importance in Radio Engineering.

In 1993, Awards included the V F Kenna Memorial Award, the Brian Priestley Memorial Award, the Norman W V Hayes Award and the Oswald Mingay Award. In addition, some Divisions of The Institution administered Students Awards.

The V F Kenna Memorial Award was introduced in 1989 following a bequest from Mrs Del Kenna in memory of her late husband's interest in the encouragement of young Engineers. The Award comprised a cash amount plus a commemorative plaque for the best paper presented at the Biennial Conference of the IREE by a young Engineer within three years of graduation, or a student.

Vern Kenna, a Past President, played a significant role in sound broadcast and television engineering, particularly with the National Broadcasting and Television Services and in his management role, encouraged young Engineers in the pursuit of excellence in their careers.

The Brian Priestley Memorial Award was endowed by Ian Shearman to perpetuate the memory of his late partner Brian K Priestley of the firm Priestley and Shearman Pty Ltd. Services provided by the organisation, a Consulting Engineering business included communications, broadcasting and television with areas of expertise comprising feasibility studies, preparation of specifications, field surveys, project management, preparation of licence submissions, radio frequency interference investigations, and designs of transmitters, translators, aerial systems, point-to-point radio communication links, sound broadcasting and TV studios, production and recording studios and screened rooms.

Brian Priestley joined The Institution in 1960 and was elected Fellow in 1980. For over 30 years, he had been involved in a wide range of Radio and TV Engineering projects and was a recognised specialist in the design and development of aerial systems, radio propagation evaluation studies, radiation hazard assessment and RF screening. Today, Brian operates the business as Shearman Pty Ltd, North Epping.

The Award in the form of a bronze medallion is presented to the author/s of the most meritorious paper related to aerials and electromagnetic propagation submitted to The Institution for publication in 'JEEEA'.

The first Award was presented in 1989. The 1995 Award was presented to M Kesteven, CSIRO Division of Radiophysics for 'Microwave Holography for Antenna Metrology', published in 'JEEEA', June 1994.

In 1995, the Medal associated with the Norman W V Hayes Award was presented to A N Thiele for 'An Improved Law of Contrast Gradient for High Definition Television', published in 'JEEEA', December 1992.

Norm Hayes, Norm Gilmore and Vern Kenna had all served as senior Engineers in the Postmaster General's Department and served terms as President of The Institution.

Departmental Engineers and Radio Inspectors were active participants in IRE affairs with many serving as Councillors or Committee Members soon after formation of The Institution with the Federal body and State Divisions in the 1930s. In 1935, Full Members included Bill Conry, Radio Inspector, Melbourne; Bill Crawford, Senior Radio Inspector, Sydney; Joe Dobbyn, Radio Inspector, Central Office; Peter Dunne, Radio Inspector, Central Office; Roy McKay, Supervising Engineer, Central Office; Jim Malone, Chief Wireless Inspector, Central Office; and Sid Witt, Supervising Engineer, Research Laboratories, Central Office.

As part of its Golden Jubilee Celebrations in 1982, The Institution arranged for a series of Golden Jubilee meetings to be held throughout Australia with the keynote address being given by Guest Speaker Jack Curtis, Managing Director, Telecom Australia.

In Adelaide, the address was delivered on 21 July 1982, IREE members associated with the event included Ian Hansen, Chairman, Adelaide Division; Peter Wing, Deputy President; Norm Sawyer, Past Chairman, Adelaide Division and Bob Green, Jubilee Co-ordinator.

Invited guests included Ross Treharne, George Whitfield, Jack Ross, Charles Tyrrell, all Fellows of The Institution, and Cliff Moule, one of the Inaugural Committee Members on the formation of the South Australian Division of the Institution of Radio Engineers (Australia) in 1936.

On 19 December 1991, The Institution of Radio and Electronics Engineers, Australia (IREE) and The Institution of Engineers, Australia (IE Aust.) signed an agreement which established The IREE Society. It was planned that The IREE Society would operate as a technical society of IE Aust., but be administered by IREE. The agreement was intended to bring advantages to both IREE and IE Aust. members.

Following formation, The IREE Society was managed by an interim Board comprised of senior office holders of IREE and IE Aust., and Society members co-opted because of their past experience.

The main task of the interim Board was to undertake the groundwork required to allow a transition to management by an elected Board.

Election of Board members was carried out in mid 1993.

The IREE Society assumed responsibility for all 'Learned Society' activities, such as organisation of conferences, technical meetings, and publication of the Journal and Monitor. The Society and The Institution of Engineers, Australia each assumed responsibility for part of the 'Professional Society' activities, such as continuing education requirements, registration issues, and representation of Professional matters to Government.

The responsibilities of The IREE was to sustain the Charter, Qualifications and Membership issues for IREE members and co-operative interaction with IE Australia. Real estate and staff remained in IREE control.

An important duty of The IREE Council is to monitor the operation of The IREE Society.

Local Area Committees, now called Chapters of The IREE Society, soon became active by electing Executive Committees and organising a program of technical activities usually in coordination with local executives of the Electrical Branch of I E Aust., IEEE, IEE and the Telecommunications Society of Australia. One lecture of interest was presented by Dr Dennis Cooper to the Queensland group in November 1993 on the subject 'Towards a Wireless World — The New Age of Mobile Communication'. Besides being Immediate Past President of the IREE and closely involved with setting up the IREE Society, Dr Cooper is a Fellow of the Australian Academy of Technology Sciences and Engineering, and Fellow of The Institution of Engineers, Australia.

The IREE Officers for 1993–94 comprised Dr David Robinson, President; Professor Graham Rigby, Chairman; Dr Dennis Cooper, Immediate Past President; A Neville Thiele, Deputy President; Geoffrey Sizer, Vice President; John Spencer, Vice President; David Hutchinson, Hon. Treasurer; Brian Cooper, Hon. Editor 'JEEEA'; Heather Harriman, Executive Director and Editor of 'Monitor'.

The IREE Society Board Officers comprised Dr David Robinson, Chairman; Harry Wragge, Deputy Chairman; Geoffrey Sizer, Hon Treasurer; John Ratcliffe, IREE Rep. M A Sargeant, IE Aust. Rep. Cherie Morris was Acting Executive Officer of the Society and Conference Administrator.

Chairmen of Permanent Boards and Committees of Council included, Qualifications and Examinations Board, Alan McPhail; IREE Society Board, Dr David Robinson; By-Laws Committee, John Ratcliffe; Council Management Committee, Professor Graham Rigby; Finance Committee, Geoffrey Sizer; and Publications Committee, J G Rathmell.

The Institution of Radio and Electronics Engineers, Australia held its 25th Annual General Meeting at Head Office of The Institution in Edgecliffe on 27 September 1994 at 6 pm, followed by the First Annual General Meeting of The IREE Society at 7 pm.

The IREE later sold its Edgecliffe property and in 1995, relocated its Head Office in premises leased from the Sydney Division of The Institution of Engineers, Australia at 118 Alfred Street, Milsons Point.

On 6 January 1996, Des Ireland became Executive Officer of The IREE Society and Editor of 'Monitor', the Society's technical publication. Des was a former Lieutenant Colonel in the Army and graduate of the Royal Military College of Science (UK) and the Australian Staff College. After leaving the Army in 1980, he had wide experience at senior management level with the High Court of Australia, Australian Academy of Science and as a Management and Computer Consultant.

Unfortunately, Des passed away on 26 January 1998. His place was taken on an interim basis by David Charrett as Director Designate and Cherie Morris as Business Manager and Editor, 'Monitor'. Robert Stove was Assistant Editor.

In 1998, President of The IREE was David Edwards and Chairman of The IREE Society was Harry Wragge.

Heather Harriman continued to fill the position of Executive Director with the IREE on a part-time basis.

Membership of The IREE Society consists of all members of The IREE and any member of The IE Aust. who nominates The IREE Society on the annual subscription form. All members of The IREE Society are members of one, other or both of the two parent Chartered Institutions. In 1994, membership totalled 4110 made up of IREE only, 1300; IREE/IE Aust. Joint, 990; and IE Aust. only, 1820.

On 12 December 1994, a new Agreement was signed between the two Institutions. The Agreement was intended to maximise the advantages to the community and to members of both Institutions.

The Agreement was signed by Dr David Robinson, President and Heather Harriman, Executive Director on behalf of The Council of The Institution of Radio and Electronics Engineers, Australia and Doug Clyde, President and Dr John Webster, Chief Executive on behalf of the Council of The Institution of Engineers, Australia.

The IE Aust., covers all disciplines of engineering and like The IREE operates under a Royal Charter and Code of Ethics. As at 1995, Membership and Grade Structure comprised Fellow, Chartered Professional Engineer; Senior Member, Chartered Professional Engineer; Member, Chartered Professional Engineer; Companion; Graduate, Professional Engineer; Affiliate, Graduate Soc. Eng. Tech., Engineering Technologist; Associate, Fellow SEA, Engineering Associate; Associate Member SEA, Engineering Associate; Associate, Grad. SEA, Engineering Associate; and Student. Membership of the IE Aust., also offers listing in the appropriate category of the National Professional Engineers Register (NPER). Members receive the journal 'Engineers Times' and the magazine 'Engineers Australia', 12 times each year.

As at 1996, membership of The Institution of Radio and Electronics Engineers, Australia comprised the following grades:

Fellow, designated 'FIREE'.
Senior Member, designation 'SMIREE'.
Member, designation 'MIREE'.
Associate (Professional), designation 'Assoc(Prof)IREE'.
Senior Associate (Professional), designation 'Snr Assoc(Prof) IREE'.
Associate (Engineering), designation 'Assoc(Eng)IREE'.
Senior Associate (Engineering), designation 'Snr Assoc(Eng)IREE'.
Associate (Technical), designation 'Assoc(Tech)IREE'.
Senior Associate (Technical), designation 'Snr Assoc(Tech)IREE'.
Companion, designation 'Companion IREE'.
Senior Affiliate, designation 'Snr Affil IREE'.
Affiliate, designation 'Affil IREE'.

The Presidents of The Institution from foundation to 1998 comprise:

1932–1937	E T (Ernest) Fisk
1937–1938	Sir Ernest Fisk
1938–1939	N S (Norman) Gilmour
1939–1940	Sir Ernest Fisk
1940–1941	J J (Jim) Malone
1941–1943	Sir Ernest Fisk
1943–1945	A S (Arthur) McDonald
1945–1947	D G (David) Wyles
1947–1948	R C (Ray) Allsop
1948–1949	M H (Murray) Stevenson
1949–1950	N W V (Norman) Hayes
1950–1951	T P (Tom) Court
1951–1952	J N (John) Briton
1952–1953	H B (Bert) Wood
1954–1955	D G (Donald) Lindsay
1953–1954	W H (Wilf) Honnor
1955–1956	L N (Len) Schultz
1956–1957	R B (Reg) Southey
1957–1958	K S (Ken) Brown
1958–1959	D J (David) Abercrombie
1959–1960	G G (Graham) Hall
1960–1961	F W J (Frank) Orr

1961–1962	R R (Ronald) Mackay
1962–1963	R D (Ronald) Boadle
1963–1964	N T W (Norm) Wedgner
1964–1965	R W (Ron) Tremlett
1965–1966	R J (Reg) Boyle
1966–1967	A W (Arthur) de Courcy-Browne
1967–1968	R M (Dick) Huey
1968–1969	V F (Vern) Kenna
1969–1970	Professor R E (Ron) Aitchison
1970–1971	A (Angus) Fowler
1971–1972	Dr A J (Albert) Seyler
1972–1973	D J (David) Hutchinson
1973–1974	W A (Bill) Brear
1974–1975	F R (Fred) Lackey
1975–1976	Professor J S (John) Ratcliffe
1976–1977	Professor J S Ratcliffe
1977–1978	L R (Les) Free
1978–1979	H F (Hugh) Bartlett
1979–1980	E J (Jim) Wilkinson
1980–1982	Professor J (John) Hiller
1982–1984	Dr P A (Peter) Wing
1984–1986	Professor G A (Graham) Rigby
1986–1988	A N (Neville) Thiele
1988–1990	Dr R (Bob) Horton
1990–1991	R A (Graham) Rigby
1991–1993	Dr D N (Dennis) Cooper
1994–1995	Dr D E (David) Robinson
1996–1997	G D (Geoffrey) Sizer
1998–	D W (David) Edwards

Executive Director from 1977 was Heather Harriman. In February 1994, Heather stepped down from full-time employment with The Institution to part-time involvement and was still active in 1998.

At a ceremony in Sydney on 6 December 1993, President David Robinson presented Heather with the Award of Honour, The Institution's most prestigious accolade.

In 1998, many former Presidents of The Institution were still involved as IREE/IREE Society Officers, Board Members, Councillors or Committee Members. They included Geoffrey Sizer, Hon. Treasurer IREE Society, IREE Councillor and Chairman IREE Board Finance Committee; David Robinson, Immediate Past Chairman and Board Member IREE Society; Dennis Cooper, IREE Society Board Member and IREE Councillor; Graham Rigby, Chairman IREE Council, IREE Councillor, and Chairman IREE Council Management Committee; Hugh Bartlett, Chairman IREE Society Board Publications Committee; John Ratcliffe, Chairman IREE Society and IREE Board's By-Laws Committees, and IREE Councillor; and David Hutchinson, Hon. Treasurer IREE and IREE Councillor.

Queensland Institute of Radio Engineers

The formation of The Institute of Radio Engineers was initiated by Ernie Dillon an active and well-respected radio experimenter. The inaugural meeting took place on 23 November 1922 in Brisbane and was attended by five local experimenters with the object of gathering together those Engineers interested in radio science for discussion on technical subjects. Six days later, a second meeting was held, this time attended by a larger body of interested people and the Memorandum and Articles of Association of the body were finalised. They were modelled on the lines of The Institution of Electrical Engineers, and The Institution of Engineers, Australia, resulting to some extent, that membership was limited to people with technical qualifications or experience.

Headquarters of the Institute was at the Observatory Tower, Wickham Terrace. The Tower had been erected in 1827 and used for many purposes over the years. The Institute operated experimental station OA4EZ which fed a six wire inverted L cage type aerial.

The Institute arranged a number of successful public demonstrations of radio technology and its application and undertook considerable experimental work in transmission, utilising both telephone and telegraphy modes; grid and anode choke methods of transmitter modulation; aerial matching techniques; propagation studies with long and short wavelengths; characteristic tests with various types of receiving valves; single and multivalve receivers with various circuit configurations and many others.

Technical lectures were a feature of most meetings, with some lectures being conducted in conjunction with the Radio Society of Queensland.

The Radio Society of Queensland had been formed during early 1924 with the object of specifically fostering the interests of wireless Amateur experimenters in Queensland. The Society expanded rapidly following its formation, with Branches being established at Toombul, Sandgate, New Farm, Howard, Maryborough, Gympie, Warwick and Ipswich by early 1925. The headquarters were located in the Brisbane Trades Hall from where broadcasts were conducted from the Society experimental room every Tuesday and Thursday evenings for two hour sessions using callsign OA4AZ and later 4RQ. Operation of the station was under control of Frank (later Sir Frank) Sharpe one of the founders of the Society.

In early 1925, the President of the Queensland Institute of Radio Engineers, T W Bridger AMIEE, AMIE Aust., visited England on private business but took the opportunity to study the latest application of wireless technology. On his return, he lectured members of The Institute and the Radio Society on his impressions. Other office bearers at the time were Vice-Presidents, J Leslie, D W Chandler; Hon. Secretary, Ernie Dillon; Hon. Treasurer, C E Sandercock; Councillors Messrs McLaughlin, Winten and Engels.

Unfortunately, enthusiasm of The Institute waned after a few years, and there does not appear to be any records available of Institute activities after 1926.

Marconi School of Wireless

The Commonwealth Parliament passed the New Navigation Act 1912 which contained a clause making it compulsory for ships trading in Australian waters to be equipped with apparatus for wireless telegraphy. Section 236 (1) of the Act stated 'Every foreign going ship, Australian trade ship or ship engaged in the coasting trade, carrying fifty or more persons including passengers and crew shall before going to sea from any port in Australia be equipped with an efficient apparatus for wireless communication in good working order in charge of one or more persons holding prescribed certificates of skill in the use of such apparatus'.

The installation and repair of ship's wireless equipment was not a problem for the newly formed Amalgamated Wireless (A/Asia) Ltd but in order to ensure suitably trained officers were available for operation of the apparatus, the company set up a training School.

The title 'Australia's Pioneer Radio Training Institution' would belong to the Marconi School of Wireless (A/Asia) Ltd conducted by Amalgamated Wireless (A/Asia) Ltd. It was the first fully equipped school to undertake instruction in radio when it opened its doors in 1913 in Sydney with George Apperley as Chief Instructor to train Ship's Wireless Operators. A branch was later established in Melbourne.

George Apperley received his technical training in telegraphy, telephony and wireless with the Dominion Post and Telegraph Department in New Zealand. While employed with the Wireless Service of the British Colonial Government, he was associated with the wireless telegraphy stations at Wellington in New Zealand and at Fiji.

When AWA was established in Australia in 1913, he was one of the early employees to join the company. The formation of a school to train Ship's Wireless Operators was one of the early priorities of the new company. George was appointed to the staff to compile and take charge of technical and operating classes. He was Chief Instructor until 1916 when he became Works Manager to organise and superintend company manufacturing operations.

In 1919, George was appointed Superintendent, Technical and Research including responsibility for the company Patent Department.

In 1923, he made a visit to England and several Continental European countries to study the latest developments in Radio Engineering technology. On return to Australia he was placed in charge of the Beam Wireless Service.

In 1927, George was appointed Traffic Manager and during the 1930s made several overseas visits associated with operation of the Beam Wireless Service.

In 1944, he took up the position, Manager of Communications, occupying the position until he left the company in 1946.

A photograph of the school shown on an early brochure shows the building comprising a ground and two upper floors designated as 'Wireless House'. There was a large sign above the top floor with the words, 'MARCONI-TELEFUNKEN SCHOOL OF RADIO TELEGRAPHY'. A company advertisement in the 1915 'Year Book of Wireless Telegraphy and Telephony' refers to the school as the 'Marconi School of Radiotelegraphy'.

During the First World War, the majority of wireless operators for the ships carrying Australian troops to the various battlefields were trained in the School. The School was well-equipped with the most modern ship's spark wireless telegraphy equipment in service at the time.

As at 1922, Superintendent of the School was A R Mancer.

Included in the early instructural equipment at the School in the early 1920s was a 0.5 kW transmitter designed and manufactured as a broadcast transmitter but also supplied to some Coast Radio Stations as an ICW transmitter as an interim measure pending the installation of specially designed equipment to replace the original spark transmitters. The equipment comprised three racks, a modulator (AF unit), an oscillator (RF unit) and a rectifier unit. Records as the Adelaide VIA station indicate the ICW transmitter was installed on 4 October 1925 with the oscillator unit including two T250 type valves in a coupled Hartley oscillator circuit with an AC anode supply of 8000 volts at 400 Hz. The 8000 volt unrectified supply was provided by a 600 watt Amalgamated type F alternator driven from a 120 volt AC source.

When broadcasting was inaugurated in Australia in the early 1920s, a great many receiving sets were homemade or made by small businesses, but with the increasing interest in broadcasting, the demand for high quality commercially produced receivers increased and skilled workers were required to build and service these sets. This called for specialised instruction and in 1928, the Marconi School commenced night classes for Radio Mechanics. It was the first course of its kind in Australia at the time. Arthur Dixon who later became Chief Engineer of 4BK Brisbane was one of the Instructors.

By end of 1928, there were some 20 broadcasting stations on air throughout Australia and about 4 persons per 100 population held a listener's licence. Total number of licences issued exceeded 270000.

At that time, Chief Instructor of the School was Harold Buik. He obtained experience as a Marine Operator in October 1911 when he was appointed a Ship's Wireless Operator on Interstate vessels. Harold transferred to the AWA Marine Service at the inception of the company in 1913. He saw War service with the Navy during the First World War including action in the Dardanelles campaign, and following discharge in 1918, was appointed Instructor at the Marconi School of Wireless. In 1921, he was promoted to Chief Instructor, in 1926 became Superintendent, and later Principal of the Marine Section, a position he still occupied at the outbreak of the Second World War.

In 1939, Principal of the Engineering Section was Dr W G (Bill) Baker. Bill received his early education in Broken Hill and in 1918 entered the University of Sydney. He had a distinguished academic career graduating Bachelor of Science in 1921 with University Medal for Mathematics and Honours in Physics and Mathematics. In 1923, he graduated Bachelor of Engineering with First Class Honours and University Medal. Bill was Science Research Scholar 1923–24 and following experience overseas in USA and England, returned to Australia in 1927 to become Lecturer in Electrical Engineering at University of Sydney. From 1928 to 1931, he was Radio Research Officer with the Council of Scientific and Industrial Research. In 1931, he joined AWA and in the following year graduated Doctor of Science. In November 1932, he was appointed to Marconi School of Wireless as Superintendent Technical Engineering Section.

Instructors at the School during the late 1930s included Frank Basden, S W Owen, P J Graves, L G Palmer, R C V Humphery and H N Quodling.

Mr Quodling who had been one of the School's graduates in 1923, was appointed to the staff of the School in January 1937 and later became Instructor-in-Charge and Organiser at the Melbourne Branch of the School which had been opened in 1919 with Sydney Tatham in charge. In 1920, the Melbourne School was in a single storey brown stone building at 422/424 Little Collins Street and was managed by Lionel Hooke. It operated Monday to Friday during the daytime and also for night classes during three nights each week. The main subjects taught were radio theory, Morse Code and Regulations as applied to Marine Operations. Instructors in the early 1930s included Joe Williams, Frank Basden, Henry de Dassel and Keith Burbury. In later years, the School operated at 162 Queen Street, Melbourne.

In 1932, it became evident that more specialised courses were needed to cater for the rapid developments in radio technology and to meet the needs of the broadcasting industry. Existing courses were completely revised and new courses added to the curriculum.

