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Sound and Vision

SEVERAL times during the recent spell of hot weather we have been reminded by the B.B.C., as we have many times in past years, to turn the volume control of the radio down if the set is anywhere near an open window. No one will deny that this is sound advice, and a very necessary reminder to a small minority of the listening public, but may we ask if there is not also a small contribution that the B.B.C. might make by first putting its own House in order?

It is frequently noticeable that when the transmitted programme changes from speech to band or orchestral music, the sound output from all loudspeakers increases twofold, and unless we are prepared to adjust our volume controls for almost every change of programme then inevitably the music will be too loud, or the speech too soft. Better by far that one fader control should be moved than that millions of listeners should have to disturb their pleasurable enjoyment to adjust their volume controls.

No claim for originality is made for this suggestion—it has been offered from many quarters, not the least by a volunteer speaker in the "Listener Answers Back" series. The official reply was that the technical difficulties were such that it would be virtually impossible to improve the programme supervision at the transmitting end.

May we suggest that the Programme Controller be simply supplied with a db. meter connected across the monitor channel? Or should preference be given to the applause-measuring meter, often used in "Discovery" features, placed near the monitoring loudspeaker?

Emboldened by the knowledge that our relations with the British Broadcasting Corporation are of the best, and that ninety-nine per cent of its work can be mentioned only in praise, we hasten to add—to have an end of carping—one other point deserving of criticism.

If Miss "Television Girl" is forced, through illness, to be temporarily absent from her duties, it is sufficient for us to be briefly given the reason for her absence, and our hearts will go out to her in her misfortune. But *please*! not the reason, then a bulletin, then another bulletin, then an announcement that the return will not be long delayed, and then that it is imminent.

Or if a group of well-wishers feel that the presentation of a dog to one of the announcers is in order, should not that, to turn a phrase, be that? Repeated appearances of the animal, however talented or charming, lead one to wonder what domestic animals, should the habit spread, the announcers of Broadcasting House might bring to the microphone.

The parallel on which this argument is based may not be justifiably close, but it at least points out the fact that the television service is still in its "Savoy Hill" days, and although it is remarkably "chummy" for the seeing and seen to be on such close terms, this must pass into the limbo of "Good Old Days" before the first regular television service can mature into the finest regular television service.

E.T.F.

PROGRESS AT SUTTON COLDFIELD

By the end of June, the television mast, which is being erected by B.I. Callender's Construction Co., Ltd., at Sutton Coldfield for the B.B.C., reached a height of 600 ft.

Some preliminary details of the mast were given in the May issue of ELECTRONIC ENGINEERING (page 184) from which it will be recalled that the mast will have a total height of 750 feet and will weigh 140 tons.

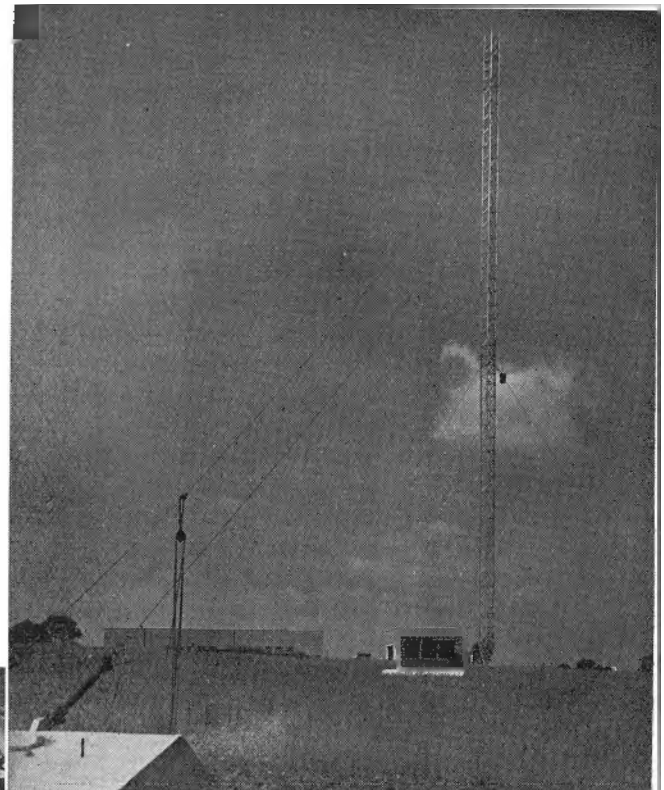
The base pedestal, which is designed to withstand a thrust of 350 tons, and the first 26-ft. section were in place in May of this year and, by June 24th, a height of 400 ft. was reached, the remaining 200 ft. being erected in one week.