In the 25 year period 1913 to 1938, more than 4000 students had been trained at the School.

In 1938, the main courses available at the School comprised:

- Course A — Radio Engineer.

  Entry requirements were Leaving Certificate with passes in mathematics, physics, chemistry and English. The duration of the Course was five years.

  The first year was undertaken by home study or correspondence and dealt mainly with general electric theory and advanced mathematics. The student was supplied with Morse Code training records and a key/buzzer set.

  The second year instruction covered theory of valves, transmitters, aerials, reception, amplification, studio equipment and design, and marine equipment and a continuation of advanced mathematics. Later in the year, practical instruction was available at the School for those able to attend.

  Practical instruction was compulsory for the third year of the Course. Technical instruction was concerned with direction finding techniques and equipment, commercial and broadcast transmitters, talking picture equipment and advanced mathematics.

  Morse Code instruction was provided in class to enable the student to qualify for the PMG's Department First Class Certificate of Proficiency.

  Continuation of instruction in the fourth year was dependent upon the student having obtained the First Class Certificate of Proficiency. Emphasis was on practical training, with six months being spent at the AWA Radio-Electric Works at Ashfield, one week in a broadcasting studio, and three months at a radio transmitting station. Instruction was also provided by correspondence in television, facsimile transmission, line telegraphy, engines, structures, surveying and advanced mathematics applicable to electricity and radio. Practical instruction in surveying and electromagnetic field strength measurements were provided at the School.

The fifth and final year of the Course was devoted to three months experience at a commercial receiving station and three months at AWA Ashfield Laboratory with remainder of the time being spent at the School receiving instruction in preparation of equipment specifications, and business principles as applied to engineering.

The subjects taught during the five year Course provided an in-depth coverage of all aspects of Radio Engineering technology. Each subject was covered in detail with a series of Papers ranging from 1 paper to 18 papers. They included constitution of matter and electron theory; theory of electricity; alternating current; rectifiers; radio frequency; theory of the thermionic valve; theory of valve transmitters; aerials; theory of reception; amplification; receivers; keying the transmitter; modulation; studio design; studio equipment; outside broadcasts; the wavemeter; quartz crystals; marine equipment; direction finding; commercial transmitters; broadcast transmitters; power valves; structures; engines; the power supply; sound reproducers; talking picture equipment; facsimile transmission; television; line telegraphy; surveying. Subjects dealt with in the advanced mathematics part of the Course included higher algebra, trigonometry, co-ordinate geometry, differential and integral calculus, statics and dynamics, vector analysis, differential equations and application of mathematics to electrical and radio engineering.

- Course B — Radio Technician.

The Course was aimed for the student wishing to obtain the PMG's Department Broadcast Operators Certificate of Proficiency. Instruction was provided in broadcast transmitters, studio design, acoustics and outside broadcast pick-up facilities. The Course covered a period of two years with practical tuition of three to five months at AWA Centres at Pennant Hills and La Perouse, and a broadcast station studio. Home study instruction papers constituted the major part of the Course followed by practical instruction at the School on assembling and testing of representative types of receivers; testing and fault finding on a receiver; selectivity, sensitivity and fidelity tests on receivers in a screened room environment; adjusting and operating two complete transmitters; adjustment and termination of an RF transmission line; and operation of a low power short wave transmitter.

- Course C — Radio Operator.

The two year Course was designed to enable the student to qualify for First or Second Class Certificate of Proficiency awarded by the PMG's Department after passing the prescribed examination. Instruction was given in telegraphy, radio and electrical theory, practical work and International Regulations as they applied to marine radio operations.

- Course D — Talking Picture Operator.

The Course was intended for the student who wished to qualify for the position of Operator in a Talking Picture Theatre. The Course extended over one year and consisted of Home Study Papers followed by practical experience with a complete talking picture installation at the School.

- Course E — Radio Mechanic.

The Course with a duration of one year was developed for people who assembled, installed and serviced broadcast receivers. After completion of the home study section of the Course, the student attended the School for three months practical work on assembly and testing standard broadcast receivers.

Subjects of the home study segment included construction of matter, the electron theory, theory of electricity and magnetism, alternating current theory, rectification, radio frequency theory, the thermionic valve, aerials, detection and radio frequency amplification, audio frequency amplification, receivers, power supply equipment, sound reproduction, loudspeakers, testing apparatus and instruments, trouble finding in receivers and Fire Underwriters Rules and Regulations.

Facilities at the School for instruction purposes included a wide range of wireless equipment as complete stations. In addition to a well-equipped Workshop there was equipment for television instruction, receiving and direction finding, and transmitters. The transmitting equipment included a 750 watt short wave/long wave ICW, AWA marine transmitter; 1.5 kW spark transmitter; a 500 watt quenched gap installation; a 500 watt crystal controlled radio telephone/telegraph transmitter; and a complete 250 watt broadcast transmitter comprising master oscillator, buffer amplifier, power amplifier and equipment for both low level and high level modulation techniques.

In 1939, Cecil Bardwell joined the School as Instructor and in 1949 became Manager succeeding J H Hawkins who had been Manager over the period 1945 to 1948. Cec occupied the position of Manager until closure of the School.

With the introduction of television, there was an urgent need in industry for TV servicemen and branches of the School were opened in every capital city in Australia to train television technicians and servicemen.

However, with the production of highly reliable solid state broadcast receivers, studio and transmitting equipment there was a decline in training needs for radio technical staff.

When the Government decided to establish the Australian Maritime College at Launceston, AWA was not keen to continue operation of the School as it was no longer making a profit. In the early 1980s, decision was made to transfer the function of training Marine Radio Operators to the new Government College. With the support and participation of AWA much of the course material, even some of the students and responsibility, was transferred to the College during 1982–83, so bringing to a close a training School that had served the radio industry for some 70 years.

On 20 September 1997, more than 100 former students of the School attended a re-union in Sydney. Included among the guests were Cec Bardwell, long-time School Manager, Alf Chandler, a 1924 student and Glen Mumford, a 1928 student.

AUSTRALIAN RADIO COLLEGE

The Australian Radio College (ARC) located at 15 Castlereagh Street, Sydney was founded by Oswald Mingay, a radio magazine publisher. He was Principal of the College during the period 1930 to 1933. The College was registered as a business in March 1931.

'Ossie' as he was known had considerable experience in conducting radio educational courses having instructed Army Signals personnel and as Principal of the Burgin Radio College.

Mingay was concerned about the vast number of people out of work during the Depression and with radio being one of the few industries at the time employing a large work force, he decided to set up a College where people could be trained in the technology, and so find work in the industry. He also arranged with the NSW Division of the Wireless Institute to take over the classes being conducted by the Institute.

The College commenced with a single radio course divided into Beginner and Advanced sections. It was at first, basically a home study system, backed by practical classes and lectures for those within range of the classrooms. The College was open only during the daytime, since most out-of-work-people had plenty of time during the day.

The College conducted an extensive advertising campaign shortly after it commenced operation, and produced a booklet 'Study Radio' which was distributed in the thousands to people interested in doing one or more of the College courses. The message in the booklet emphasised that radio work was no longer limited to the building and servicing of radio receivers but had expanded into the fields of Public Address Systems, Sound Pictures, Aviation, Industry, Security Systems, Police Communications, Remote Control Systems and others. Also, Radio Servicing had become a business in its own right and so lessons were provided on such subjects as Salesmanship, Dealing with the

Customer in the Home, Updating Old Receivers, Stockholding Procedures, Agencies etc. Although reference to people servicing radio sets was usually 'Radio Servicemen' there was also a number of women who conducted radio businesses at the time.

Response from the public was encouraging and courses were restructured and divided in three distinct classes:

- Class B1 — Radio Day Course.
- Class B2 — Radio Trade Course, conducted as a night attendance class.
- Class B3 — Preliminary Radio Course, conducted as a night attendance class.

It was not long before College graduates were taking their place in industry or setting up their own businesses. Day students who graduated with a Diploma on 4 June 1931 included C Gee, H Selman, C Whiting, S Piggott, H Fennelly, J Brown, D Bateman, A Stevens, L Element and J Dudgeon.

Following a study of the training needs of the radio industry, it became evident that there was a requirement for a day course to upgrade the skills of Radio Dealers and Radio Servicemen. The College put on a Radio Mechanics Day Course which took six months to complete. It was a very intense course covering all aspects of practical and theoretical instruction work. A class which commenced on 2 November 1931, attracted more than 20 students.

In February 1933, the College expanded activities to include premises at 22 City Road, Glebe.

The College was one of the supporters of the move in the 1930s, that a qualified Radio Serviceman should be referred to as a Certified Radiotrician. Although a number of the College graduates advertised themselves as such, it did not receive much support from influential areas and the title was not seen after about 1938. One prominent Victorian Radio Dealer who advertised himself as a Radiotrician was R Johns of Geelong West.

About 1933, a change of ownership of the College took place and its activities were transferred to the E S and A Bank premises in Broadway. Lancelot Graham became Principal in August 1934, and in 1935, became a Director of the organisation which was registered as Australian Radio College Pty Ltd in July 1935.

A considerable amount of course restructuring was made, with the courses being grouped as Radio Engineer's Course, Radio Serviceman's Course, Radio and Television Engineer's Advanced Course and Amateur Operator's Proficiency Certificate Course. In addition, students were coached for examinations set by The Institution of Radio Engineers (Australia).

Although some commercially manufactured test equipment was in use at the College for student instruction purposes, the majority was provided by Radio Equipment Pty Ltd, a business located in the same building as the College and which had Lance Graham as Managing Director. The business made a range of test equipment and meters including Valve Checkers, Oscillators, Multimeters, Speaker Test Units and others. They could be purchased in kit form by students and the public. The business also produced for sale, a publication 'ARC Fault Finder' which comprised a series of bound service charts dealing with faults normally encountered in radio servicing.

During the War years, Radio Equipment Pty Ltd provided a large number of test instruments and meters for the Services.

The College had a well-equipped workshop for practical instruction, while correspondence students were provided with kit sets and detailed construction procedures. The main lecture hall at the College could seat 300 students and was frequently a busy area with many different classes being in progress.

In 1937, the College had a staff of 10, five of whom, including Lance Graham were Instructors.

With the advent of television, the name of the College was changed about 1956 to Australian Radio and Television College Pty Ltd.

Many instructors were employed over the years and included Bob Chilton, Chief Instructor 1931 and Superintendent 1933; Rex Lackey, Chief Instructor; John Lawler; Philip Watson; F W Freeman, Superintendent and Peter Bessell.

Rex Lackey who was Chief Instructor for many years played a major role in developing the College course material and keeping students abreast of the latest technology. Prior to joining the College he had worked in industry including Home Recreations in 1930 and Airzone Ltd before joining ARC in late 1932. He was an Associate Member of The Institution of Radio Engineers (Australia).

The College ceased operations about 1974, after having trained thousands of people in radio technology. At its peak, about 400 students were on the College roll each year, with many being Asian correspondence students.

The printed lecture material provided by the College was very comprehensive and today, is eagerly collected as memorabilia by vintage radio buffs with an interest in the history of broadcast technology.

Before joining the ARC, Lance Graham who controlled the College for over 40 years had been involved in the commercial radio industry since 1925. He joined Amplion (A/Asia) Pty Ltd when that company was formed in 1930 and later worked with Philips Lamps (A/Asia) Ltd.

In 1934, after he became associated with the College, he was Sales Manager and Secretary of University Radio Co., located at 22 City Road, the same address as the College. The Proprietor of University Radio Co., was Ben Broadhurst who had conducted his own radio business since 1927, and on 11 January 1933 registered University Radio Co., for the purpose of manufacturing receivers. Receivers were produced under the brand names University, Chancellor, Dean and Librarian.

Lance Graham was also associated with the company operating today as University Paton Instruments Pty Ltd but about 1970 ceased having an interest.

SYDNEY TECHNICAL COLLEGE

The Sydney Technical College was formed in 1882 taking over the Working Men's College which had began in 1878. Control of the College was originally the responsibility of the Board of Technical Education. The Technical Education Branch of the Department of Public Instruction later took over this responsibility.

In 1920, subjects related to communications were offered in Electrical, Telephone and Telegraph Engineering. The basic subjects for Diploma in 1920 included:

- Stage I. Maths III, Physics II, Chemistry II, Descriptive Geometry.
- Stage II. Maths IV, Electrical Engineering I, Engineering Drawing and Design I.
- Stage III. Maths IV, Electrical Engineering II, Engineering Drawing and Design II.
- Stage IV. Electrical Engineering III, Applied Mechanics IIa, Heat Engines Ia.
- Stage V. Electrical Engineering IV, Applied Mechanics IIIa, Heat Engines IIa.

Entrance requirement was Leaving level with the course being part-time, involving 37 weeks a year, with 1258 hours of instruction.

One of the well-known graduates with a Diploma in Electrical Engineering in the early 1920s was Miss Florence Violet Wallace (later Mrs McKenzie). She was a well-known Radio Amateur Station operator, conducted a large Radio Shop in the Royal Arcade, Sydney until the early 1930s, was one of a small group who began publication of the magazine 'Wireless Weekly' now published as 'Electronics Australia', and during the years of the Second World War, started a school to train women as Wireless Operators.

By the early 1930s, the Sydney Technical College was one of the few public educational institutions to provide courses in Radio Engineering at professional level leading to a Diploma.

From 1933, the College conducted two courses, a Radio Engineering Diploma Course and a Radio Mechanics Trade Course. Both were of five years duration and were evening classes.

A condition of entry to the courses was employment in the radio industry as the courses were designed to be supplementary and complementary to the daily work of the students.

The standard of entrance to the Diploma course was the same as for other Diploma courses conducted by the College. Subjects of the first two years were the same as those in the Electrical Engineering Diploma Course. The third year was also the same, except that another subject was substituted for Electrical Engineering II. In the fourth year, Applied Mechanics II and Heat Engines I were taken, and a special course in Electrical Machinery. The rest of the time in the fourth year, and the whole of the fifth year, were devoted to Radio Engineering and Sound Projection, including suitable practice in Drawing and Design.

In the Radio Mechanics Course, the first three years were taken up with Elementary Science and Mechanics, Trade Calculations, Applied Electricity, Drawing and Laboratory Work. The fourth year was devoted entirely to Radiocommunications lectures and Laboratory activities, followed by more advanced work in the fifth year.

The Electrical Engineering Department in 1935 was under the control of Mr R C Simpson, with Mr H R Harrington being one of the full-time teachers in the Diploma subjects in Sydney. The College also had teachers in Electrical Engineering located at Newcastle and Broken Hill. By 1940, additions to the Sydney teaching staff included Mr A G Doe and Mr L J Fathers. It is of interest that not one of the recommended text books dealt exclusively with Radio Engineering. They all concerned various aspects of Electrical Engineering.

One of the evening lecturers from industry lecturing to final year students was Noel Smith, Chief Engineer Breville Radio and formerly Chief Engineer Raycophone Ltd.

A number of Advisory Committees served with College for various courses. In 1940, those members on the Advisory Committee for Radio Courses comprised representatives of:

Amalgamated Wireless (Australasia) Ltd, (Arthur McDonald); Standard Telephones and Cables (Australasia) Ltd, (Stuart McPhee); Institution of Radio Engineers, Australia, (Oswald Mingay); James Manufacturing Co., Ltd (Richard Kennell); Raycophone Ltd (Ray Allsop); Postmaster General's Department (Dick Knuckey); Western Electric Co. (Aust.), Ltd, (Robert Hill); Institution of Engineers, Australia, (Dr Geoffrey Builder); Airzone (1931) Ltd (Phil Parker); Electrical and Radio Development Assn of NSW (Norm Gilmour); Electrical Trades Union of Australia (N J Thom); Gramophone Company (John Briton); Stromberg-Carlson (Aust.) Pty Ltd (Allen Scott); and Thom and Smith Pty Ltd (Fred Thom).

By 1950, course subjects had changed in some areas, to take account of new technology, and extra courses added to the curriculum. Additional subjects included frequency modulation broadcasting, relaying and television. The Institution of Engineers, Australia had granted complete exemption to Technical College Associates in Radio Engineering. The Institution of Radio Engineers (Australia) accepted the College's Diploma in Radio Engineering in place of the preliminary and Associate membership examination of The Institution.

The College offered from time to time, Post-diploma courses in Radio Engineering subjects. There were Special courses in UHF Engineering to cater for Engineers who required updating of their knowledge in frequency modulation broadcasting, television and microwave principles.

One of the Special courses provided was for Cadet Radio Inspectors of the PMG's Department. The training extended over four years but attendance at the College was required only in the second, third and fourth years. Mathematics and Physics were taken at the University during the first year and this study at the University was continued in the second year simultaneously with attendance at the Technical College.

Prior to 1951, Radio Engineering at the College was a five year part-time post matriculation course leading to a Diploma of Associate of Sydney Technical College (ASTC) but in 1951, Diploma teaching was transferred to the University of Technology (later to become the University of New South Wales). Trade course were moved to the School of Electronics and Communications at North Sydney Technical College.

In 1967, courses in engineering included a full-time BE in Electrical Engineering with electronics and communications being subjects in third and fourth years of the course and a part-time B Sc (Tech) in Electrical Engineering with electronics being subjects in fourth and fifth stages and communications in the sixth stage of the course.

Winston Muscio was one College graduate who devoted a lifetime to Radio Engineering, making an important contribution to the broadcasting industry. He joined Standard Telephones and Cables Pty Ltd in 1933 where he worked on the design and manufacture of radio receivers for eight years. During the War years, he was involved in the design, manufacture and testing of a range of HF transmitters up to 20 kW output power. After the War, he was responsible for a new generation of MF and HF transmitters and in 1953 became Chief Radio Engineer, Consumer Products Division. In the 1960–70s, Winston was associated with development of a range of broadcasting equipment and radio link equipment as Senior Commercial Engineer of the Radio Transmission Division. In 1974, he was responsible for all Radio Engineering activities of the company, except mobile radio.

MELBOURNE TECHNICAL COLLEGE

The College was formed in 1882 as Melbourne Working Men's College with the support of Francis Ormond a local philanthropist who became the first College President.

The College became the Melbourne Technical College in 1934, the prefix Royal added in 1954 and the name Royal Melbourne Institute of Technology (RMIT) adopted in 1959.

In order to meet a demand for professional courses, a number of three year Associate Diploma courses including one in Engineering were introduced in 1899.

One of the early graduates was Donald McDonald who attended the College from 1900 until 1903 studying Electrical Engineering. He joined the Postmaster General's Department, later becoming an Engineer in the Telephone Department, Melbourne. In 1912, he was Wireless Engineer on the project which established a chain of radio stations around the coast of Australia and New Guinea employing wireless equipment designed and manufactured in Sydney. At the outbreak of the First World War, he joined the Royal Australian Navy, becoming Lieutenant Commander (Engineer). In 1921, he left the Navy to take up a career in Broadcast Engineering. Donald made an extensive overseas tour studying the latest developments in Radio Engineering, particularly as it applied to broadcasting. On return, he set up business in Melbourne as Consulting Radio Engineer and was responsible for the design and construction of many A Class and B Class stations in Victoria, South Australia and Tasmania.

Although a three year Associateship Diploma course was available in the 1920s for Electrical Engineers specific classes in wireless technology were not available until 1928. They were mainly provided as public interest classes but following a strong demand in the early 1930s as a result of the rapid expansion of broadcasting stations and receiver manufacturing organisations in Melbourne, a course leading to a Certificate in Radio Engineering was commenced in 1932 followed by a course in Radio Mechanics in 1933, a course for Radio Technicians in 1937 and a Diploma in Communications Engineering in 1937. A Broadcast Operators course was also conducted in 1937 for the benefit of staff responsible for operation and maintenance of broadcast transmitters and studios. There were eight broadcasting stations in operation in Melbourne at the time.

Instructors of the period included Ron Mackay, Joe Dobbyn and Reg Crow.

Ron Mackay joined the College staff in 1923, the year that broadcasting officially began in Australia. By the 1930s, he had become Supervisor of the Radio Engineering and Electrical Trades School of the College and it was due mainly to his efforts that the teaching of Radio Engineering subjects had reached the high level that existed at the time. In 1938, he presented a paper 'Education Aspects of the Radio Profession in Australia' to the World Radio Convention held in Sydney during 4 to 14 April. During the year he was a Member of The Institution of Radio Engineers (Australia) and was Secretary of the Melbourne Division.

Ron joined the Royal Australian Air Force at the outbreak of the Second World War and was in charge of Defence Training at the College. In 1943, he became Squadron Leader (Hon.). He oversighted the first wartime training course for the RAAF which started on 11 November 1939. Training continued until 12 October 1945.

In 1952, he was appointed Principal of the College and during 1961–62 served as President of The Institution of Radio Engineers (Australia).

Joseph Dobbyn began his career as an Apprentice Electrical Engineer during 1908–11 and between 1911 and 1925 worked in the PMG's Department Electrical Engineers Branch, Melbourne. During the First World War, he served in the RAN Transport Service as a Ship's Wireless Operator.

In 1925, he took up a position of Radio Inspector in the Department and still occupied that position at the outbreak of the Second World War. Classes at the College were basically evening classes so he was able to combine his teaching role with his Departmental duties. He was a Member of The Institution of Radio Engineers (Australia) and was Assistant Secretary to Ronald Mackay with the Melbourne Division.

Just before the outbreak of the War in 1939, the Radio School was constructed at the northern end of Bowen Street and later extended to Franklin Street.

During the War period, the College was a major training centre for Wireless and Radio Mechanics for the Royal Australian Air Force. Even before War, links were established between the RAAF and the College for training of technical staff, particularly Wireless Operator Mechanics. Before the first course had been completed, the War started and training arrangements were greatly expanded. The first course commenced in November 1939, and training of students continued until October 1945.

The most outstanding feature of the intensive training course was that it produced tradesmen in six months. This concentrated training and the subsequent field experience resulted in large numbers of former trainees entering the broadcasting industry after their discharge from the RAAF after cessation of hostilities.

Included in the wartime output of students, were 5324 Wireless Mechanics and 316 Radio Mechanics. The Radio Mechanics went on to do Radar Courses conducted by RAAF Schools.

One of the Instructors was Walter Chamberlain who was on the College staff for the period 1941 to 1944. Prior to joining the College, he was a Technician at 3XY Melbourne from 1936 until 1941 where L Shepherd was Chief Engineer responsible for the 600 watt series modulated AWA designed and built transmitter feeding a T type aerial on the Princess Theatre Building, Spring Street. In 1944, he spent a short period with the International High Frequency Station (Radio Australia) Shepparton during the commissioning stage and in 1945 returned to 3XY as a Technician, being appointed as Chief Engineer in 1956. Walter became a Student member of The Institution of Radio Engineers, Australia in 1936 and an Associate Member in 1937. He was still an active member in the 1970s.

The College introduced a five year Fellowship Diploma Course in 1943. A Diploma Course in Radio Engineering commenced in 1945. Later, some of the subjects became available as correspondence lessons.

In 1945, the College provided for the first time in Victoria a course in Electro-Acoustics. The classes were held one night each week in the Physics School. The course was a professional one and included demonstrations and practical work on vibratory motion, loudspeakers, pick-ups and microphones. A course was also available in Electronics, being an advanced professional course dealing with theory and application of gas and high vacuum valves. Instructors included S L Martin and J Straede.

In the early 1960s, staff at RMIT included Ian Angus, Martin Gawler, Kendale Green, Donald Matheson, Robert Rose, Robert Tymms and Rex Wales.

In 1967, subjects in the full-time course of 34 weeks per year for Associateship and Fellowship Diplomas in Communication Engineering comprised:

- First Year.
  Maths I; Diploma Physics I; Chemistry for Engineers; Engineering Perspective; Engineering Drawing I; Electronic Machine Shop; Diploma English.
- Second Year.
  Maths II; Diploma Physics II; Engineering Materials 1A and B; Communications and Electronic Principles A and B; Applied Electricity I/II; Engineering A; Computer Programming for Technologists.
- Third Year.
  Maths III; Electrical Engineering IIC; Communications and Electronic Engineering IA, B, C and D; Communications Drawing; Engineering Practices; Social Science; Lib. and Rep. Writing.
- Fourth Year.
  Maths IV; Physics IIIE; Communications and Electronics Engineering IIA and B; Systems Engineering A, B, C and D; Electrical Materials; Design Practice; Manufacturing Processes; Industrial Administration I; Social Science II.
- Fifth Year.
  Maths V; Physics VE; Communications and Electronics Engineering IIIA, B and C; Communications Engineering Project; Computer Application; Accounting for Engineers.

By 1971, a Degree Course in Communications Engineering was available and the early Diploma Course phased out. Degrees were issued by the Victorian Institute of Colleges on behalf of the RMIT but from 1981, RMIT issued its own Degrees.

In 1992, the establishment became RMIT University.

One of the Australia's most distinguished Radio Engineers, E J (Jim) Wilkinson was a former student of the College. He joined the Postmaster General's Department in 1937 as a Junior Mechanic-in-Training and qualified as Engineer in 1944. In his service with the Department he was associated with many important Radio Engineering projects.

They included Radio Australia Shepparton; trials for the introduction of FM broadcasting; Radio Australia Cox Peninsula; and expansion of the National Television in Australia. In 1971, he transferred to the Australian Broadcasting Control Board as Director of Engineering and in 1976 moved to the Postal and Telecommunications Department as first Assistant Secretary Radio Frequency Management.

Jim was associated with the Melbourne Technical College and later RMIT, for some 60 years as a student, lecturer and Chair of Faculty Course Advisory Committee for Communications Engineering. In 1996, he was honoured by being admitted to the Degree of Doctor of Engineering, Honoris Causa at RMIT.

Another former student who achieved high office in broadcasting was Roy Badrock.

Roy commenced work with the Postmaster General's Department in Melbourne in 1950 as Technician-in-Training. After completion of the course he worked in various areas of broadcasting throughout Victoria occupying positions up to Supervising Technician level.

During 1955 to 1962, Roy studied Radio Engineering at the Royal Melbourne Institute of Technology on a part-time basis and graduated in 1962. The following year he was appointed Engineer in the Department's Central Office Radio Section at Jolimont. His work involved system design, equipment development and provision of small and medium capacity radio bearers followed by a period planning the expansion of the national broadband bearer network.

In 1971, he returned to broadcasting, working as Supervising Engineer in a number of areas involving MF Broadcasting, Television New Works, Radio Australia Operations and National Operations.

Early in 1986, Roy was promoted to Assistant Director Operations with responsibility for oversighting the broadcasting network throughout Australia and interfacing with the National Transmission Agency on all network operational matters. He retired in November 1992 after 43 years service.

SOUTH AUSTRALIAN SCHOOL OF MINES AND INDUSTRIES

The South Australian School of Mines and Industries commenced classes in March 1899 and with increasing interest in radio in the early 1920s, the School was keen to provide classes in the new technology.

Although the local Wireless Institute conducted classes for members and potential members, there was clearly a need to meet a public demand for classes, so the School drew up a plan for a series of lectures and advertised in the local newspaper and radio magazine.

One of the students who attended the 1924 class was Ernest J Hume who later became Chief Engineer of Commercial station 5DN established by his father. The station was the first Commercial station to begin operation in the State.

The Wireless Course conducted during 1925 was attended by 74 students with the lectures extending over three terms.

In 1926, the course comprised 11 lectures with the syllabus being expanded on lectures of previous years. The syllabus included elementary theory of electricity applied to wireless; technical terms and symbols in general use in wireless; theory, operation and notes on the construction of crystal receivers; the three electrode valve as a detector; description of various kinds of valves and their characteristics; single valve receivers employing various methods of regeneration; the three electrode valve as a low frequency amplifier; construction and operation of low frequency amplifiers; the valve as a high frequency amplifier; resistance coupled, transformer coupled and tuned anode high frequency amplifiers; description and notes on the building of complete multi valve receivers, and the use of meters and tools. The lectures were illustrated throughout by actual apparatus and demonstration of receivers using various circuits.

By 1933, the scope of the course was such as to provide the necessary preliminary training for Radio Mechanics and Radio Servicemen and while not covering all details of transmitting technology, the course was useful for people preparing for Amateur Operators Certificate. The course extended over two years, and about 45 students were enrolled. The School also conducted a course in Electronics which dealt with theory and industrial application of electronic devices for practising Engineers.

Wilf Honnor, a former student of the School was a junior staff member during the period 1921 to 1925 and because of his association with the local Wireless Institution he took on the role of Instructor for the first classes conducted by the School. From 1925 to 1932, he was Instructor in Physics and Mathematics and from 1933 to 1937 was Lecturer in Wireless and Electronics, assisted by Stan Ackland and J M Honnor. In 1935, he visited England and spent time working with the BBC and the Marconi Wireless Telegraph Co., Ltd studying the latest developments in Broadcast Engineering. In 1937, he left the School and joined the AWA Research Laboratories.

One of the students in the 1930s was Johann (Lew) Schaumloffel. He was educated at Unley High School and attended the School of Mines before joining 5AD Adelaide as Junior Technician in 1937 under Chief Engineer Don Gooding. At the time, RCA heavy duty two-speed turntables were being installed in the studios for playing 16 inch (40 cm) discs for both lateral and vertical cut discs. AWA disc recording equipment with Presto 1B cutting head was also being installed for the production on a commercial basis of recorded features and programs. The 500 watt transmitter had a water cooled final stage employing an STC 4228 type valve. The enormous quantity of distilled water required for the valve cooling system was supplied by Fauldings in 20-litre carboys and had to be manhandled to the floor where the transmitter was installed.

In 1942, Lew transferred to 2BH Broken Hill as Chief Engineer remaining there until 1947 when he returned to Adelaide to take up a position in the PMG's Department Radio Laboratories. He later returned to 5AD and in 1958 when Don Gooding left to take up a position of Chief Engineer with ADS7 television station, Lew was appointed Chief Engineer of the Advertiser Network comprising 5AD Adelaide, 5PI Port Pirie, 5MU Murray Bridge and 5SE Mt Gambier, a position he held for many years until retirement.

By 1939, a number of radio manufacturers were active in South Australia and the two year course was expanded to produce graduates with a high level of skill in the radio trade.

After the War, there was an unprecedented demand for skilled Radio Tradesmen and Engineers and in 1947, the School introduced an Engineers Certificate Course in Radio Engineering which extended over a period of five years. In addition to practical training at local broadcasting stations, students also spent time at the PMG's Department Frequency Measuring Station operated by the local Radio Inspector at Somerton.

In 1949, practical classes commenced in newly constructed and well-equipped laboratories in the Bonython Jubilee Building. Thirteen distinct classes were conducted during the year embracing Applied Electronics, Morse Code and Procedure, Radio Engineering Design, Radio Physics and Electric Technology. In addition to classes conducted for Diploma students, others were provided for Technicians, Tradesmen and Trainees of the PMG's Department.

By 1952, to meet the needs of industry and Government Departments and Instrumentalities, a Communications Engineering Course extending over six years was introduced. The Physics component of the course was conducted by nearby University of Adelaide. There was also a Radio Technicians Certificate Course extending over five years encompassing Radio Physics, Radio Receiving, Radio Transmission, Radio Servicing and Radio Engineering Design.

In 1960, the School became part of the South Australian Institute of Technology with campuses at The Levels and Whyalla.

In the 1950s, the Radio Trades School took over responsibility for Technician Courses in radio, electrical and other courses.

In 1951, courses in which qualifications satisfied the examination requirements of The Institution of Engineers, Australia for professionals working in the broadcasting industry included Fellowship in Electrical Engineering and Associate Diploma in Electrical Engineering, Electronic Engineering or Communication Engineering. In 1951, the Radio Engineering course became Communications Engineering with a further change in 1957 when it became Electronic Engineering.

In 1958, Associateship courses were superseded by similar courses leading to the Bachelor of Technology Degree awarded by the Adelaide University but conducted by the School. Administration was controlled by a Faculty with half members from the University and half from the Institute. It was a three year course with the majority of students being from the Postmaster General's Department and the Weapons Research Establishment.

In 1991, the University of South Australia was established taking over the work of the Institute. By 1998, it was the most diverse University in the State with six campuses.

One of the long-time staff members of the School of Mines was David Cox. He attended the University of Adelaide 1932–1935, graduating with a Science Degree and the following year completed an Honours Course. Professor Kerr-Grant was Professor of Physics at the University at the time. He had been at the University since 1910 and was a foundation member and first Chairman of the South Australian Division of The Institution of Radio Engineers (Australia) when the Adelaide Division was formed in 1936.

David became interested in radio in the third year of his science course. He constructed a two-valve regenerative receiver followed by a superheterodyne type.

His first job was with the School of Mines where for 12 months he was Instructor in Wireless I and II evening classes while Wilf Honnor was overseas on study leave. About three years later, he was offered a full-time position to lecture in Mathematics, Physics and Wireless I and II for evening students and an Electronics course for Saturday morning students. The Electronics course has basically an industrial subject. Courses in Electronics for communications were not developed until after the War.

During the War years, David provided instruction for Army and Air Force personnel in a Radio Mechanics Course of three months full-time duration. Course material and equipment for practical instruction were provided by the Army. There were five courses conducted over a period of 18 months with each course comprising 20–25 students. Other subjects taught included Morse Code by Bill Gill and Navigation by George Haskard, Head of Mathematics Department.

David was an active member of The Institution of Radio and Electronics Engineers, Australia, being admitted as Associate Member in 1943.

PERTH TECHNICAL COLLEGE

Although the Perth Technical College (PTC) was involved in training students in Electrical Trades courses as early as 1927, it did not begin to provide courses in radio subjects until 1938.

The College was established in 1900 as the Perth Technical School. It changed its name to Perth Technical College and in 1901 affiliated with the University of Adelaide to offer the first Degree courses in Western Australia. In 1915, affiliation was transferred to the University of Western Australia and in 1965, the WA Institute of Technology was established at Bentley, carrying on the professional courses operating at the PTC. However, the PTC continued to play a major role in training tradesmen, technicians and para-professionals until it eventually closed to become a College of TAFE.

The WA Institute of Technology (WAIT) became the Curtin University of Technology in 1987. Curtin University was the first of the CAE's to become a University and the first Australian University to enrol full-fee international students with its main strength being in its technical and vocational courses. It has a historical library dedicated to former wartime Prime Minister John Curtin.

One of the early lecturers at the Perth Technical College in radio subjects was George Moss who began employment as a part-time lecturer in 1938 in a newly established evening class of Radio Technology. This course was soon followed by one for compulsory daytime technical training for Radio Service trade apprentices.

After the War, Donald Farquhar joined the staff to provide a full-time training program for discharged Servicemen in Radio Servicing under the Commonwealth Government CRTS arrangement. The course lapsed after the CRTS students had graduated.

Associateships and Diplomas in Communications Engineering which embraced Radio and Electronics were introduced in the immediate post War period by Dr A H Nash who joined the College in 1946 after having spent some years with AWA and the Radio Research Board. In 1967, he became Dean of the School of Engineering and Surveying in the newly established WAIT.

Associateships in Electrical Engineering, Communications Engineering and Electronic Engineering were recognised in 1950 as qualifications which satisfied the examination requirements of The Institution of Engineers, Australia. Courses in the various engineering disciplines had common basic and engineering sciences in the first and second years of study but students took subjects in their respective disciplines from first year onwards. Electrical Engineering had an emphasis on mechanical aspects but low current electrical engineering was catered for by a course in either Communications or Electronics. All courses included subjects of English Expression, Workshops, Analysis Errors, Slide Rule, Engineering Management and a course in First Aid. Part-time courses were introduced in 1925 but full-time courses were not available until 1945.

Classes at Technician level were also available at the College mainly to meet the requirements of the Postmaster General's Department and the Department of Civil Aviation staff training programs.

About 1948, there was a growing public interest in a range of Radio courses, in particular for people to pass the appropriate examination to qualify as Broadcast Station Operator. Two courses in Radio 1 and Radio 2 which were already available were upgraded and combined with other subjects to provide a Radio Operators Certificate course. The Course involved four years part-time study for the students.

About 1950, a condensed course leading to the Amateur Operators Certificate was introduced to meet the needs of those who were interested in radio as a hobby or for recreation.

By 1954, Certificate courses for Television Technicians were being conducted and in 1956 an additional course was provided to enable Radio Servicemen to practise as TV Servicemen.

One of the best-known teachers and administrators at the Perth Technical College was George Hayman who was associated with the College over the period 1918 to 1962. He became Director of Technical Education in 1961, and during his career made a major contribution to Radio Engineering in the State. Included in his many activities was radio research into Radio Direction Finding (RDF), later to be known as Radar. At one stage, he studied under Robert Watson-Watt the British Radar pioneer. He also made significant contributions to the advancement of Amateur Radio extending over a period of more than 30 years.

In 1934, he was appointed Head of the Perth Technical College Professional Engineering Department and helped to pioneer Associateship courses in Engineering in 1944. Just prior to his retirement, he was awarded life membership of The Institute of Radio Engineers, USA.

One of the staff in the mid 1960s was Alan Cook an Associate Member of the Institution of Radio and Electronic Engineers, Australia since 1951.

UNIVERSITIES

Australian universities contained little course material directed specifically towards Radio Engineering in Engineering Degree courses before the 1930s. However, many of the Science Degree courses encompassed related subjects such as propagation, the ionosphere, atmospherics, etc, in the final year of the course. In the early 1930s the University of Sydney had an arrangement whereby, as an alternative to Electrical Engineering II in the fourth year, students could, with the approval of the Faculty, take a course in Electrical Communication. Professor John Madsen was Chairman of the Government's Radio Research Board from 1927, and he was able to involve students in some of the Board's research projects. William Baker was active in research in the radio field at the University from about 1927.

In 1932, Professor Madsen arranged for Herbert (Bert) Wood, a young graduate working in the Radio Research Board to prepare and deliver the first course of lectures in Radio Engineering to final year Electrical Engineering students at the University. Many years later in commenting about the situation at the time he said that the only books which could be located and which would be suitable for the lectures were 'The Admiralty Handbook of Wireless Telegraphy 1931' published in the UK and used for training Wireless Telegraphists in the Royal Navy and another book, 'Wireless Principles and Practices' by W T Palmer. A couple of overseas produced magazines were also helpful in the preparation of lecture material.

Professor Tom Laby of the University of Melbourne was also a member of the Radio Research Board from 1927 and he too, was able to involve students in research projects. Dr Brown, head of the Electrical Engineering Department had been devoting particular attention to certain phases of radio work at the University for some years.

Although not a member of the Radio Research Board, Professor Kerr-Grant of the University of Adelaide had been consulted about the desirability of establishing such a Board as he had been instrumental in introducing Radio Engineering subjects to the University curriculum. He was active in providing lectures in radio prior to the establishment of broadcasting and in 1922 acquired some R type valves using these for instruction purposes. The University soon achieved a reputation for its high class radio research work and in the World Radio Convention sponsored by The Institution of Radio Engineers (Australia) in 1938, Professor Kerr-Grant and Mr M Iliffe presented a paper and gave a working demonstration on the maintenance of a tuning fork in vibration by a valve, using electro-static drive.

The University of Adelaide has had active involvement in radio science since 1897 when Professor William Bragg gave the first recorded public demonstration in Australia of the working of wireless telegraphy apparatus and has continued the tradition of being a leading teaching institution to present times.

Even in more modern times, not all Universities conducted courses in Engineering. In the 1960s, Universities which did not include Engineering as a course included Australian National University, Canberra; Flinders University, Adelaide; University of New England, Armidale; Macquarie University, Sydney and La Trobe University, Melbourne.

All Engineering faculties offered four year courses for the Degree of Bachelor of Engineering, although there were some exceptions such as a Degree of Bachelor of Technology being conferred by the University of Adelaide for a three year course which was conducted by the South Australian Institute of Technology.

At the time, there were some minor variations in handling non-technical subjects of the Engineering course. For example, at University of Sydney, Mathematics was conducted by the Faculty of Arts and Physics and Chemistry subjects by the Faculty of Science, whereas at University of Melbourne all subjects were provided within the Faculty of Engineering with the subjects being specially designed for the Engineering course.

Some Universities included non-technical subjects in the Engineering course. At the University of Western Australia, Engineering History and Management were included as subjects in the final year, and at Monash University and University of New South Wales, Humanity subjects were part of the course.

By the mid 1950s, many additional topics were included in Electrical Engineering courses to take account of new and rapid developments in technology. Increased lecture time was devoted to such topics as electromagnetic theory, network analysis, electronics and measurements. By the mid 1960s, more advanced studies over a wider range of topics were part of most final year courses. While electron valves and their application as rectifiers, oscillators, amplifiers, modulators and demodulators etc, dominated electronic studies in the 1950s, the 1960s witnessed a change-over to solid state devices involving application as film integrated circuits, high speed switching circuits, and other devices with application to communications and computer technologies. Computer Programming was also introduced, especially on project and assignment course work.

Courses were more theoretical, more mathematical and more abstract compared with the approaches of the 1950s. The computer had a major impact on the way the student approached the course work. The courses were intended to produce Professional Engineers with greater potential to handle an environment of rapidly changing technology. Today, there are some 38 Universities in Australia with the great majority offering courses in Engineering and Technology. Monash University, one of the first of the post War Universities offers 13 different disciplines in its Engineering Faculty.

Although University of Sydney was founded in 1850 followed by University of Melbourne in 1853, it was the University of Melbourne which introduced the first formal Engineering course in Australia. Over the years, it has produced many Engineers which have served the broadcasting industry with distinction. Two who graduated with BEE Degrees were A J (Alec) McKenzie and W E (Bill) Beard.

Alec McKenzie joined the Research Laboratories of the Engineering Branch of the Postmaster General's Department in 1927. Amongst many projects on which he was involved were the design of the 6WF transmitting station in 1932, development of high frequency transmitting aerials for Lyndhurst and Radio Australia, and development of flat top radiators for MF broadcasting stations. During 1948 to 1968, he worked with the Australian Broadcasting Control Board being Director of Technical Services on retirement.

Bill Beard joined the Research Laboratories of the PMG's Department in 1946 working on Primary Frequency Standards, UHF radio propagation and ionospheric and tropospheric scatter research. He transferred to the Department's Radio Section as Head of the Division in 1961, being responsible for extensive development of the National Broadcasting and Television Services including the establishment of Radio Australia, Cox Peninsula. In 1976, he transferred to the Australian Broadcasting Control Board to take up the position of Director of Engineering.

TAFE

In recent times the system of TAFE Institutes and Colleges provides the basis for technical education for the broadcasting industry work force and is also seen as an alternative to University education. TAFE is Australia's major provider of vocational education and training. Unlike Universities, which generally offer a more broadly-based education, TAFE provides training for specific jobs or professions. The courses are designed to meet the educational and training needs of industry and students.

In 1998, there were some 250 TAFE centres throughout Australia. Classes are usually small in number with 15 students being an average class and unlike Universities, there are few large lectures.

A feature of TAFE education is its flexibility. Many courses are available full-time, part-time in the evenings and weekends, and through self-paced learning or distance education which may include computer work or satellite transmission.

In the past, TAFE institutions were places where Apprentices and Tradespeople were trained, but many changes have taken place since those days. In addition to Apprenticeships and Trades, TAFE institutions now train Professionals and Paraprofessionals.

Broadly, Universities offer Degrees, Advanced Diplomas and Diplomas at Professional and Paraprofessional level while TAFE offers Advanced Diploma, Diploma at Professional level, Certificate IV at Trade Technician/Supervisory level, Certificate III at Skilled Trades level, and Certificates I and II at Skilled Operative level.

A new system of qualification, Australian Qualifications Framework (AQF) is being introduced into Australian education. TAFE institutions started to award AQF qualifications in 1995 but will not phase out the existing qualification system completely until end 1999.