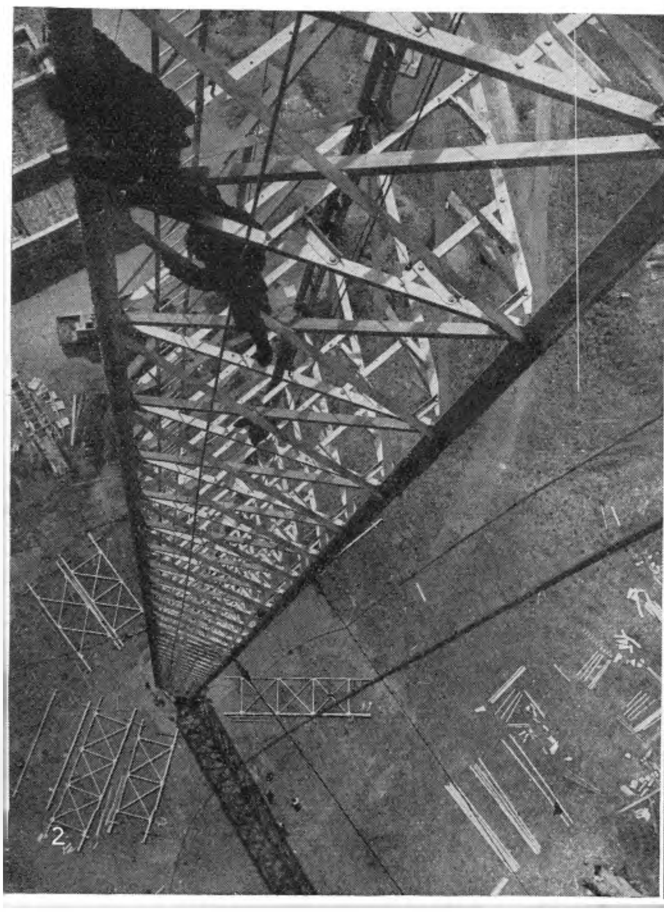
At a height of 600 ft. the cross-section of the mast changes from a triangular to a circular section, and at 710 ft. the eight dipoles will be erected which, with obstruction light and lightning conductors, will extend the mast height to 750 ft. The present state of construction is illustrated in the accompanying photographs.

Fig. 1. Erecting the Television Mast at Sutton Coldfield. When this photograph was taken the mast had reached the 400-ft. level. Near the mast can be seen the bo'sun's chair in which the riggers are hoisted to the top.

Fig. 2. A bird's-eye view of the Sutton Coldfield Television Mast under construction from 400 ft. The photograph shows assembled sections of the mast on the ground ready for erection.

Fig. 3. Sections are assembled on the ground and then hoisted up and bolted into position. The base of the mast and the supporting pedestal are clearly seen in the photograph.





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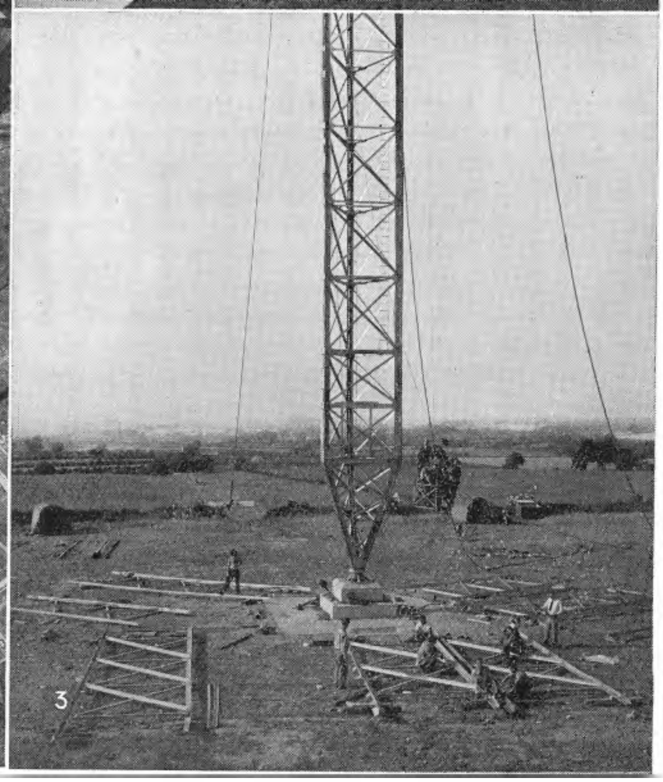