The framework sets up a new progression of qualifications which for Higher Education are Doctoral Degree, Masters Degree, Graduate Diploma, Bachelor Degree, Advanced Diploma and Diploma. For Vocational and Education Training, qualifications are Advanced Diploma, Diploma, Certificate IV, Certificate III, Certificate II and Certificate I.

An example of a typical course popular with workers in the broadcasting industry is Electronics (Communications) provided at a number of TAFE centres in New South Wales in 1998 leading to qualification of Certificate III AQF. It is a three year Course comprising 864 hours and intended for Electronics Trade Apprentices, Trainees or other Tradespeople working in broadcasting, radiocommunications, television, and satellite communications. Other Courses which would follow completion of the Course include Electrical Engineering Advanced Certificate and Electrical Engineering Associate Diploma. Core subjects are Electrical Principles I and II, Workshop Practices, Occupational Health and Safety, Digital Electronics I and II, DC Power Supplies, Electronic Hand Soldering Technology, Filters and Resonance, Amplifiers I and II, Feedback Filters and Oscillators, Digital Sub-Systems, Microprocessor Fundamentals, Advanced Test Equipment and Industrial Relations and Apprenticeship. There are a wide range of Elective subjects available with those of particular industry to people in the broadcasting industry including Oscillators, Telecommunications, Communications Fundamentals, Antenna Installation and Servicing, Operational Amplifiers, Microprocessor Programming, Switching Power Supplies, Amplifier Principles, Modulation, Receivers, Transmitters, Transmission Lines and Antennas, Introduction to Microwave Links and others.

One of the popular Courses was that provided to prepare students for the Examination held by The British Institution of Radio Engineers.

The Examinations were held throughout the British Empire on a regular basis. The Course subjects comprised Practical Mathematics to the required standard; Physics; Radio Technology; Radio Engineering; Radio Measurements; Radio Transmission; Radio Reception including Radio Receiver Design and Practice; and Television. The Course was highly rated by the broadcasting industry. In the 1940 Examination, the President's prize was awarded to a student of the BIET.

During the ten year period 1932–42, Institute students achieved at least 90% success for Examinations conducted by various Engineering Institutions.

In 1940, The Australian Branch of BIET undertook to coach without charge, RAAF Air Crew Reservists waiting to be called up under the Empire Air Training Scheme. The Air Board officially approved the Institute to conduct correspondence tuition to those Air Crew Reservists whose circumstances prevented them from attending classes. At one stage the Institute was coaching 800 of the Reservists in subjects of Mathematics, Physics and associated subjects.

One BIET student was Staunton McNamara who completed a Course in 1947 and was awarded the BIET Diploma. Staunton had a distinguished career in broadcasting having worked at Commercial stations, the National Broadcasting Service, the Australian Broadcasting Corporation, 5UV University of Adelaide and Technical Director of Quality Broadcasters.

THE BRITISH INSTITUTE OF ENGINEERING TECHNOLOGY LTD

The British Institute of Engineering Technology (BIET) with Head Office in London was established in the early 1920s, specialising in Engineering Technical Training by correspondence with students throughout the English-speaking world.

The Institute was represented in Australia by The British Institute of Engineering Technology (Australasia) Pty Ltd located in MacDonell House, 321 Pitt Street, Sydney. The Branch was inaugurated in August 1934 to cater for the Institute's students in Australia, New Zealand and the Far East.

The BIET catered for a very wide range of Technical Education with Courses being categorised under Groupings of Civil and Constructional Engineering; Surveying, Architectural and Building; Mechanical Engineering; Commercial Engineering and Administration; Automobile Engineering; Aeronautical Engineering; Electrical Engineering and Radio Engineering and Allied Groups.

Courses forming part of the Radio Engineering and Allied Group included AMBrit.IRE Examination; City and Guilds Examinations in Radiocommunications; General Radio Engineering; Radio Servicing, Maintenance and Repairs; Advanced Radio Engineering and Design; Short Wave Wireless; Practical Television; Talking Picture Engineering; and PMG's Operators Certificates of Proficiency Examinations.

Courses were divided into two main branches:

* Examination Courses, compiled with the specific object of covering the actual requirements of recognised Engineering Examinations and termed 'coaching courses'.
* Non-Examination or General Courses designed for the student who did not wish to study immediately for any particular examination, but who desired a comprehensive course of education in certain subjects.

The Diploma of Membership of the Institute (MIET) was awarded to students on completion of the Examination Course which enabled the student to become an Associate Member of the British Institute of Engineering Technology.

OTHER SCHOOLS AND INSTITUTIONS

Many other schools and institutions provided courses and instruction in the science of radio, with some opening in the 1930s to meet public demand for knowledge and practical instruction. A number closed down at the outbreak of the Second World War when many of the instructors left to join the Services.

They included:

* **WIRELESS INSTITUTE OF AUSTRALIA**

  The Wireless Institute of Australia can trace its beginning back to 11 March 1910 when a group of wireless telegraphy enthusiasts assembled in Sydney with the intention of establishing an Institute of Wireless Telegraphy. The provisional committee comprised George Taylor, Chairman; Frank Leverrier; Harry Leverrier; Charles Bartholomew; Jack Pike; W H Hannam; A Garnsey; I Cleary; Major Fitzmaurice; Major Rosenthal; Captain Cox-Taylor; Dr Brissenden and Mr Gosche. The organisation became the Wireless Institute of Australia with Divisions being subsequently established in all States.

  One of the primary objectives of the WIA was to 'impart instruction both theoretical and practical in various branches of wireless work'.

  In 1930, The New South Wales Division conducted a Radio School in which it provided for two courses. One was a General Technical Course and the other a Trade Technical Course.

  The General Technical Course covered a series of five terms with each term being of three months duration. The final term included subjects such as audio amplifiers, radio frequency amplifiers, receiving and transmitting valves, modulation techniques and transmitters. At the end of the course, students were encouraged to sit for the Wireless Institute Trade Certificate and to continue on through the Trade Technical Course, prior to sitting for the Trade Certificate.

  The Trade Technical Course covered a total period of six months in one term, requiring attendance for one night each week. Instruction was given in both theoretical and practical respects of radio. The course was of particular benefit for Radio Servicemen and Radio Mechanics. Satisfactory completion of the course entitled students who had reached a certain standard, to sit for the Trade Certificate Examination.

The School conducted a correspondence course for students who could not attend classes in Sydney.

The Australian Radio College took over responsibility for the courses from the Institute as from 1931.

The Victorian Division also conducted technical instruction classes in Melbourne. At the beginning of 1929, following preparation of a syllabus just before Christmas 1928, it began a course of lectures on a regular basis, one night per week for a period of four months. The syllabus was prepared by Divisional Council with inputs from leading Victorian Amateurs. Principal lecturers for the start of the series of courses were Max Howden (VK3BQ) and G W Steane (VK3UX).

Lectures by prominent Engineers, Technicians and Mechanics particularly those who were active members of the Institute was an important feature of all State Divisions educational activities.

In South Australia, one of the regular lecturers in the late 1930s was Gilford White, Technician-in-Charge of the Service and Maintenance Laboratory of Charles Birks and Co., Ltd, a prominent Department store in Rundle Street, Adelaide which sold and serviced radio receivers. Mr White began studies in Electrical Engineering at the University of Adelaide and completed the course at the SA School of Mines. He was an Associate Member of The Institution of Radio Engineers (Australia) and held a Broadcast Station Operators Certificate.

* **AUSTRALIAN RADIO ENGINEERING ACADEMY**

The Academy was located in Perry House, Elizabeth Street, Brisbane, and began operation in 1939 just before the outbreak of the Second World War. Joint Principals were Albert Brayne and Mr A E Murphy.

Mr Brayne was well-known in Radio Engineering circles in Brisbane. He was Manager of the Radio Department of Trackson Bros., Pty Ltd in Elizabeth Street, President of the Electrical and Radio Industry Club, President of the Australian Trained Radio Servicemen's Institute and Vice-Chairman of the Brisbane Division of The Institution of Radio Engineers (Australia).

Courses at the Academy covered a wide range of subjects for Radio Engineers, Radio Servicemen, the Broadcast Engineers Certificate, Professional Wireless Operators, Dealers and the Radio Hobbyist. There were ten courses altogether.

Instruction was given during evening periods 6.45 pm – 9.30 pm weekdays, and 1.30 pm – 5.00 pm Saturday. As well as classrooms, there were well-equipped laboratories plus a large screened room.

* **AUSTRALIAN SCHOOL OF RADIO ENGINEERING**

This school located in Wembley House, Railway Square, Sydney was basically a correspondence school. It was active during the 1930s when it conducted 10 courses ranging from a Beginners Course, to an Advanced Radio Engineering Course. It also had courses for Amateur Operators, Sound Projectors and in Morse Code.

The School provided a comprehensive set of parts as part of practical training at home. They remained the property of the student after completion of each project.

The School was the official representative in Australia of the Institute of Wireless Technology (London) which conducted courses at Diploma level.

Principal of the School was Reginald T Andrew, a graduate of the Institute of Wireless Telegraphy.

In 1937, Chief Examiner of the School was Ernest Beard, a well-known Radio Engineer who constructed 2KY and 2GB and founded Ace Amplifiers.

* **RADIO TRAINING INSTITUTE**

The Radio Training Institute was located at 407–409 Swanston Street, Melbourne. It had a curriculum that included all phases of Radio Technology from elementary electricity to broadcast transmitters and television receivers. In addition to the class lectures, there were extensive workshop and laboratory facilities with equipment and test instruments for conducting experiments and practical work projects.

Special attention was given to the training of Radio Servicemen by Instructors who had considerable experience in this field. The Institute was active during the early 1930s when several factories were established in Melbourne, and it made a significant contribution to meeting the needs of these factories for qualified mechanics. During 1933 and 1934, the courses being conducted were so popular that there was a long list of students waiting to be enrolled.

* **THE WIRELESS CONSTRUCTION SCHOOL FOR AMATEURS**

This was one of the early schools having been active before the advent of broadcasting. It was primarily concerned with training people who wanted to obtain the Amateur Operators Certificate. Courses were conducted on Morse Code as well as theoretical and practical application of wireless.

In 1923, the School was located at Dengate Lane, Ashfield, Sydney having previously operated from premises in Burwood. It was run by a well-known firm Dixon and Grove who were Electrical, Mechanical and Radio Engineers.

Classes were conducted Monday, Thursday and Friday evenings for two hours each evening. Correspondence courses were provided for country students.

* **CROYDON RADIO SCHOOL**

The Croydon Radio School was established in 1925 by Charles Slade and many people who later became prominent in various fields of radio, particularly as Ship's Operators, Radio Servicemen and Mechanics owed much to the encouragement and expert teaching skill of 'Charlie' as he was known to the students. One of his former students Les McMunn, played a leading role in Radio Engineering with EMMCO for many years. The School was located in Lang Street, Croydon, a Sydney suburb.

Charles Slade was an expert Ship's Wireless Operator and Radio Engineer having served in the Royal Navy for 15 years from 1909 until 1924 with service on battleships and submarines. His duties as Instructor of wireless trainees gave him a good background when he established his own school after coming to Australia.

Prior to setting up the School he worked as a Radio Engineer for W H Wiles. He then spent three years as Technical Editor for 'Wireless Weekly' and the 'Daily Telegraph Radio Supplement'. After a short time as Radio Engineer for Keogh Radio Ltd, he commenced business as proprietor of Croydon Radio, Lang Street, Croydon where he specialised in the manufacture of superheterodyne receivers. With establishment of Slades Radio Pty Ltd, he produced specialised precision test equipment as the Calstan brand including set analysers, multimeters, signal generators, output meters, valve testers, portable valve checkers and oscillators.

* **INTERNATIONAL CORRESPONDENCE SCHOOLS (A/ASIA) LTD**

In the early days of wireless telegraphy, the International Correspondence Schools was one of the few organisations which provided instruction in the technology for people unable to attend a place of instruction.

The organisation was founded in the USA about 1890, with a branch subsequently being established in the UK. Students in Australia could undertake courses for Radio Operators through the USA office or a course in Wireless Telegraphy through the UK office. The UK Wireless Telegraphy course was available from 1917 just before the end of the First World War. No doubt the School Principals could envisage the surge of interest in the technology with the end of the War following the training of great numbers of Service personnel in the new science.

One of the early students of the ICS Wireless Telegraphy Course was George Cookson who later became a prominent Engineer with Amalgamated Wireless (A/Asia) Ltd.

After completion of the course and obtaining a Certificate, George joined the Coast Radio Service at the Townsville station in 1917. At the time, the Royal Australian Navy had control of all Coast Radio Stations as the country was at War, and all staff became members of the Navy.

In October 1920, the Postmaster General's Department resumed control of the Coast Radio Service but because of commercial implications, the Department did not wish to operate the Service, and on 28 March 1922 signed an Agreement with AWA for that company to take over the network of stations.

George Cookson and other members of the Service then became members of AWA staff. By that time, George had also served at Cooktown and Sydney.

The company made a number of changes to staff arrangements with one change being to transfer George to the AWA Radio Centre at Pennant Hills as Resident Engineer.

With the construction and operation of 2FC by AWA on behalf of 2FC licensee Farmer and Company at Willoughby in 1923, George transferred to the station as Resident Engineer, residing in part of the main transmitter building with his family.

After a period at 2FC, AWA sent him to England in 1926 to study the latest developments in wireless technology and on his return was posted to Pennant Hills for a second time as Resident Engineer. Included in the large number of transmitters at the site was short wave transmitter VK2ME at 20 kW, the most powerful short wave transmitter in the southern hemisphere. Through regular overseas broadcasts it became known as 'The Voice of Australia'.

By about 1938, George had become Construction Engineer with AWA.

Another well-known Radio Engineer who obtained a Diploma in Radio Engineering from ICS was Tom Taylor. Tom had been conducting radio experiments for some years during the early 1920s and in 1926 established Taylor's Radio Service in Cessnock where he was distributor for many well-known brands of radio receivers, manufactured receivers to his own design in his workshop, built audio amplifiers for public address systems and carried out receiver servicing in the district.

When Commercial station 2CK was commissioned on 9 January 1939 with a 300 watt AWA transmitter and self-supporting lattice steel radiator, he was appointed Chief Engineer of the station. He was an inventor of some standing having been granted two Patents for radio circuit designs.

When The Institution of Radio Engineers (Australia) was founded in 1932, Tom was one of the early members being admitted as Associate Member in 1932. In 1952, he became a Senior Member and was still an active member in 1964.

An Australian office, International Correspondence Schools (A/Asia) Ltd was opened in 1920 with the UK Wireless Telegraphy course being available for local students.

Two of the early students were members of the West Suburban Radio Club in Australia. They were helped in working through the Course by experienced members of the Club and in particular, Lance Coombe one of the Club's Council members.

In addition to lecture material, courses included textbooks printed in the USA by the publishing arm of the organisation. Some of these early books can be seen in vintage radio collections today and include 'Undamped Wave Radio Communication', 1922; 'Radio Antennas', 1929; 'Radio Tubes', 1932; 'Codes and Practices', 1931; 'Radio Telegraph Transmitters', 1929; and 'Radio Telephone Transmitters', 1930. In subsequent years, these separate publications were combined into larger updated issues.

By 1934, the School by an arrangement with the Radio Corporation of America, offered courses in the subjects of Radio Engineering, Radio Servicing, Radio Equipment, Radio Salesmanship, Radio Mathematics and Talkie Operating.

When people from the Services began to return to civilian life after the Second World War, ICS provided a number of courses to encourage those who had experience in radio to undertake studies to upgrade their qualifications. The School advertised the setting up of special courses of instruction prepared by experts with individual correction of students work for those studying for radio examinations particularly Commercial Operators Certificates, Amateur Operators Certificates and examinations conducted by Radio and Wireless Institutes.

In the 1970s, the ICS conducted six courses in radio-TV engineering and servicing, courses for PMG's Department certificates, a course for IREE examination, twelve courses in electronics and three in electronic computers, with all courses giving revision in basic mathematics and graded study manuals, to the more advanced work.

Periods of study varied from about 250 hours for a basic electronics course to about 1175 hours for the practical radio-TV engineering course.

Enrolments were effected by personal interviews with a trained careers officer or by mail in which guidance forms were used to assess the potential student's educational standards.

By 1993, Radio Engineering technology was covered by a single subject, Electronics Technicians Course with television being a separate subject.

* **Stotts Technical Correspondence College**

Another organisation providing a correspondence course for wireless enthusiasts in the early 1920s, was Stotts Technical Correspondence College which had been established in 1883.

Well before the establishment of broadcasting stations in Australia, the College catered for the needs of experimenters and potential Ship's Wireless Operators.

At the time, Director and General Manager of the College was Fred Everett who joined the College in 1922. He had received a technical education at Gordon Technical College, Geelong and was particularly interested in expanding the College technical courses, especially in the wireless and electrical fields. He left Stotts in 1926 to found Everetts Business College Pty Ltd, Melbourne but during his period with the College the number of courses had increased through various State offices.

To meet the need for the broadcasting industry with the establishment of broadcasting stations in Sydney and Melbourne in 1923, the College offered an Engineer-Operator Course through its Melbourne, Sydney and Brisbane offices. It was a popular course and by the end of 1925 when some 17 A Class and B Class stations were operational in Sydney, Melbourne, Brisbane, Hobart, Perth, Adelaide, Newcastle, Bathurst and Toowoomba, the College had 36 students enrolled in the Engineer-Operator course.

An office in Perth trading as Stotts Business College held a licence for operation of Amateur station 6BP in mid 1924.

At the time, offices of Stotts Technical Correspondence College were located at 100 Russell Street, Melbourne; 70 Pitt Street, Sydney; and 524 Queen Street, Brisbane.

In 1934, Stotts provided a new correspondence Radio Course designed to meet the needs of Amateurs, Radio Salesmen, Experimenters, Dealers, Radio Servicemen, and Manufacturer's Production and Testing staff. The Course was prepared by Arthur Box who had been associated with radio journalism since 1925. He was a member of the technical staff of 'The Listener-In' during the period 1926–30, Editor of 'Popular Hobbies, Radio Trader and Modern Sets 1930–32'. He rejoined 'The Listener-In' in June 1933 and it was about this time that he began preparation of the text for the Stotts Radio Course.

In 1993, the College operating as Stotts Correspondence College Pty Ltd was still active in the radio education field providing a range of subjects of interest to Radio Technicians including Certificate in Basic Electronics, Radio/TV Servicing, Introduction to Electronics, Digital Electronics, Radio Receivers, Marine Radio Certificate and others.

By 1997, Stott's Off-Campus College had more than 400 courses available and in addition to the 1993 Radio courses there were courses in CD Servicing, VCR Servicing, Cellular (Mobile) Phones and PC Maintenance.

One of the early Instructors at Stotts Technical Correspondence College was Bill Finney who was on the staff of the College in

Brisbane for many years as Instructor, Wireless Telegraphy. Bill was educated in Brisbane at the Brisbane Grammar School, and following completion of studies at college, entered the State Public Service followed by service in the Commonwealth Public Service, resulting in a period of some 25 years as a Public Servant.

He had been a keen student of wireless telegraphy from as early as 1910 when he conducted experiments employing equipment he constructed himself, including transmitter spark coil; transmitter capacitor made from glass plates, shim brass and immersed in a tub of oil; coherer using iron filings as receiver detector; and several designs of aerial systems. When the Brisbane Coast Radio Station became operational on 2 September 1912, Bill built a crystal set using a homemade loose coupler and a piece of galena which he obtained from a friend, and learnt the Morse Code by listening to the transmissions from the station. After the War, he obtained a R type valve and built his first valve receiver.

He was one of the foundation members of the Queensland Division of the Wireless Institute of Australia and an active member with his Amateur station A4AU from 1923, and later OA4WF.

During his period with the Commonwealth Public Service, he worked in the Postmaster General's Department as a Telegraphist and when the Department established the Radio Inspector's Office in Brisbane in 1924, Bill was appointed Acting Radio Inspector. In 1925, he resigned from the Department about the time that A Class station 4QG became operational and later entered the radio industry becoming a partner in the Brisbane office of National Radio Corporation Ltd.

* **BRADSHAWS BUSINESS COLLEGE**

In the 1920s, Bradshaws Business College, Prince's Bridge, Melbourne conducted Radio Experimental Classes with Howard Kingsley Love being the Course Director.

Instruction was provided one hour per week during the period 7.30 pm to 8.30 pm and covered electrical and radio theory, and training in Morse Code.

Course Director Howard Love, had operated a wireless telegraphy station in Melbourne prior to the First World War and at the outbreak of hostilities joined the AIF serving in Europe.

After the War, when the PMG's Department began to issue Experimental Station licences, he was granted a licence and operated station A3BM from his residence 'Lindum', Ferncroft Avenue, East Melbourne. He was one of the early experimenters who operated a radio telephone station designed for speech and music transmissions. The station operated with an umbrella type aerial about 22 m high with programs being transmitted in the 440 metre band.

He was an active member of the Wireless Institute of Australia serving as President of the Victorian Division; Editor of 'Radio Experimenter'; and later Managing Director of the magazine 'Radio Broadcast'.

Following work with Firth Bros., and Radiovision, he established a business, Kingsley Radio, to manufacture receivers about 1931. Students at the College where he was Course Director received their practical experience in receiver assembly and testing at his factory in Spring Street, Melbourne under supervision of experienced staff.

• **COMPANY IN-HOUSE TRAINING**

Large commercial organisations associated with the broadcasting industry also had a need to train technical staff to meet their particular requirements. Standard Telephones and Cables Pty Ltd (now Alcatel Australia) was one of these companies.

Even before the introduction of broadcasting in 1923, the company then known as Western Electric Co. (Australia), Ltd recruited Apprentices. The first Apprentice was A Morgan an Apprentice Electrical Mechanic who joined the company in 1921.

During the 1930s when STC was heavily involved in the manufacture of broadcast transmitters for Government and Commercial stations and domestic radio receivers, large numbers of Tradesmen and Engineers were recruited as well as Technical staff to fill positions between Tradesman and Engineer for work on design and production. Many Tradesmen were given additional training to fill positions of Technician but later, advantage was taken of courses provided by Technical Colleges to Certificate level to provide staff with appropriate qualifications for Technician.

During the 1950-60s, many Apprentices, Trainee Technicians and Cadet Engineers were recruited to meet the huge demand for telecommunications products. Trainees of all categories spent their first year in the Apprentice Training College to undertake basic practical work. On the second year, Apprentices were allocated to various production departments for on-the-job training and part-time study at Technical College trade courses. Trainee Technicians were allocated to various departments for on-the-job training such as test rooms, laboratories, workshops, drawing office, tool design, and production planning. They also attended Technical College to undertake appropriate Certificate courses.

By the late 1960s, training activities came under the control of a Superintendent of Training to include an Apprentice Training School attached to the Tool Room and an Operator Training School for production operators.

To take account of rapid technological change in the electronics industry in recent years, extensive retraining programs were implemented to provide for a multi-skilled work force. New orientation and training programs were introduced for new Apprentices, Trainees, Cadets and Graduates. The first year included activities designed to assist in their development and integration into the full life of the company.

* **MORE RECENT TRAINING ORGANISATIONS**

There are many training and educational bodies in operation to meet today's needs for technical, production and management staff engaged in the broadcasting industry. In the mid 1980s, those providing technical training courses, mainly for studio staff included:

- Axent Recording Studio, Kogarah, NSW providing Audio Engineers training courses comprising Stage 1 (12 weeks) and Stage 2 (12 weeks).
- Byrne and Ross Productions, Fortitude Valley, Qld providing a Sound Engineering course offering private tuition in a professional 16-track recording studio. Course covered all facets of the recording and music industry.
- Emerald City Studios, Brookvale, NSW, providing an 'In-House' Studio Engineering course.
- The Future School of Radio, North Sydney, NSW conducting a 15-week course in all aspects of Radio Broadcasting.
- National School of Audio/Vision Engineering, Lyons, ACT conducting a one year Certificate course in Audio Engineering theory and practice using a 16-track studio facility.
- Royal Melbourne Institute of Technology, Melbourne, Vic., with the Electronics Technology Division conducting courses leading to Certificates of Technology (Audio Visual Media, Electronics) and Audio Techniques as well as other courses.
- School of Audio Engineering, Surry Hills, NSW with schools in Melbourne, Adelaide, Brisbane, Perth and overseas, providing training and tuition at Certificate and Diploma level in Audio Engineering and production. Course duration was one year with 8-track and 24-track studio facilities.

In 1994, the University of Sydney announced that in 1995 it would be offering two units of study (Acoustics and Music) as a lead-in to a two year part-time Diploma in Design Science (Audio) course. A three years Master's course was also proposed. Course core subjects was to include Audio

Practice, Audio Acoustics, Electrics, Electronics and Electroacoustics as well as Music and Analogue and Digital Audio. Students would also be able to participate in electives including Multimedia, Architectural Acoustics, Project Management and Computer Studies.

- The Australian Film, Television and Radio School, North Ryde, Sydney runs many short courses with the object of developing a supportive and challenging environment capable of preparing and sustaining professional practitioners in the production of programs for film, television and radio audiences. The courses are aimed at people already working in the industry with the course programs including conferences, seminars, forums, workshops and masterclasses.

  Courses of particular relevance to the Radio Broadcasting industry include Radio Production 1 and 2; Radio Announcing and Presentation; Radio News; Studio One; Radio Documentary and Feature Masterclass; Radio Voice-over; Radio Copywriting; Radio Microphones; Stereo Sound Post Production and Operational Training.

  Some of the courses involve considerable hands-on training. For example, the Radio Production 2 Course is designed to teach radio production skills using the two-track and multi-track recording procedure. It covers voice recording, dub and cut editing, mixing music beds with voice, the use of sound effects, and recording with analogue and digital equipment to develop the professional skills required to make radio commercials, station promos and soundscape.

  Short Sound Courses available during early 1998 included Sound Technology, comprising basic electronics, acoustics, recording technology and synchronisation systems; Music Recording, a hands-on intensive course dealing with microphone techniques, comparisons and experimentation; Music for the Screen; and Operational Training Courses comprising Sadie Digital Audio Workstation; Protools V4 Digital Audio Workstation; Fairlight MFX3 Digital Audio Workstation; Harrison Series X mixing desk; and Editron and Adams-Smith synchronisers.

PMG's Department Courses

Primary training for new technical recruits was conducted by the Postmaster General's Department as early as 1914 when a three year Junior Mechanic-in-Training course was introduced. By 1926, the course had been extended to five years' training with major subjects Workshops Practices, Electrical Theory, Drawing, Telegraphy, Telephony and Internal Combustion Engines being taught in the Department's own training centres and Postal Institute Classes.

In 1929, when the Postmaster General's Department acquired the A Class stations to form the National Broadcasting Service, the technical staff of the operating organisations had a variety of titles. The Officer-in-Charge was known as Chief Engineer, a title still used today at many Commercial stations, staff at the transmitter were designated Station Operators, staff at the studio were Control Operators and those engaged on pick-up duties were classified as Outside Broadcast Operators. Each designation was on a different pay scale. Most of the staff declined an offer to transfer to the Public Service.

The Department had no staff trained specifically in broadcasting, but in most States, the Transmission Section was allocated the task of operating and maintaining the facilities. Fortunately, some staff were active Amateur Radio Operators and it was not difficult to put together a group of competent people.

Major modifications and upgrading works were implemented almost immediately, installation of stations in country areas soon followed, and expertise in Broadcast Engineering was quickly obtained.

By 1942, there were some 27 transmitting stations in the NBS and staff were also responsible for operation of the ABC studio technical facilities. Specialisation was introduced for the first time into the technical training scheme with Broadcasting being a major subject. Trainees began to specialise in their third year of training. In 1958, specialisation was brought forward when trainees entered this phase at the end of their first year.

In 1964, responsibility for installation and operation of studio technical facilities of the NBS was transferred to the Australian Broadcasting Commission who established training facilities to meet their needs.

Unit courses were introduced in 1965 by the Department to provide specialised training for a combination of skills required in the field. At that stage the number of National stations had grown to 64 with many being maintained by staff whose prime responsibility was for the telephone network.

In the 1970s, a new tradesman/sub-professional technical staffing structure was implemented. The classification Technician (Telecommunications) was replaced by new classifications of Telecommunications Tradesman, Telecommunications Technician and Telecommunications Technical Officer. New courses of training were established for the tradesman and sub-professional classifications.

Trainee Telecommunications Technical Officers participated in a four year part-time course at an Institute of Technology or Technical College, and also undertook in-house and on-the-job training. On completion of the course, a trainee was advanced as Telecommunications Technician pending accumulation of the required six years experience including training before being advanced as Telecommunications Technical Officer.

With the formation of the Australian Telecommunications Commission on 1 July 1975, staff of the Postmaster General's Department who were responsible for the National Broadcasting Service were transferred to Telecom, the Commission's trading arm.

The beginning of the 1990s brought a restructure of the technical grades to provide seven levels of Technical Officer. Staff could be recruited into this structure at Level 1 with no previous experience or at Level 2 if they had completed two stages of an Associate Diploma (Electronics). Progress through the levels was via the normal staff selection process and depended on formal training, accredited on-the-job training and relevant work experience. The formal training could be conducted by a recognised training organisation such as Telecom Training Services or a TAFE College. Much of the core training to meet the requirements of this scheme was conducted by Telecom Training Services using computer managed training.

The trend with training in general, and radio training in particular, is for efficiency and economy. Since most maintenance with modern equipment is by unit change and people have such a wide range of equipment types and tasks, they do not have the time or the need to delve deeply into system operation. They expect training to provide information that will allow them to quickly complete their duties. The limited number of people who require greater levels of expertise for design and difficult fault diagnosis usually need to obtain their knowledge by personal study, research and experience.

The PMG's Department/Telecom has employed many people to train technical staff to meet its needs in various disciplines, including broadcasting. One Instructor who spent most of his career in Technician Training Schools was John Naumann who was associated with radio training in Queensland and Headquarters for most of his 42 years service with the Department/Telecom. He was still involved in this field in 1993.

For many years the Postmaster General's Department recruited its Professional Engineers from three sources. These were from an internal Open Engineer's Examination, a Cadet Engineer's scheme or University graduates.

The Open Engineer's Examination enabled permanent staff to qualify as Engineer by examination. Classes and lectures arranged by the Postal Institute helped many pass this and other examinations. The Postal Institute was set up during the First World War and eventually branches were established in all States. Most of the lecturers were experts within the Department. One lecturer was Frank O'Grady of South Australia. He provided many lectures on radio broadcasting and transmission and later became Director General of the Department.

The Open Engineer's Examination involved five subjects all of which were compulsory. They were Natural Science, Transmission (Line and Radio), Line Construction, Telephone Equipment and Telegraph Equipment.

One Engineer who obtained his Engineering qualifications through the Department's Open Engineer's Examination scheme was Staunton McNamara. Staunton was interested in radio as a schoolboy and obtained his Amateur Operators Certificate of Proficiency in 1938.

In 1939, he fulfilled the requirements for a Broadcast Operators Certificate of Proficiency and began work with Commercial station 5AD Adelaide under Chief Engineer Don Gooding. He later worked at 5MU Murray Bridge and in 1940 took up a position with the PMG's Department Transmission Laboratory in Adelaide.

He left the Department in 1943 to rebuild 5KA Adelaide and then re-establish 5AU Port Augusta. Both stations had been closed down in 1941 under Government Security Regulations.

In between work on these projects, he completed a course with the British Institute of Engineering Technology for the British IRE Graduate Examination, receiving a Diploma on completion of the course.

Staunton returned to the PMG's Department in 1948 to a position in the Radio Section where he worked on a number of projects including installation of 5AL Alice Springs and field strength survey work.

In 1953, he passed some of the subjects of the Open Engineer's Examination and on passing all subjects by 1956 was appointed Engineer Grade 1. In 1958, he was promoted to Group Engineer.

Staunton transferred from the Department to the ABC in 1962 to accept a position of Engineer Class 2 Television. With the transfer of the technical facilities associated with the ABC studios from the Postmaster General's Department to the ABC in 1964, he was promoted to the position of Senior Engineer, Radio where he was heavily involved in many aspects of studio planning, design, installation and maintenance. A highlight was the design of the FM studio and switching system during 1975-76 which incorporated Solo-Dual principles and other innovations. Staunton retired from the ABC in 1976.

The Cadet Engineer's scheme formed the basis of Professional Engineering in the Department. It was first introduced before the First World War, suspended during the War years and reintroduced in the 1920s.

Roy McKay who later became Engineer-in-Chief was one of the first three trainee Engineers in the Department, joining as Cadet in 1908 and qualifying as Engineer in 1913. Roy was one of the first Full Members of The Institution of Radio Engineers (Australia) on formation of The Institution in 1932. In 1948, he was elevated to Fellow of The Institution.

The Cadet Engineer's scheme was intended to encourage talented staff from all areas of the Department to acquire a Science Degree in part-time University study and to obtain on-the-job training by spending periods in most of the Engineering Department's sections. Although the control and direction of the Cadets was under the guidance of a senior Engineer specially allocated to this work, there was a fair degree of freedom during the course which allowed the Cadet to follow through on projects of particular interest to the Cadet.

The first two years comprised University courses in Mathematics and Physics and practical and theoretical studies at Departmental Training Schools. Supplementary lectures were provided by Engineers from various sections. The first three years also included on-the-job field training in workshops, telephone equipment, telegraph equipment, long line equipment, line construction, radiocommunications and broadcasting. At the end of three years, the Cadet was required to sit for written final examinations in Line Construction and that portion of Telephony and Transmission covered during the training. The fourth year final examination was conducted in Automatic Telephony, Telegraphy and Transmission.

The Transmission component of the course comprised Transmission I in third year and Transmission II in fourth year. Transmission II comprised Radio and Long Line Equipment with the Radio part including instruction and examination in the following:

- Propagation of electromagnetic waves.
- Aerials for transmission and receiving, directional arrays and transmission lines.
- Thermionic valves.
- Radio frequency and audio frequency amplifiers.
- RF oscillators, modulators and detectors.
- Transmitters including speech input and associated equipment.
- Receivers.
- Aids to navigation and location of aircraft.
- Radio frequency measurements.
- Studio equipment including microphones, amplifiers, switching facilities and associated equipment.
- Power plant for transmitters and studios.
- Principles of acoustics in so far as they apply to problems met within the broadcasting system.

It is of interest that when the Commonwealth Public Service Board placed an advertisement in the press and technical magazines in mid 1928 advising of a competitive examination to be held for appointment of Cadet Engineers, the applicants were required to be between the ages 17 to 23. Salaries payable ranged from £123 ($246) per annum under 19 years to £228 ($456) per annum over 21 years. Upon passing an Examination for advancement to Engineer at the end of four years training, the officer would be paid £372 ($744) per annum.

Unfortunately, Cadets recruited in response to this particular advertisement who entered the PMG's Department, did not complete their four years training as planned because of the Depression.

In 1929, the first year of the Depression, the Department's telephone and telegraph services operated at a loss with cancellations exceeding new connections and the number of telephone calls fell sharply.

The permanent staff numbers declined and no replacements were made during the period 1929 to 1931. All technical training ceased and Cadet Engineers and Mechanics-in-Training were transferred to clerical, sales, postal or other duties. When training resumed in the late 1930s, some of the former Cadets of the 1928 intake continued their career in their new position while others keen to get back into engineering continued studies privately and became Engineers through the Open Engineer's Examination scheme.

One Cadet Engineer whose training was suspended after being appointed in 1927 was Jim Hutchison. However, shortly after taking up a clerical appointment he was fortunate in being able to secure a Sydney University Free Place in 1929. He graduated in 1933 with Honours in Electrical Engineering.

Jim subsequently became Engineer Radio Research Board; Divisional Engineer Radio and Broadcasting, Sydney; Assistant Supervising Engineer Radio and Telegraphs, Sydney and later, Director Posts and Telegraphs for New South Wales.

When the Post Office resumed training Cadet Engineers under the scheme, many of the graduates spent long periods of their Professional Engineering career working in the Department's activities associated with the National Broadcasting Service. They included Reg Boyle, Doug Brooke, Eric Brooker, Alan Fowler, Brian Hammond, Harry Kaye, John Lamprey, Jack O'Shannassy, Brian Perkins, Alan Poulsen, Harold Robertson, Jack Ross, Jack Truss, Alan Varey and many others.

When Universities began to offer courses more suitable to the Department's needs after the Second World War, the original Cadet Engineer scheme was in 1949 replaced by a different scheme in which second year Engineering undergraduates were recruited from Universities and channelled into a career with the Department. By 1952, there were more than 200 Cadet Engineers on the staff.

Included among many graduates under the new Cadetship scheme who worked for many years in the Department/Telecom Broadcast Engineering area were Robin Blair, Lawrie Derrick, Dave Ellis, Gordon Evans, Giff Hatfield, Janis Ozolins, Jim Rule, Terry Sellner, Bill Shapley, Graham Shaw, Frank Shepherd, Ron Tolmie, David Young and others.

By mid 1992, the then Broadcasting Division of Telecom employed a total staff exceeding 700 and included 40 graduate Professional Engineers and some 450 Paraprofessional staff skilled in radio, electronics, rigging and civil construction associated with broadcasting activities.

The staff skills were such as to allow the organisation to design, construct and maintain a complete range of services including engineering consultancy; system planning and design; turnkey project management; installation of transmitters, aerials and associated equipment; civil engineering works and rigging associated with masts and towers; field strength surveys; network operation, maintenance and fault rectification; and proof of performance measurements.

The Postmaster General's Department was not the only organisation which had a Cadet Engineer scheme to cater for its ongoing requirements for Professional Engineers.

Amalgamated Wireless (A/Asia) Ltd was one such organisation. Some of the company graduates later transferred to the PMG Department to work on its NBS facilities. They included Vince Thompson who became a Cadet Engineer with AWA in 1943 and transferred to the Department in 1950. Vince subsequently became Supervising Engineer Radio and in 1983 was appointed the first State Broadcasting Manager of the Broadcasting Directorate in New South Wales. Vic Audet was another AWA Cadet Engineer who joined the Broadcasting Directorate when he took up an appointment in 1983 having transferred to the Department in 1966.

Standard Telephones and Cables Pty Ltd, like AWA, also had a Cadet Engineer scheme in addition to Technician and Apprentice training schemes.

Selected applicants, on joining the company, were chosen from various disciplines and offered scholarships for part-time study leading to Diploma and Degree courses in Electrical Engineering, Electronic Engineering, Production Engineering and Industrial Engineering. There was also provision in company policy for granting full-time study scholarships and higher Degree courses.

In the 1950–60s, all company trainees whether Apprentices, Technicians or Cadet Engineers attended the Apprentice Training College for the first year of their training in order to develop their manual skills. Cadets then proceeded to on-the-job training in electrical wiring and assembly, electrical testing and engineering laboratory work. In addition, they attended a University or Institute of Technology part-time.

RADIO CLUBS AND SOCIETIES

The role Radio Clubs and Societies played in the 1920s and 1930s has generally not been given due credit for their contributions in popularising the technical aspects of radio, and in particular, broadcasting. In 1923, at least 37 Radio Clubs were active throughout Australia.

Each State had its Wireless Institute organised for the benefit of Amateur Operators but there were also district, town or private Radio Clubs or Societies, many of which had the blessing of the Wireless Institute. Additionally, there were Clubs devoted to people with specific interests in radio such as listening to local or overseas stations or program watchdogs. These included Dx Clubs and The Listeners League.

Some Radio Clubs were active well before the commencement of broadcasting, and the number throughout Australia reached a peak in the mid to late 1920s but by the outbreak of the Second World War in 1939 most of the Clubs, with the exception of the Wireless Institute, were no longer active.

The start of broadcasting in the capital cities over the period 1923 to 1926 acted as a catalyst in the proliferation of Radio Clubs. Many of the Clubs acquired a licence to operate an Experimental station and with well-known local Experimenters, Engineers and Technicians becoming members, this was a draw card for young enthusiasts to join. Instruction, particularly on the construction of receivers and in radio theory by experts was a major activity at meetings and this initiation for the younger members was the grounding for a subsequent career in Broadcast Engineering by some members.

The keen interest of boys in the new science was a surprise to many parents. The boys looked forward to the lectures, built crystal sets and battery receivers and some sat for examinations to obtain an Amateur station licence. The social activity of the Club was an important factor in maintaining local family interest. Radio picnics by car or train, boat trips, dances and film evenings were very popular. So eager were some members to build receivers that some Clubs met on a weekly basis. For example, the Malvern Club in Melbourne had a membership of over 100, including a large group of boys, and the Club met every Wednesday from 8.30 to 10.30 pm with a prominent lecturer rostered to talk on a specific engineering topic. The facilities included work benches, test instruments, library and basic workshop facilities. So keen were some members that one of the Club officials was in attendance every night of the week except Sunday, to provide assistance.

Radio magazines and Club newsletters had a lot to do with creating and maintaining interest in radio. Many of the technical articles were written specially for boys in a language which they could understand. The enthusiasm of a boy in his hobby often led to his father also becoming interested in radio as a hobby. Although girls were encouraged to become members, there was not a great deal of interest. However, those who did participate were just as competent as boys as witnessed by the standard of entries at Radio Exhibitions. Some girls later established radio shops or became Radio Service specialists.

One of the important activities of Radio Clubs was to encourage members to exhibit their projects at Radio Exhibitions. Members of the Wooloowin Radio Club in Brisbane usually began planning items at least six months before closing date of entries. Their efforts were well rewarded and the results at the 1926 Radio and Electrical Exhibition held in Brisbane during Show Week were typical. Categories comprised:

- Section 1 Low Power Transmitter.
- Section 2 Short Wave Receiver.
- Section 3 Home Made Apparatus — Open Class.
- Section 4 Novel Crystal Set.
- Section 5 Selective Crystal Set.
- Section 6 1, 2 or 3 Valve Receiver.
- Section 7 Multi Valve Receiver — Four or More Valves.
- Section 8 Home Made Apparatus — Juvenile Class, 14 years or Under.
- Section 9 Wave Trap.

The Club members exhibited 22 items, representing 31% of total entries, and its members collected 50% of the Prizes. In addition to 10 Prizes received for items entered in the various Sections, members were awarded Special Prizes provided by Mullard Wireless Service and Keith Stokes Pty Ltd.

The best Multi Valve Receiver, regarded as the principal class, resulted in 10 high class entries being received. The Section Prize was awarded to Mr H Kington of the Wooloowin Radio Club. Second Prize was awarded to an entry with the receiver enclosed in a glass cabinet with a meter mounted on the front panel. One of the unsuccessful entries was a large cabinet which housed an eight valve superheterodyne circuit receiver.

The Adjudicator was Mr W Monkhouse AMIEE, AMIE (Aust.), a well-known Brisbane Engineer.

Many Clubs had distinguished members who were keenly interested in the operation of Radio Clubs and the active promotion of their place in society.

One such member was Llewellyn (Lew) Griffiths a member of the Blackwood Radio Club in South Australia. The Club was founded in 1923 and within two years of formation, members had constructed a studio/transmitter facility for broadcasting regular programs on 210 metres. In 1926, Lew Griffiths was the official station operator of the station OA5BR. By 1928, broadcasts were being conducted every night and all day on Sunday.

Lew began work in the SA Postal and Telegraph Department in 1880 when South Australia was a Colony. By 1900, he was Assistant Electrical Engineer and in 1910 was appointed first Manager of the Telephone Branch of the Postmaster General's Department. Lew subsequently became Deputy Postmaster General for South Australia, the highest position in the Post Office in the State. In 1935, he received the Kings Jubilee Medal and was later awarded the Order of the British Empire for distinguished public service.

In 1938 when Lew retired he, had over the years, witnessed the Department becoming firmly established in the Broadcast Engineering scene. Local staff had taken over 5CL in 1930 when the A Class station was acquired as part of the National Broadcasting Service; the first regional NBS station 5CK Crystal Brook was commissioned in 1932; ABC Adelaide studios were upgraded in 1935, and a second NBS station 5AN, was commissioned in 1937.

It is not possible to list all Clubs and Societies as most records are no longer available, but well-known organisations included:

- VICTORIA
  Albert Park, Bendigo, Brighton, Camberwell, Canterbury, City of Prahan, Coburg, Collingwood, Elsternwick, Essendon, Footscray, Hawthorn, Ivanhoe, Kew, Malvern, Northcote, South Yarra, Sunshine, St Kilda, Toorak, Williamstown, Xavier College, YMCA Radio Clubs and others.
- SOUTH AUSTRALIA
  Blackwood, Glenelg, Murray Bridge, North Adelaide, Port Adelaide, Quorn, Railways, Sacred Heart College, Southern Suburban, St Peters College, Wayville, West Suburban, YMCA Radio Clubs and others.
- NEW SOUTH WALES
  Balmain, Bondi, Burwood, Campsie, Concord, Croydon, Illawarra, Killara, Kuring-gai, Leichhardt, Lismore, Newcastle District, Newcastle Tramway, Newcastle Western Suburbs, Northbridge, North Sydney, Postal Institute, Railways and Tramways, Sydney Metropolitan, Sydney Technical High School, Wahroonga, Waverley, Western Suburban Sydney, Wireless Society of Newcastle, Wyong, Zero Beat Radio Clubs and others.
- QUEENSLAND
  Auchenflower, Cairns, Central Technical College, Eastern Suburbs, Graceville, Gympie, Indooroopilly, Ipswich, Junction Park, Maryborough, Nundah, Radio Society of Queensland, Rockhampton, Sandgate, South Brisbane, Toombul, Townsville, Wooloowin, Wynnum-Manly Radio Clubs and others.
- WESTERN AUSTRALIA
  Claremont Radio Society, Donnybrook Radio Society, Engineering Department University of WA Radio Club, Freemantle Radio Club, Goldfields Radio Society, Mt Lawley Radio Club, Subiaco Radio Society, The Darlington Radio and Electrical Society, WA Radio Club, West Perth-Leederville Radio Society, Wireless Development Association of WA and others.
- TASMANIA
  Hobart Radio Research Club, Launceston Radio Experimental Club and others.

The majority of Radio Clubs and Societies were affiliated with their State Wireless Institute of Australia Branches. This had a number of advantages including the preparation of a Roster of Lecturers of WIA experts to attend Club meetings. For instance, lecturers rostered for the last few months of 1924 for Clubs in the Melbourne Metropolitan area included such well-known Engineers and Experimenters as E H Cox (A3BD), S C Baker (A3BK), H K Love (A3BM), Max Howden (A3BQ), C Hiam (A3LW), J R Alsop (A3MI), J A Muir (A3QW), Tom Court (A3TC) and others.

Members of Radio Clubs were frequently requested to give talks to A Class broadcast station listeners on the technical aspects of wireless. Among members who provided talks included Arthur Cotton, President of the Port Adelaide and Suburban Radio Club in 1925 over 5CL, Bert Lampe, President of the Blackwood Radio Club over 5CL in 1926 and George Moss of the Freemantle Radio Club over 6WF in 1925.

Mr Moss was an active Amateur operator when 6WF went on air in 1924, and in 1931 began work at the 6PR studios after obtaining his Broadcast Operators Certificate of Proficiency. At the time, the transmitter was maintained by AWA technical staff. In 1938, he became a part-time lecturer in the newly established course of Radio Technology at the Perth Technical College. George later was appointed to the permanent lecturing staff after obtaining the necessary academic qualifications. During the War, part of his responsibility included training of Army Radar trainees. He retired from the College in 1971, but continued his involvement in radio with a part-time laboratory tutorship at the West Australian Institute of Technology until 1989.

The YMCA Radio Club in Adelaide which was established on 4 October 1924, had what was reputed to be one of the best displays of working receiving circuits from the pre-valve wireless telegraphy era. The Club Instructor Roy Cook had students construct, as a means of gaining practical experience in receiver construction, a series of receivers in breadboard format using circuits developed by some of the world's best-known wireless inventors.

By the 1925 Christmas break-up party, six receivers had been completed and mounted in a showcase. The display was opened by Lance Jones, Manager of Adelaide Radio Company who had donated a large amount of equipment and components to the Club since it had been established.

The receivers in the showcase were constructed to circuits known as Telefunken, Shoemaker, Stone, Fessenden, Masse and De Forest. The detector for all receivers was galena crystal obtained from an early silver-lead mine in the Adelaide Hills.

A seventh receiver based on the Marconi magnetic detector was not completed because of problems experienced in making the drive mechanism with the limited resources available to the Club.

The receivers were still in the display case until about mid 1926 but the subsequent fate is not known.

Lance Jones imported many radio receivers and components for his business direct from manufacturers in USA and UK. He often had in stock items not available from Radio Shops in the Eastern States. A Stock Book title 'VALVES' recorded the arrival of valves from the USA during 1926–27 and included; Goldentone from United Radio and Electrical Corpn; Universal 201A from Magnavox Co.; DP10 from Donle-Bristol Corpn; QRS Red Top from QRS Music Co.; Teletron from Champion Electric Co.; Phonotron from Vacuum Products Co.; Royal Blue from Royal Blue Laboratories; Daven MU20 from Daven Radio Corpn, and Radiotrons UX120, UX112, UX171, UX210, UV201A, UV199, UX199, UX201A, WD11 and WX12 from Radio Corporation of America. Quantities received varied from 4 to 50. Samples from some of these valves were donated to the YMCA Radio Club for experimental work by members. A Minute Book recorded 12 valves being received from Mr Jones during November 1926.

In 1926, the Club held a competition for the best receiver constructed to a reflex circuit employing a crystal detector and using no more than three valves. Single valve entries included Acme, Harkness and Erla reflex circuits but the winner was a three valve Priess reflex circuit with a carborundum detector and a type UV1714 radio frequency transformer made by Radio Corporation. The prize was a box of six Radiotron valves donated by Mr Jones.

Of the centres outside the Capital cities, Newcastle was one country town which supported many Radio Clubs. Active Clubs included Newcastle District, Newcastle Western Suburbs, Newcastle Tramways and Wireless Society of Newcastle. The Wireless Institute was also active.

Interest in wireless was such that it led to the establishment of the first regional broadcasting station in Australia when 2HD began operation on 27 January 1925. The station is still in operation today.

The various Clubs did much to encourage Newcastle residents to take an interest in broadcasting as an entertainment and information medium. Typical of public demonstrations was provided by the Newcastle District Radio Club when it provided a demonstration in the vestibule of the Union Pictures Theatre, Hamilton on the nights of 25, 26 and 27 October 1923. At the time, broadcasting station 2SB was undergoing tests in Sydney. Program for the demonstration was broadcast from Mr N P Olsen's 2ZX transmitter at Waratah and received at the Theatre using a receiver owned and built by Mr A Metham. The three valve receiver fed an Amplion loudspeaker.

The crowd was so dense that the organisters had to erect an iron rail around the receiving equipment to allow the operator room to carry out adjustments. Crowds also stood out in the street to listen to the programs until the transmitter was closed down. A collection was taken, to obtain funds for material to enable construction of a transmitter for the Club.

The owner of the 2ZX transmitter, Mr Olsen was Publicity Officer for the Club and was also the Newcastle representative for licence purposes for Broadcasters (Sydney) Ltd, the owners of 2SB Sydney.

Today, when many of the Radio Clubs if still in existence, would be celebrating their 75th Anniversary, the equipment which they built so many years ago and which was state-of-the-art at the time has now become much prized items by vintage radio collectors.

Organisations like the Historical Radio Society of Australia established in 1982 is one organisation which is keeping alive interest in the early technology and the equipment produced.

A more recent organisation, The Association of Radio Mechanics Inc., was formed in Western Australia in 1998 to provide a forum for people interested in the technical aspects of vintage valve radio sets and who are in need of information and practical training in a workshop environment. John Holmes was the Association Secretary.

HISTORICAL RADIO SOCIETY OF AUSTRALIA INC.

From the very beginning of wireless, people began to put aside various components and items of equipment to form private collections, and it was not long before shops selling second-hand goods and antiques began to acquire wireless sets and parts for sale.

However, the real interest by organised groups in collecting early items of wireless (radio) did not take place until after the Second World War when people banded together to form associations, societies or clubs. Many Public Museums and Libraries have, of course, been in the business of building collections of equipment or publications related to radio, for many years.

One of the first organisations established in the USA is the Antique Wireless Association Inc., which was founded in 1952. It has a worldwide membeship including members in Australia.

In Australia, a number of attempts were made to establish an organisation for collectors of antique radio equipment and historical records including, Frank Burch an ABC announcer in Adelaide and Len Davenport proprietor of the Magic Spark Museum which was established in Alice Springs in 1975, but it was Ray Kelly who followed up on the groundwork done by Len Davenport. Len found that his commitments with his Museum and his remoteness, were factors in handing over the proposal to Ray who lived in Melbourne where there were many collectors eager to participate in the formation of a society.

Ray's interest in wireless began in the Depression years when he was a schoolboy. With the outbreak of the Second World War, Ray enlisted in the Royal Australian Air Force where he undertook a six months full-time course at the Melbourne Technical College in Radio, followed by a two months course in Radar. After the War, he rejoined the PMG's Department where he had worked before enlisting, and began working in a number of broadcasting areas including ABC studios, installation of transmitters and Shift Supervisor at Radio Australia, Shepparton. He later moved to the Australian Broadcasting Control Board where he worked for some 17 years until retirement. His special interest in radio history includes early horn and cone loudspeakers, radio receivers of the 1920–30 period and radio books and magazines.

It was while he was working with the Board that Ray was 'bitten by the antique wireless bug'. During an inspection of Commercial station 3BA Ballarat, he saw a magnificent display of early radio equipment in a museum there set up in the basement. Most of the collection came from donations by the public following an appeal by 3BA for early radio sets as part of its 40th Anniversary celebrations. Chief Engineer Keith Ridgway and Bob Turnbull who later became Chief Engineer on the retirement of Keith in 1974, were involved in its establishment ably supported by Managing Director Ernest Whykes, one of the original members of 3BA staff when it was established in 1930.

The Australian Historical Radio Society was formed on 17 April 1982 in Melbourne with the Committee comprising Norm Way, Chairman; Ray Kelly, Secretary; Doug Dowe, Treasurer and Allan Sargant and Rod Foster, Committee Members. Members of the newly formed Society comprised, in addition to the office bearers, people from all States except Western Australia. They were Barry Webb, Brian Lackie, Ted Huckell, Lou Albert, Alan Wentworth and Ric Havyatt, New South Wales; Morris O'Brien, Ray Gillette, Peter Naumov, Laurie Bennett, John Sheridan, Dr Ken McTaggart and Colin Gracie, Victoria; Bill Russell, Queensland; Jack Ross and Peter Thomas, South Australia; Len Davenport, Northern Territory and Russell James, Grote Reber and Jim Davis, Tasmania.

Within five months of formation, the membership of the Society had reached 55.

The aim of the Society is to assist members interested in the preservation and restoration of early radio and associated equipment and the collection and interchange of relevant information. A quarterly publication — 'HRSA Radio Waves' — is produced with a great deal of the contents being devoted to various circuit descriptions, repair and restoration techniques, club displays, radio history and other matters of interest to members. The publication was initially known as 'HRSA Newsletter' with the first issue being April 1982.

Within five years of establishment, the number of members of the Society had increased fivefold with members having a wide range of interests. The present membership includes retired or active Engineers, Technicians, Servicemen, Ship's Wireless Operators, Amateur Operators, Instructors, Hobbyists and those with a nostalgic interest in radio. Interest has been so great by collectors throughout Australia that there are now a number of groups where local members meet to discuss technical issues, restoration, repair, organisation of displays, trade or swap parts and magazines and to enjoy social activities.

At the Annual General Meeting of the Society held in Melbourne on 21 September 1997, the following Committee was elected for 1997–98; President, Warwick Woods; Vice President, Allan Smith-Goode; Secretary, Tony Lightfoot; Treasurer, Leo Lloyd; Membership Secretary, Rex Wales; Society Archivist, Ray Kelly; Data Base Manager, Maree Johns-Lever; Radio Waves Editor, Bill Smith; Technical Editors, Ray Kelly and Rex Wales; Radio Waves Assistance, Allan Smith-Goode, Ray Kelly, Keith Hoffman and John Walters; Committee Members, Doug Ellis, Ray Hosking, Mike Osborne and Tony Zuiderwyk.

Interstate Affiliate Secretaries comprised Sydney, John McIlwaine; Adelaide, Les Jolly; Mid North Coast, Ted Gill; South East Qld, John Murt; Central West, Phil Ireland and Tamworth, Richard Betts.

The Clubroom of the Society in Melbourne was located at Gardiner Church of Christ Hall, Glen Iris.

Active membership at mid 1993 was about 400 with some members being located in several overseas countries. In mid 1997, the Society had more than 800 members on the books.

Many of the Society members have, or have had, noteworthy collections of vintage radio equipment with those established by the late Ed Huckell and Fin Stewart being of particular interest to collectors and historians. Ed Huckell who died on 18 July 1994 aged 96, was a foundation member of the HRSA. He established a radio retail shop 'Huckell's Corner' in Cremorne Junction, Sydney in 1928. Fin Stewart, an authority on early electric lamps and valves has an extensive collection put together over a period of many years starting when he was only four years of age. The collection includes items mainly of pre early 1930s and includes 1916 White triode, Arcturus Coronet series, Mullard, de Forest, Philips, Cunningham, Ediswan, BTH, RCA, Telefunken, Osram, AWA, Western Electric, Marconi, H J Round, Ferranti and many others. Fin is a member of the Antique Wireless Association USA and Author of 'Illustrated History of Philips Radio Valves to 1935' and a series of articles 'The Valve Box' in 'Radio Waves'.

Public and private Museums housing collections of vintage radio equipment are growing year by year. The year 1998 will be of particular interest to collectors and historians, being the 75th Anniversary of the establishment of broadcasting in Australia.

Included among the many Museums housing radio equipment collections, particularly that related to radio broadcasting include, Wireless Hill Museum, Perth; Science Museum, Melbourne; Magic Spark Museum, Alice Springs; Orpheus Museum, Ballarat; The Geelong Radio and Electronics Club Museum; Cat's Whisker Wireless Museum, Chiltern; Melbourne Wireless and Sound Museum, Seaford; National Film and Sound Archive, Canberra; Sound Preservation Association of Tasmania, Hobart; Antique Sounds, Newcastle; Ellison Museum of Magnetic Audio Recording and Playback Equipment, Malvern, SA; and the Telecommunications Museum, Electra House, Adelaide, SA.

The Telecommunications Museum, Adelaide was established by Telecom Australia and officially opened on 6 July 1978 by Sir Mark Oliphant, Governor of South Australia. It was established for the preservation and display of historical documents and items of telecommunications equipment related to telegraphy, telephony and radio technologies used over the years in South Australia and Northern Territory. While the majority of equipment items were imported from other places for use in the State and Territory, some were indeed designed and manufactured locally.

Many of the items in the Museum collection dated back to the period when South Australia was still a Colony. Typical are items of wireless telegraphy equipment employed in 1899 used in the first wireless telegraphy link established in Australia between sites at the Adelaide Observatory and Henley Beach. Included amongst historical documents associated with broadcasting in the State was the original log book signed by the Engineer-in-Charge and Radio Inspector Bert Harrington when 5CL went to air at 8 pm on 29 November 1924.

Items of equipment and historical documents had been put aside over many years by various officers of the Postmaster General's Department but it was not until 1962 that a serious attempt was made to establish a museum with a view to placing the items on public display. The first major public display was staged in Electra House, King William Street in 1976 with a display of telephone apparatus to commemorate the Centenary of the invention of the telephone by Alexander Graham Bell in the USA in 1876.

At the time of the inaugural Report of the Museum, members of the Telecommunications Museum and Engineering Historical Committee comprised Ken Work, Chairman; Milton Gooley; Jack Ross; Peter McIntee; and Brian Taylor. Bernie Woodrow retired at the time, and former Chief Draftsman, was responsible for technical research on items received for the collection.

The Museum occupied the entire three floors and basement of the Electra House building but was closed on 30 September 1992 when decision was made by Telecom to sell the building.

Telecom and the History Trust of South Australia agreed on a plan of management for the Collection.

In November 1992, Mr Peter Strawhan of the History Trust in his appointed capacity as Curator of Technology arranged for the Radio and Telegraph items of the Collection to be stored at the Norwood Telephone Exchange Building with Archives being located at Croydon. The Archives were later relocated to the State History Centre in Edmund Wright House, King William Street, Adelaide where they were rearranged to conform with current Standards.

Members of the local Historical Radio Society of Australia were concerned that the Radio items of the Collection could be disposed of, and a Sub-committee approached the Director of the History Trust, and subsequently Telecom, the Owner of the Collection.

As a result of their efforts, an Incorporated body was formed to take over custody of the entire Collection so that the core collection would be available for display by the Australian Museum of Technology.

A major part of the Radio Collection is stored and displayed at the ABC Collinswood studio complex and some items are on loan to Affiliates of the History Trust in various parts of the State.

International Broadcasting Organisations

There are a number of international broadcasting organisations throughout the world set up as liaison points where Engineers can meet to discuss developments in Broadcast Engineering Technology. Some of the organisations have a worldwide role, while others maintain a regional role. Those of particular interest to Engineers of Australian government-funded and Commercial stations include the International Telecommunications Union, particularly the World Administrative Radio Conferences and the International Radio Consultative Committee; the Technical Committee of the European Broadcasting Union; the Engineering Committee of the Asia-Pacific Broadcasting Union and the Commonwealth Broadcasting Association.

The aims of the various organisations, particularly the European Broadcasting Union (EBU), the Asia-Pacific Broadcasting Union (ABU) and the Commonwealth Broadcasting Association (CBA) are broadly similar. Typically, the aims are to foster and co-ordinate the development of broadcasting, to develop ways and means of establishing closer collaboration and co-operation among broadcasting organisations.

They also publish regularly, magazines and other technical literature of interest to technical staff. Publications include the 'EBU Review' published monthly, 'ABU News' and 'ABU Technical Review' both published bimonthly and 'COMBROAD' a quarterly magazine. The publications receive wide distribution and are of particular benefit to technical staff who are unable to attend the meetings because of cost considerations.

Some of the larger Australian broadcasting organisations including Australian Broadcasting Corporation, Telecom Broadcasting, National Transmission Agency and Australian Broadcasting Authority maintain regular contact with major overseas broadcasters such as Radio New Zealand, Canadian Broadcasting Corporation, British Broadcasting Corporation and others. The Federation of Australian Radio Broadcasters also maintains a watching brief on behalf of its members on broadcasting technology developments.

The Commonwealth Broadcasting Association was originally known as The Commonwealth Broadcasting Conference and held its first meeting in London in February 1945. Charles Moses went to London to represent the ABC and after the meeting, he was accredited to the Supreme Headquarters Allied Expeditionary Forces as War Correspondent and with one of the newly developed wire recorders, described General Montgomery's crossing of the Rhine.

The Conference, organised by the BBC, was the first opportunity for broadcasters to discuss post War plans for expansion of services. The BBC was anxious to erect strategically placed stations for relaying HF signals to improve reception to Commonwealth countries and Colonial Territories. This included improved signal strength in Australia by the establishment of high power relay transmitters in the Caribbean and Singapore. A technical sub-committee was established to study the proposal.

The second Conference was also held in London in 1952, but the third took place in Sydney-Melbourne to coincide with the Olympic Games in Melbourne during 1956.

In 1981, by which time the organisation had become known as the Commonwealth Broadcasting Association, the Conference was held in Sydney.

In 1996, the CBA decided to broaden its membership base. It extended membership to Commonwealth broadcasting organisations with a commitment to public service broadcasting. It also opened affiliate membership to broadcasting regulators, trainers, rights organisations and other broadcasting associates.

The Asian Broadcasting Union (later the Asia-Pacific Broadcasting Union) was formed in 1964 with the ABC as a foundation member with the inaugural meeting being held in Sydney. In 1975, the ABC was host to the General Assembly meeting held in Adelaide.

Some 265 delegates and observers representing more than fifty broadcasters and allied organisations attended the 25th General Assembly of the Asia-Pacific Broadcasting Union held in Sydney in October 1988.

As a principal founding member of the ABU, the Australian Broadcasting Corporation was privileged to host this Silver Jubilee Conference and chose as its venue the Holiday Inn Menzies Hotel where the inaugural General Assembly was convened in 1964.

The late Sir Charles Moses, General Manager of the Australian Broadcasting Commission from November 1935 to January 1963, chaired the first ABU General Assembly and held the post of Secretary-General of the Union from January 1965 to February 1977.

In his welcoming address to delegates, the Managing Director of the ABC, David Hill referred to the memorable contribution Sir Charles made to the development of broadcasting services in the region. Several retired staff members who were also present at the 1964 General Assembly, and who in subsequent years contributed significantly to the work of the ABU were welcome guests at a number of Conference sessions.

Telecom Broadcasting representatives included Leon Sebire, Director and Max Chadwick, Assistant Director.

In 1993, John Bigeni of the Australian Broadcasting Corporation was Chairman of the ABU Standing Engineering Committee.

RESEARCH ORGANISATIONS

WIRELESS TELEGRAPHY PIONEERING WORK

Many Australians made important contributions to the advancement of radio science in the formative days of wireless telegraphy before the First World War. Post Office Engineering staff in particular, saw a use for the new technology in supplementing the wire line communication systems. These people included Sir Charles Todd and Carl Unbehaun, South Australia; Mr P B Walker, New South Wales; Messrs G P Stevens, W Know, A G Rosser and Phillips, Western Australia; Messrs W P Hallam, F W Medhurst and F P Bowden, Tasmania; Mr H V Jenvey, Victoria; and Messrs J Hesketh and Smith, Queensland. In some cases these pioneers employed equipment much of which was developed and built locally using Post Office Workshops facilities, or privately.

Typical of work undertaken, was that carried out in Adelaide by Professor William H (later Sir William) Bragg of the University of Adelaide who worked very closely with Sir Charles Todd. Fortunately, Bragg had on the University staff a skilled technician and instrument maker named Arthur Rogers. Under Bragg's research guidance, Rogers built a number of coherers of various designs and employing a range of materials for trial as detecting materials. The outcome of the work was the establishment of the first two-way working of wireless telegraphy stations in Australia. The stations were constructed at the Adelaide Observatory and at a site on the sand hills at Henley Beach, a seaside suburb. The first messages were exchanged on 15 July 1899.

Even before Bragg had commenced his trials, Professor Richard Threlfall of Sydney University had repeated Heinrich Hertz's experiments in the same year, 1888, that Hertz published his paper 'Electromagnetic Waves in Air and Their Reflection'. It is likely that Bragg would have been aware of this before undertaking his work as there is evidence of correspondence over many years between Bragg and Threlfall.

In March 1910, Henry Sutton of Melbourne was granted a provisional patent for a detector of electromagnetic waves using a galena/galena combination device. He had demonstrated the invention to Defence and Government officials some years earlier.

Another pioneer who made a significant contribution was John Graeme Balsillie, appointed in 1911 as the Commonwealth Government first Engineer for Radiotelegraphy. His charter was to establish what was later known as the Coast Radio Service and to administer the provisions of the Wireless Telegraphy Act.

Balsillie was born in Brisbane and educated at the Brisbane Grammar School and the Brisbane Technical College. He later went to England to study Electrical Engineering. He subsequently invented a magnetic detector and a system of wireless telegraphy known as the Balsillie System. Balsillie installed the system in a number of countries including Germany, China and Siberia and later formed the British Radiotelegaph Co., to market the facility. However, in 1911 it was judged to be an infringement of the Marconi system by the Courts.

At the time, his wireless telegraphy system was in competition with others including Marconi, Telefunken, Lepel, Poulsen, Fessenden, Lodge-Muirhead and Hozier-Brown Systems.

On his arrival in Australia he set about to develop another system which would not infringe patents of other organisations. He developed what became known as the Commonwealth System for which he was granted a Patent. It survived a challenge by the Marconi Company in 1912, with the challenge being subsequently settled to the Australian Government's advantage.

By late 1915, he had oversighted the design, installation and commissioning of some 20 stations around the Australian coastline.

In 1920, Walter Sweeney, former Construction Engineer, Commonwealth Wireless Branch and Inspector of Wireless Telegraphy, Royal Australian Navy wrote a book 'Wireless Telegraphy' in which he described Balsillie's and other major systems. The book was published in Australia by E W Cole, Book Arcade, Melbourne and as far as is known, was the first book on Radio Engineering published locally and written by an Australian author.

Walter Sweeney later left his mark in broadcasting when he established Essanay Manufacturing Co., Pty Ltd in South Melbourne in 1928 in partnership with E A Austin. The firm name Essanay was derived from the initials of the two partners 'S and A'. His partner Ern Austin had previously been Works Manager of Radio Corporation from 1925 to 1928.

The company manufactured a range of domestic receivers under the Essanay brand and component parts.

Research and developmental activities increased after the War with the expansion of radiocommunication services and when broadcasting was established in 1923, AWA in particular had a sizeable Research organisation in operation to tackle the new field of Broadcasting Engineering.

It was soon joined by a research organisation set up by the Postmaster General's Department and later one by the Radio Research Board.

THE PMG'S DEPARTMENT RESEARCH LABORATORIES

The Postmaster General's Department Research Laboratories played a major role in the planning and development of both the early National and Commercial station facilities from the time broadcasting services were established, until about 1936 when NBS planning activities were transferred to the Transmission Section of the Engineering Department. The Laboratories still provided specialised research and investigation services for National station problems in more recent years. A typical example is the investigation into corona and plume problems associated with the high power aerial systems at Radio Australia, Cox Peninsula in the 1960–70 period.

From March 1921 until March 1922, Sid Witt, at that time head of the Telephone and Telegraph Equipment Section of the PMG's Department Central Office, undertook an extensive worldwide trip to investigate the latest developments in telecommunications. During the visit he made a detailed study of the technical facilities at high power radio transmitting stations in England (Leafield, Carnarvon), France (Saint Assasi, Bordeaux, Eiffel Tower, Lyons), Italy (Rome), Germany (Nauen, Königswusterhausen) and Egypt (Cairo), and discussed the latest technological developments in Radio Engineering with many eminent Engineers and Scientists. These included Guglielmo Marconi, Professor John Fleming, Dr William Eccles, Ernst Alexanderson of Radio Corporation of America, General Ferrie of the French Military, Dr Mayer of the German Telefunken Co., and others.

In 1923, shortly after his return to Australia, he was given the task of establishing the Research Laboratories, and in 1924 was permanently appointed to the position of Supervising Engineer of the Laboratories, then located at Treasury Place in Melbourne.

It was during this period that the Government approved the establishment of broadcasting in Australia, and with the PMG's Department being given responsibility for licensing and oversighting the orderly development of the service, it was natural that the Laboratories should become involved.

By 1925, the Laboratories staff had equipped themselves with radio frequency field strength measuring equipment and were carrying out measurements on the stations then in operation. They were also busily engaged in adapting the telephone network to meet the needs of the broadcasters to handle program transmission. In 1925, they designed and planned the set-up to allow the first simultaneous interstate hook-up of A Class stations when 2FC, 2BL, 3AR, 3LO, 4QG and 5CL broadcast a speech by the Secretary of the Treasury promoting a Commonwealth Loan. In 1927, they successfully engineered a more ambitious project to enable the broadcast of the opening of Parliament in Canberra by HRH The Duke of York.

The Government of the day was not satisfied with the rate of progress being made in broadcasting, particularly with expansion to country areas by the A Class stations and in 1927, Sid Witt together with some members of his Laboratories staff was seconded to prepare plans to provide for a National service to provide reception for at least 90% of the population.

In 1928, the Government introduced legislation to acquire all the A Class stations as part of the plan for establishment of a National Broadcasting Service. Responsibility for planning and technical aspects were given to the PMG's Department, and the Research Laboratories became heavily involved in Broadcast Engineering planning, design and provisioning activities.

Included in the main activities were:

- Programs of measurement of the conductivity of soil with respect to the transmission of radio waves over the surface of the earth. These measurements were carried out over a large area of the Commonwealth ranging from Cairns to Perth. The results were used in determining the best sites to locate transmitting stations.
- Development of engineering procedures for design of transmitting station buildings and associated electrical services.
- Preparation of designs and specifications for broadcast station transmitting equipment.
- Research and development of vertical radiating aerials of great height. Designs of structures varied from 400 feet (122 m) to 730 feet (222 m) and were the tallest engineering structures built in Australia at the time.
  The design, development and manufacture of base, guy and other insulators required for these structures involved considerable original work.
- Development of control, distribution and amplifying equipment for handling programs in studios as well as special forms of amplifiers and other apparatus for linking studios to transmitters, including interstate relays circuits.
- Acoustic designs for studios, requiring original contributions to knowledge in this sphere.
- Determination of appropriate wavelengths for the service.
  This required decision on whether long waves (150–300 kHz) or medium waves (550–1500 kHz) should be adopted.
- Setting up of a primary frequency standard for measuring transmitter carrier frequencies.
- Development of specialised forms of testing and measuring equipment to meet the needs of research work in the Laboratory and for investigations in the field.

Besides Sid Witt, staff associated with many of these activities included Bruce Mair, Alec McKenzie, Don McDonald, Len Harris, D O'Donnell, E P Wright, A A Lorimer and others.

As part of the investigations into ways of providing broadcast coverage to isolated communities in the country, the Laboratories set up an experimental short wave broadcasting transmitter at Lyndhurst in 1928. It became a permanent part of the NBS network in 1934.

The first major design and construction project undertaken by the Laboratories staff was the provision of a new station to replace the facilities taken over in 1928 from Westralian Farmers Ltd station, 6WF Perth. The work was completed in 1932, and staff associated included Roy Badenach, Bruce Mair, Ted Stewart, Hec Adam and Alex McKenzie.

Soon after the start of the Second World War, the Government decided to establish a high power International Broadcasting Station operating in the short wave bands, and Research Laboratories staff played a major part in planning, design and oversighting the installation and commissioning in 1944–45. Research staff involved included Sid Witt, Alec McKenzie, Bruce Mair and West Hatfield.

In addition to major contributions in the MF and HF fields the Laboratories staff made major contributions in studies associated with introduction of FM and TV broadcasting and the establishment of the VNG time service using transmitters in the short wave bands at Lyndhurst. The radio time signal service commenced in 1964 and the service closed down in 1987 when the Lyndhurst station ceased operation as a broadcasting station. The service officially known as The Australian Time and Frequency Service VNG was later re-established at Llandilo near Canberra with funding by a consortium of users of the service. In 1993, the service intended primarily for the Sydney area, transmitted on 2500, 5000, 8638, 12984 and 16000 kHz.

The Laboratories later became known as Telecom Research Laboratories, and although they continued to provide support for Telecom Broadcasting activities, this work diminished over the years with the transfer of some of the NBS technical responsibilities to other organisations principally studio provision and operation to the ABC; field strength surveys, planning the broadcasting network and broadcasting technical standards to DTOC; and more recently, the establishment of the National Transmission Agency.

In addition to research into technology to ensure Telecom radio program circuits for broadcasting purposes are of the highest standards, recent contributions to broadcasting technology have included guy insulator performance measurements and investigations into aerial corona problems using the Laboratory high voltage testing facilities under Principal Physicist Ed Bondarenko. Also, work associated with Australian and International RF exposure standards for staff working at broadcasting stations was an important contribution in ensuring safe working environment for staff at transmitting stations.

During 1989–90, the Laboratories staff of 530 included 230 qualified in Engineering and Applied Science and 190 technical support staff. Head of the organisation was Harry Wragge.

In 1995, the Laboratories were known as Telstra Research Laboratories.

AMALGAMATED WIRELESS (A/ASIA) LTD

AWA undertook research activities into a wide range of Radio Engineering projects over many years as support to its role as designer and manufacturer of equipment to Government, Defence, industry and the domestic market.

The establishment of a Laboratory was one of the earliest priorities of Ernest Fisk when he headed up the establishment of the company in 1913.

A considerable amount of research and development work was necessary when the company became involved in the design and manufacture of the 5000 watt broadcast transmitters with the establishment of 4QG, 2FC, 3LO, 5CL and 6WF when broadcasting commenced in Australia in 1923–25.

In 1924, AWA spent more than £7000 in research and development work. The Laboratory was then part of the Technical and Research Department. One major item of equipment installed at the time was a Standard Multi-Vibrator Wavemeter. It comprised multi-vibrator and control selector circuit, selector capacitor and inductance coils together with an ultra selective synchronising amplifier.

Radio frequency standardisation was secured with the assistance of a multi-vibrator. A valve controlled a tuning fork whose frequency was 1 kHz and from this frequency, numberless harmonics could be picked out with the aid of the high and low frequency sections of the multi-vibrator proper. It was one of only about six such instruments in existence anywhere in the world at the time and was designed and calibrated by the National Physical Laboratory, London.

Other test equipment included a Field Strength Measuring Instrument, a Co-ordinate Alternating Current and Direct Current Potentiometer, Radio Frequency Bridge for measuring resistance, capacitance and inductance, Cathode Ray Oscillograph and many others.

When AWA began the mass production of domestic receivers, the Laboratory played a major role in the development of components required for these receivers. Some components marketed for sale included AF transformers, RF transformers, honeycomb coils, duo-lateral coils, no-loss coils, crystal detectors and valve types 109X, 55, 33, 99X, 101A and 101X.

In mid 1924, AWA took steps to publicise its Radio Research activities with advertisements in the technical press. An advertisement in 'The South Australian Wireless and Radio Monthly' of 1 July 1924 is typical of a number of such advertisements:

> 'Research is a vital factor in any industry; in the wireless industry it is absolutely essential. The utility of patents lies in being able not only to apply them to the solution of particular problems, but by means of research to improve and extend their application to newer fields of endeavour and enterprise.
>
> Amalgamated Wireless (A/Asia), Limited, disburses the sum of £7000 per annum in maintaining a Radio Engineering research staff, constantly engaged in seeking improved and more economic methods for the advancement of wireless communication. By so doing, the Company assists in developing the ingenuity and research talent of Australian Engineers in the wider application of the science of radio.
>
> Last year the Company sent abroad four Australian Radio Engineers, members of the staff, to study the latest developments in all phases of wireless, but more especially trans-ocean communication and radio broadcasting.'

By the mid 1930s, the AWA Standards Laboratory as it was then known, was among the world's top organisations engaged in the development of Radio Engineering technology. The Laboratory was well-equipped with the most modern equipment with new instruments being continually developed and added to the facilities. Many of the staff were highly trained Engineers, Physicists and Chemists with wide experience overseas and locally. Senior staff made frequent visits overseas for update on the latest developments and research practices.

In addition to meeting the needs of AWA's design, construction and manufacturing arms, the Laboratory contracted out its services to industry and made valuable contributions for the design and production of new broadcast transmitters and receivers by other Australian companies and organisations.

With the rapid increase in broadcasting stations throughout Australia during the 1930s, there was a pressing need for expert advice on the problem of noise control to Architects preparing designs for new and remodelled studios. Being itself involved in the construction of many new studios, the company scientific staff conducted research on this important aspect of Broadcast Engineering. The findings were also useful in dealing with the problem of noise in factories and other non-studio premises. One of the first actions was the development of suitable 'sound proof' windows for use between studio and control room and for use with studios with windows facing a busy and noisy street.

Other studies were concentrated on sound attenuation in air conditioning ducts and scientifically designed absorption treatment of studio interiors. Among early studios so treated were 2KO in the Colonial Mutual Building, Newcastle in consultation with Architects Hennessy, Hennessy and Co.; 4BK in the Courier Mail Building, Brisbane in consultation with Architects Conrad and Atkinson; and a suite of studios for Country Broadcasting Services Ltd in Penfolds Building, Sydney in consultation with Architects Trenchard, Smith and Maisey. Country Broadcasting Services Ltd owned the 2000 watt station 2GZ Orange and had studios in both Orange and Sydney and was part of The Provisional Network (TPN).

In 1935, AWA began publication of the long running 'AWA Technical Review' in which Laboratory staff published articles concerning some of their research activities. Dr Ernest Benson was its Editor for 27 years and contributed many articles before his retirement. Publication of the 'Review' ceased in September 1977.

During the 1960s, the company became involved in the applications of transistors in its equipment designs and construction, and soon followed with production of its own integrated circuits. This was a period of considerable activity for the Laboratories.

When AWA celebrated its Golden Jubilee in 1963, the Laboratories were under the control of Dr James Rudd and had a staff of more than 40 Scientists, Engineers and other professional and technical people. It was located on three floors of one of the

AWA Ashfield buildings with other activities including a Reference Library, Model Shop, and an Environmental Test Centre being located elsewhere. AWA has operated the Laboratory for over 40 years under registration from the National Association of Testing Authorities, Australia (NATA). This registration confirmed the high calibre of technical expertise, test standards and instrumentation and the Laboratory management procedures. The licence allowed the Laboratory to undertake precise measurements of electrical quantities such as resistance, capacitance, inductance, frequency, current and voltage for outside organisations as well as for its own activities. It also undertook environmental testing using facilities specially constructed for the purpose.

In 1990, the Calibration and Repair Facility was transferred from North Ryde to Leichhardt at a site occupied by the AWA Electronic Services complex. However, by this time the company had divested itself from radio broadcasting and other communications interests.

An important contribution that the Laboratories made over the years to the development of broadcasting was in connection with the establishment of Commercial broadcast transmitting stations. In addition to the design and manufacture of transmitters and aerial system designs and commissioning, particularly with directional systems, by other AWA staff, the Laboratory staff carried out extensive field surveys to determine the most suitable site for location of a transmitting station and prediction of field strength contours for the final installation.

Another contribution was the design and development of test equipment. For many years, broadcasting stations, whether installed by AWA staff or others, were equipped with test equipment racks containing a wide range of AWA test instruments. These included Attenuator, Noise and Distortion Measuring Set, Output Indicator, Valve Voltmeter, Audio Oscillator, RF Oscillator, Beat Frequency Oscillator, Off-Air Monitor, Short Wave Receiver for broadcast program rebroadcast purposes and many others.

Many Scientists, Chemists, Engineers and other skilled people contributed to the work of the Research Laboratories over the years. They include Dr Ernest Benson, Dr Geoffrey Builder, Dr Alfred Green, Dr Oliver Pulley, Wilbur Christiansen, Eric Burbury, Wilf Honner, Dr James Rudd, Doug Sutherland and others.

Dr Ernest Benson joined the Laboratories in 1934, after completing Degrees in Science in 1929 and Engineering with First Class Honours in 1934. He made a particular contribution to the advancement of Broadcast Engineering technology and was Editor of 'AWA Technical Review' for 27 years, contributing many articles.

Dr Benson's early work was associated with the generation of carrier frequencies for broadcast transmitters. He made a particular study of piezo-electric crystals and published some 10 papers on the work carried out. In 1946, he was awarded the ME degree with First Class Honours and the Sydney University Medal for a thesis containing his published papers on piezo-electric crystals.

With the company's involvement in television, he prepared a number of papers which became landmarks in the science. He later became associated with work in electro-acoustics with particular emphasis on the design of loudspeakers for high quality sound reproduction. Dr Benson made a major contribution to sound equipment for the Sydney Opera House and shared in the Prince Philip Award received by AWA for the design and manufacture of this equipment. He retired in March 1975.

Dr Geoffrey Builder joined AWA Research Laboratories in 1934, subsequently being appointed Officer-in-Charge. In 1942, he left AWA to take up an appointment as Commissioned Officer in the AMF. He was the author of numerous scientific papers in 'Terrestrial Magnetism'; 'Physical Society Proceedings'; 'Journal of the Institution of Electrical Engineers'; 'Proceedings of the Royal Society, London'; 'Journal of the Institution of Engineers, Australia'; 'Proceedings of the Institution of Radio Engineers, USA'; 'AWA Technical Review' and others.

Before joining AWA he had been an observer at Watheroo Magnetic Observatory 1928–30; the British Polar Year Wireless Expedition 1932–33; and with the Australian Radio Research Board 1933–34.

At the Institution of Radio Engineers (Australia), World Radio Conference held in Sydney during 1938, Dr Builder was joint author of two papers and was Chairman of one of the sessions. With Dr Benson he delivered a paper 'Precision Frequency Control Equipment Using Quartz Crystals' and with Jim Gilchrist delivered a paper 'Communication Equipment for Vehicles'.

He also contributed articles in the 'Radiotron Designers Handbook', Edited by Fritz Langford-Smith and published by Wireless Press for AWA in 1953.

Dr Alfred Green joined AWA in 1935 and was still with the Research Laboratory at the outbreak of the Second World War. He was educated in England and conducted research under Professor Appleton and followed this work with a period at the Peterborough Radio Research Station of the British Research Board working on ionospheric investigations. From 1925 to 1935, he was a Senior Research Physicist with the Australian Research Board. He made the first precise measurement in Australia on the Kennelly-Heaviside layer. He became Chief of Research in 1945.

Dr Oliver Pulley joined AWA in 1935 serving as Senior Design Engineer until he resigned in October 1939 to become Principal Research Officer in the Radiophysics Laboratory of CSIRO.

Prior to joining AWA he spent two years with Standard Telephones and Cables Ltd, London followed by a period working under Professor Appleton at London University before becoming a member of AWA staff.

He was the author of many papers associated with his extensive research activities including 'A Self Synchronised System for Ionospheric Investigations', 'Radio Field Strength Survey Around Sydney' and 'Marine Radio Beacons'. The latter was published in 'AWA Review' in 1938 and was also the subject of a paper delivered at the World Radio Conference in Sydney in 1938 sponsored by the Institution of Radio Engineers (Australia).

Wilbur Christiansen, an authority on propagation and aerial technology, was instrumental in developing a field strength meter in the late 1930s, and during the War years worked on improvements to short wave aerial systems. The work resulted in a number of Patents being granted to the company. He worked for AWA during the period 1937 to 1948, and then transferred to CSIRO where he worked until 1960.

From 1960 to 1978, he was on the staff of the University of Sydney and subsequently moved to the Research School of Physical Sciences at the Australian National University, Canberra where he was associated with the Mount Stromlo and Siding Springs Observatories. He was the Author of 'Aerials and Transmission Lines', in the 'Radiotron Designers Handbook', Edited by Fritz Langford-Smith.

In 1978, Mr Christiansen was elected President of the International Union of Radio Science in recognition of his contribution to radio science.

Eric Burbury joined AWA in 1914, being involved in the company marine service and doing long distance experimental work. He visited England in 1921 to gain experience in the Marconi Co., works and on his return, worked on a number of Broadcast Engineering projects including 2FC and 2SM transmitter installations before transferring to the Research Laboratories.

At the World Radio Convention held in Sydney in 1938, he delivered a paper entitled "The Trend of Radio Development as Disclosed by a Study of the Inventions for which Letters Patents Have Been Granted During Recent years'.

Eric specialised in Letters Patent for some 30 years. He was company Patent Engineer from the early 1930s, later becoming Chief of Patents in the Patents Department, a position he held until the 1960s.

Jim Rudd became Chief of Research Laboratories in 1960 following a long period of research work with the company. He succeeded Wilf Honnor who had been in charge of Research since 1947.

As a result of his work associated with development of loudspeakers he contributed a number of articles to the 'AWA Technical Review' and delivered a paper at the 1938 World Radio Convention convened by The Institution of Radio Engineers (Australia) in Sydney. The paper was titled 'Loudspeaker Response Measurements'.

In 1962, Jim was appointed a Fellow of The Institution of Radio and Electronics Engineers, Australia.

Doug Sutherland joined the Laboratories in 1935 and was placed in charge of the Measurements Section. A graduate of the University of Melbourne in 1931 he had previously worked in research in Physics and for a time was on the staff of Geelong Grammar School.

A company photograph taken about 1936 of Research Laboratories staff when Dr Geoffrey Builder was in charge shows that staff included Doug Sutherland, Harold Brown, Dick Huey, Ern Benson, H A Ross, C A Saxby, G R Walters and F Maynard. It is not known whether this was the complete staff at the time.

RADIO RESEARCH BOARD

The Radio Research Board was founded in 1927 following the efforts of Professor John Madsen of Sydney University and Professor Thomas Laby of Melbourne University. Madsen was successful in obtaining assurance of funds from Farmer and Co., Ltd (2FC Sydney) for research into radio, while Laby obtained finance from the Broadcasting Co., of Australia (3LO Melbourne) for investigations into matters affecting broadcasting generally in Victoria.

On establishment, the Board comprised Professor Madsen; Professor Laby; Harry Brown, Postmaster General's Department and Electrical Commander Frank Cresswell. The Board members remained unchanged for a decade.

The Board approved a program of investigation into broadcasting matters including field intensity measurements, atmospherics, fading, distortion and modulation. All these bore directly on the immediate problems which the Postmaster General's Department was facing in planning, developing and regulating the broadcasting service.

The Board concluded, after a study of priorities, that investigations should begin in conjunction with PMG's Department staff into determination of the appropriate wavelengths to be used with the Australian Broadcasting Service. This was closely tied in with ways of extending the service coverage to people living in remote areas of the continent.

The Board published its first paper in 1927. It was 'Signal Strength Measurements of 3LO Melbourne' with the study being paid for by the owners of the station.

During the early 1930s, Board staff were actively engaged in a number of projects with emphasis on transmissions in the ionosphere, and atmospherics. Reports and individual papers issued during 1931–33 included:

- Corrections to Field Strength Measurements with Loop Antennae.
- A Radio Field Strength Survey Within 100 Miles of Sydney.
- The State of Polarisation of Sky Waves.
- Height Measurements of the Heaviside Layer in the Early Morning.
- The Influence of the Earth's Magnet Field on the Polarisation of Sky Waves.
- A Preliminary Investigation of Fading in New South Wales.
- Studies of Fading in Victoria: A Preliminary Study of Fading on Medium Wavelengths at Short Distances.
- Studies of Fading in Victoria: Observations on Distant Stations in Which no Ground Wave is Received.
- Atmospherics in Australia.
- A Field Intensity Set.
- Measurements of Attenuation, Fading and Interference in South Eastern Australia at 200 Kilocycles per Second.
- The Polarisation of Sky Waves in the Southern Hemisphere.

By mid 1935, a considerable amount of research work had been undertaken over both short and long paths from 2FC Sydney to study ground wave propagation using both medium wave and long wave signals, and also into atmospherics. One of the conclusions reached was that a signal strength of at least 0.5 mV/m was required for acceptable reception conditions in the medium wave band.

After analysing all the data from its studies, and on the advice of overseas experts, the Board came to the conclusion that a combination of long and medium wavelength stations was necessary to provide satisfactory service to the Australian population.

However, staff of the Postmaster General's Department did not accept the recommendation. Departmental officers had done considerable work on antifading radiators which they had intended to use at major stations. The employment of anti-fading radiators at long wavelengths would have been extremely expensive and the employment of long wavelength stations in expansion of the broadcasting service was not further considered by the Department.

Up to the outbreak of the Second World War, the Board's staff had been engaged in ionospheric research, particularly in relation to the role of the ionosphere in the transmission of medium and short waves.

With the aid of a network of ionospheric recorders distributed throughout Australia, researchers were able to develop a basis for the prediction of maximum useable frequencies for short wave communication and broadcasting. This was of major importance for wartime communications and later for determining frequencies to be employed with the Radio Australia service.

During the War, the Board lost many of its key people to Defence work. It decided that its activities would be confined to research which would benefit the national defence.

Many staff of the Board contributed to the advancement of radio and up to the outbreak of the War, they included Alfred Green, W G Baker, R O Cherry, L S C Tippett, R Fallon, J Pawsey, W J Wark, F W Wood, L G H Huxley, D F Martyn, G H Munro, O O Pulley, H B Wood, H C Webster, V A Bailey, G Builder, R W Boswell, J H Piddington, D M Myers and A H Mutton.

One of the staff who later played a major role in the advancement of the broadcasting and communications industries was Herbert (Bert) Wood. Bert graduated from the University of Sydney with Bachelor of Science and Bachelor of Engineering Degrees in 1928 and later completed a Master of Engineering Degree.

His first experience in Radio Engineering was with Philips when he began work on domestic receiver design under Ir Groeneveld formerly Chief Engineer of Philips Holland, following the establishment of a receiver manufacturing factory in Australia. One of his tasks was to modify some circuits developed in Holland employing triode valves to operate with the newly released screen grid valve E442S type.

In 1932, he joined the Radio Research Board in Sydney as Research Assistant following discussions with Professor Madsen of the University who was also a member of the Board. The previous year, the Sydney University had been granted a licence to operate a transmitter with callsign VK2CL with 1000 watts into the aerial and covering the frequency range 290 to 7000 kHz for experimental purposes. It was operated by a Technician under Professor Madsen. The transmitter was employed extensively by the Radio Research Board staff on work associated with propagation of radio signals and ionospheric studies.

One of Bert's early projects was with Dr Martyn in the development of an ingenious mechanico-electronic assembly to receive automatically, continuous height recordings by the rotating capacitor method. A Report 'A Heaviside Layer Height Recorder' described the project. Another Report compiled in 1932 in conjunction with Dr A L Green was 'Field Intensity Tests on 2UW'.

In 1933, he was granted a Walter and Elizabeth Hall Research Fellowship and went to England where he began work with Standard Telephones and Cables on design of a 250 watt Model TS4 radio telegraph transmitter for installation in South Africa. After 12 months with STC, he moved to the Marconi Company, Chelmsford to further his experience in Radio Engineering.

In travelling back to Australia, he visited the USA spending time in the Bell Telephone Laboratories and RCA Laboratories. When he arrived back in Australia he resumed work with the Radio Research Board.

In 1935, he designed and developed a self-contained automatic multi-frequency ionosonde to operate over the frequency band 1.6 to 10 MHz. It was described in a paper in the 'Journal of the Institution of Engineers Australia' in 1936.

In 1936, Bert left the Board to take up a position with Standard Telephones and Cables in Sydney. One of his early projects was to design and install a 2 kW transmitter for National station 6GF Kalgoorlie. He was assisted by Engineer Bill Mallinson and commissioned the transmitter on 10 December 1936.

He later became Technical Director at STC and when a vacancy became available at ITT Headquarters in Hong Kong, Bert took up duty as Area Technical Director for the Far East and Pacific area. In 1968, after five years in Hong Kong he moved base to Kuala Lumpur where he retired in 1971.

The Board's role as an active research organisation steadily declined over the years, particularly with the entry of the CSIRO Radio Research Laboratories into the field, and by 1958, the Board had shed most of its functions to become a grant distributing body to aid research in Australian Universities.

In July 1985, the Radio Research Board was reconstituted and became the Australian Telecommunications and Electronics Research Board. Members included representatives from Commonwealth Scientific and Industrial Research Organisation, Defence Science and Technology Organisation and Australian and Overseas Telecommunications Corporation Ltd. In 1993, Chairman of the Board was Professor D F Skellern of Macquarie University.

The Board encourages and sponsors research with funding from its sponsors AOTC, CSRIO and DSTO. The Board includes representatives from Universities.

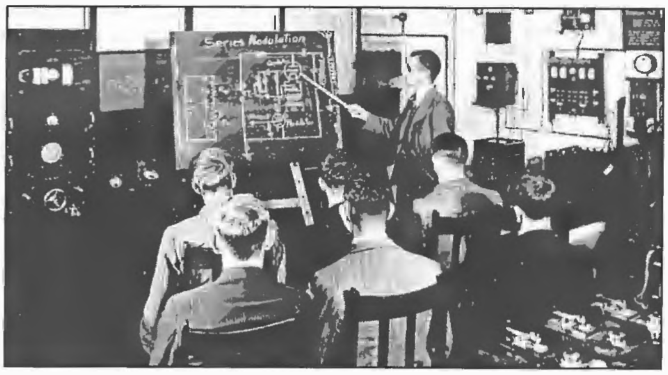
With its long history of support of research and training ATERB believes that it is critically important for Australia to increase the number of professionals, researchers and academics in the area of telecommunications to meet the projected demand. To further this goal, ATERB awarded nine, one year postgraduate scholarships each worth $11000 tax free in 1993.

Winners of the Awards were Leslie Bright, University of Adelaide; Geraldine Fitzpatrick, University of Queensland; Eric Heyde, University of Sydney; Brenden Jones, Macquarie University; Stephen Lawrence, University of Queensland; Michael Steel, University of Sydney; Jacqueline Walker, Curtin University of Technology; Craig Watkins, Australian National University and Samson Yeung, University of Melbourne.

Another Award with which the Board is associated, is the ATERB Medal awarded jointly by ATERB and the Australian Academy of Technological Sciences and Engineering since 1988 to recognise outstanding contributions in the fields of telecommunications and electronics by a young Australian. Such contributions can be recognised by research papers, patents, commercial success and benefit to Australia. The Award consists of a silver medal and a prize of $2500. The fifth ATERB Medal was awarded in 1992 to Dr Marwan Anwar Jabri, Senior Lecturer in the School of Electrical Engineering at the University of Sydney.

The 1995 ATERB Medal was awarded to Dr Arthur Lowery for his efforts which have assisted in establishing an international reputation for Australian research in the field of photonics, the application of lightwave techniques to communications systems. Dr Lowery joined the University of Melbourne in July 1990 as a Senior Lecturer and in January 1993 was promoted to the position of Associate Professor and Reader in recognition of his outstanding performance in many areas of research and his innovative approach to teaching.

Marconi School of Wireless classroom and ship's spark wireless equipment used for training. School opened in 1913 and until its closure about 70 years later offered a range of courses up to the level of Professional Radio Engineer. First Chief Instructor, George Apperley who joined AWA in 1913 and retired in 1946.



Class instruction at Marconi School of Wireless circa 1939. Courses conducted during the period catered for the Radio Engineer, Radio Technician, Radio Mechanic, Radio Operator and Talking Picture Operator. About that time, Dr Bill Baker was Principal of the Engineering Section of the School. Bill joined AWA in 1931 and was appointed to the School the following year. The School closed in 1983.

Wayville Radio Club display at Adelaide Radio Exhibition 1931 showing the Club's transmitting and receiving facilities. The Club was formed in September 1924 and disbanded about 1934. First President, Ben Wilson.

The Adelaide Division Committee of the Institution of Radio Engineers (Australia). The Committee held its first meeting on 1 June 1936 attended by 72 persons. It was the third Division to be established in Australia.
Back Row (L to R): Stan Ackland, Jack Risely, Cliff Moule, Don Gooding, Bob Oakley, Ben Wilson.
Seated (L to R): Wilf Honnor; Professor Kerr Grant, Chairman; Bert Harrington, Vice-Chairman; Harry Garth, Secty/Treasurer.

Part of the Standard Frequency facility at Amalgamated Wireless (A/Asia) Ltd Radio Laboratory, Ashfield, circa 1939. The Laboratory was well-equipped with the most modern equipment and was staffed by highly qualified Engineers, Physicists and Chemists. In addition to catering for company needs, the Laboratory contracted out its services to the broadcasting industry. Officer-in-Charge of the Laboratory in 1939 was Dr Geoffrey Builder who joined AWA in 1934.

Frank O'Grady (L) former Director General, Posts and Telegraphs, Postmaster General's Department who was associated with the installation of 5CK in 1932 and upgrading of 5CL in 1936, and Harry Kaye, Director, Posts and Telegraphs, South Australia and Northern Territory viewing transmitter components at display in Adelaide GPO, 1973 to commemorate Golden Jubilee of establishment of broadcasting in Australia. The water cooled valves were from 5CL at Brooklyn Park in 1950s and air cooled 3J261E was from 5CL at Pimpala in 1960s.

Sir Mark Oliphant, Governor of South Australia inspecting part of the Radio Section display following official opening of the Telecommunications Museum, Adelaide, 31 July 1978. The Museum closed on 30 September 1992 when decision was made to sell the building. (L to R): Murray Coleman, State Manager, Telecom Australia; Mr Joseph, Lord Mayor Adelaide; Sir Mark; Jack Ross, State Broadcasting Manager and Museum Committee Member.

Jack Ross (Centre), Member of the Telecommunications Museum and Engineering Historical Committee being interviewed by Carol Whitelock and Philip Satchell in the Telecommunications Museum, Adelaide, on 1 July 1982. The ABC set up a temporary studio in the Radio Section of the Museum as part of a series of special broadcasts to celebrate the Golden Jubilee of the establishment of the Australian Broadcasting Commission on 1 July 1932.

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TERMINOLOGY & ABBREVIATIONS

TERMINOLOGY

In a technical historical work where the technology has extended over a long period of time, it is difficult to be consistent with terminology. Changes occur for a number of reasons. Some words or terms — e.g. elastance, ether, jars — disappear from the Technical Dictionary, others are added — e.g. transistor — while some words are dropped in preference to others, e.g. capacitor in place of condenser. Changes also result from the adoption of International Standards — e.g. Hertz in place of Cycles per Second — and when a Nation adopts a new currency. In the Australian case, when the currency was changed from pounds and pence to dollars and cents, the word 'guinea', a popular method of pricing home broadcast receivers, had no corresponding replacement.

When Philips produced the first five element amplifier valve in 1927, Philips marketed it as 'penthode' until about 1936, Mullard marketed it as 'pentone' while all other manufacturers marketed it as 'pentode' from the start.

There are also many instances of more than one word being used to describe an item of equipment, a process, a technique etc. These include Wireless/Radio, Atmospherics/Statics, Mast/Tower, Rejector/Stopper, Transmitter/Sender, Detector/Demodulator, Detector/Rectifier, Condenser/Capacitor, Capacity/Capacitance, Triode/Radiotron, Diode/Fleming Valve, Accumulator/Storage Battery, Blanket/Wipe Out, Antenna/Radiator, Microphone/Transmitter and many others.

In the case of broadcasting technology, terminology has been further confused by the use of different words in referring to the same items of equipment by English and USA Engineers and Technicians. These include Aerial/Antenna, Valve/Tube, Anode/Plate, Barretter/Ballast, LT Battery/A Battery, HT Battery/B Battery, Grid Bias Battery/C Battery, Dummy Aerial/Dummy Antenna, Earth/Ground, Curtain Aerial/Mattress Antenna, Frame Aerial/Loop Antenna, Terminal/Binding Post, and others. For consistency in this history of broadcasting, the Author has used aerial, valve, anode, barretter, A battery, B battery, C battery, dummy aerial, earth and curtain aerial as these appear to have been more popular with Australian Engineers and Technicians during the period of seventy five years of radio broadcasting in this country.

Since the introduction of television in Australia in 1956, there has been some difference of opinion concerning the usage of the term 'broadcasting'. In general, it is taken to refer only to radio, but sometimes the term is understood to include television. In this work, the term 'broadcasting' refers specifically to radio broadcasting.

ABBREVIATIONS

Some abbreviations, such as ABC and BBC, refer to organisations which went through changes of names over periods of time. For example, ABC refers to Australian Broadcasting Company Ltd in the period 1930–1932, to Australian Broadcasting Commission in the period 1932–1983, and to Australian Broadcasting Corporation from 1983 to the present. Similarly, BBC refers to British Broadcasting Company in the period 1922–1926, and to British Broadcasting Corporation from 1927 to the present. However, it would not be difficult for the reader to conclude which organisation is meant from a reading of the text.

A	Ampere
Asia	Australasia
ABA	Australian Broadcasting Authority
ABC	Australian Broadcasting Company Ltd 1930–1932 Australian Broadcasting Commission 1932–1983 Australian Broadcasting Corporation 1983 to present
ABCB	Australian Broadcasting Control Board
ABT	Australian Broadcasting Tribunal
ABU	Asia-Pacific Broadcasting Union
AC	Alternating Current
ACU	Aerial Coupling Unit
AF	Audio Frequency
AFC	Automatic Frequency Control
AGM	Annual General Meeting
AGPS	Australian Government Publishing Service
Ahr	Ampere Hour
AM	Amplitude Modulation
Amps	Amperes
AOTC	Australian and Overseas Telecommunications Corporation Ltd
APO	Australian Post Office
ARC	Australian Radio College
ARTS & P	Australian Radio Technical Services and Patents
ATERB	Australian Telecommunications & Electronics Research Board
AVC	Automatic Volume Control
AWA	Amalgamated Wireless (Australasia) Limited AWA Limited
BBC	British Broadcasting Company 1922–1926 British Broadcasting Corporation 1927 to present
BFO	Beat Frequency Oscillator
BRACS	Broadcasting Reception for Aboriginal Communities Scheme
BSS	Broadcasting Satellite Service
BVA	British Radio Valve Manufacturers Association

CBC Canadian Broadcasting Corporation
CCIR International Radio Consultative Committee
CCTV Closed Circuit Television
CD Compact Disc
CMF Cymomotive Force
CP Candle Power
CPS Cycles Per Second
CRO Cathode Ray Oscilloscope
CRTS Commonwealth Reconstruction Training Scheme
CSIRO Commonwealth Scientific and Industrial Research Organisation
CWT Hundredweight
DAB Digital Audio Broadcasting
DACM Dynamic Adaptive Carrier Modulation
DAMS Digital Audio Mass Storage
DAT Digital Audio Tape
dB Decibel
dBm Decibel referred to 1 milliwatt
DC Direct Current
DCC Digital Compact Disc
Double Cotton Covered
DCFM Direct Carrier Frequency Modulation
DIV Division
DOC Department of Communications
DRB Digital Radio Broadcasting
DSC Double Silk Covered
DSB Digital Sound Broadcasting
DT & C Department of Transport and Communications
EBU European Broadcasting Union
EHT Extra High Tension
EIA Electronics Industries Association
EMF Electromotive Force
EPP Emergency Power Plant
ERP Effective Radiated Power
FACTS Federation of Australian Commercial Television Stations
FAP Frequency Allotment Plan
FARB Federation of Australian Radio Broadcasters
FCC Federal Communications Commission
FET Field Effect Transistor
FM Frequency Modulation
ft Feet
GPH Gallons per Hour
GR General Radio Company
HACBSS Homestead and Community Broadcasting Satellite Service
HCMV Hot Cathode Mercury Vapour
HDC Hard Drawn Copper
HF High Frequency
HRSA Historical Radio Society of Australia
HP Horsepower
HT High Tension
Hz Hertz
IE Aust. Institution of Engineers, Australia
IF Intermediate Frequency
IPS Ionospheric Prediction Service
IPS Inches Per Second
IRE Aust. Institution of Radio Engineers (Australia)
IREE Aust. Institution of Radio and Electronics Engineeers, Australia
ISDN Integrated Services Digital Network
ITU International Telecommunications Union
JEEEA Journal of Electrical and Electronics Engineering, Aust.
kHz Kilohertz
km Kilometre
kV Kilovolt
kVA Kilovolt Ampere
kW Kilowatt
LAP Licence Area Plan
LED Light Emitting Diode
LF Low Frequency
LP Long Playing
LV Low Voltage
m Metre
Ma Milliampere
MF Medium Frequency
MFD Microfarad
MHz Megahertz
MIC Monitoring Information Centre
mm Millimetre
MPM Multi Parameter Modulator
MSP Manufacturers' Special Products
mV/m Millivolts Per Metre
NAB National Association of Broadcasters
NBS National Broadcasting Service
NTA National Transmission Agency
OB Outside Broadcast
OIC Officer-in-Charge
OTC Overseas Telecommunications Commission
PA Power Amplifier or Public Address
PBAA Public Broadcasting Association of Australia
PBX Private Branch Exchange
PC Personal Computer
PCB Printed Circuit Board
PCD Pitch Circle Diameter
PFD Picofarad
PIE Program Input Equipment
PLL Phase Locked Loop
PMG's Dept. Postmaster General's Department
PPM Parts Per Million
PTC Perth Technical College
RAAF Royal Australian Air Force
RAN Royal Australian Navy
R-C Resistance-Capacitance
RCA Radio Corporation of America
RDS Radio Date System
RF Radio Frequency
RFDS Royal Flying Doctor Service
RI Radio Inspector
RM Regional Manager
RMS Root Mean Square
RPM Revolutions Per Minute
RX Receiver
SA/NT South Australia/Northern Territory
SBM State Broadcasting Manager
SBRS Self-help Broadcasting Reception Scheme
SBS Special Broadcasting Service/Corporation
SCC Single Cotton Covered
SEC State Electricity Commission
SMA Spectrum Management Agency
SMPTE Society of Motion Picture and Television Engineers
SPL Sound Pressure Level
SRRN Second Regional Radio Network
SSB Single Sideband
STC Standard Telephones and Cables Pty Ltd
STL Studio Transmitter Link
Superhet Superheterodyne
SWG Standard Wire Gauge
TAG Technical Advisory Group
Telecom Telecom Australia
Australian Telecommunications Commission/Corporation
Telstra Corporation Ltd
TPG Technical Planning Guidelines
TRF Tuned Radio Frequency
TU Transmission Unit
TV Television
TX Transmitter
UHF Ultra High Frequency

UK	United Kingdom
USA	United States of America
V	Volt
VCR	Video Cassette Recorder
VDC	Volunteer Defence Corps
VDU	Visual Display Unit
VLF	Very Low Frequency
VHF	Very High Frequency
VSWR	Voltage Standing Wave Ratio
W	Watt
WAIT	West Australia Institute of Technology
WE	Western Electric Company
WIA	Wireless Institute of Australia
Z	Impedance

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Radio Broadcasting Technology

75 Years of Development in Australia

1923 – 1998

John F Ross AM