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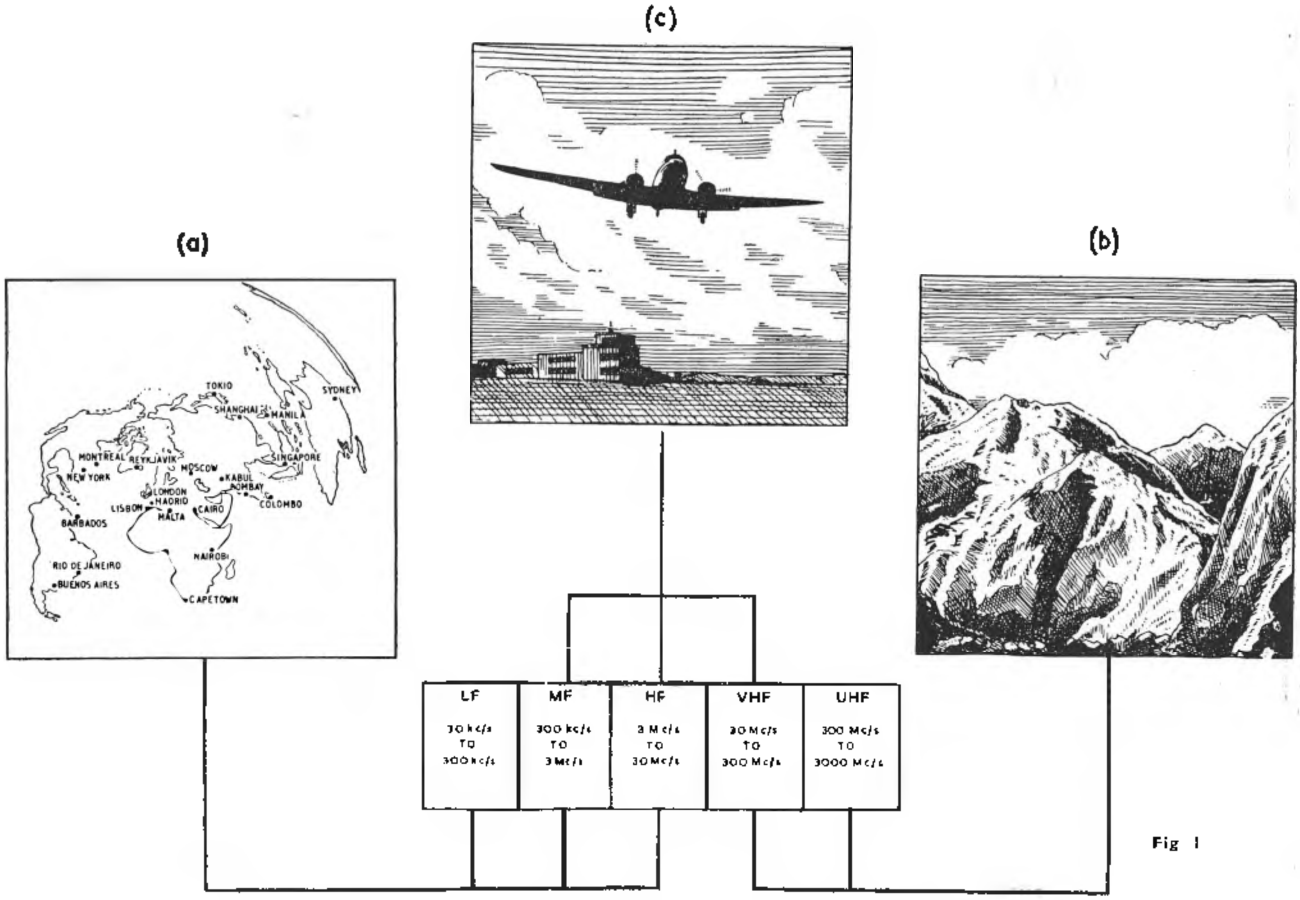


Fig 1

Commercial Systems of Radiocommunication

By H. D. B. KIRBY, M.A.*

RADIO as a means of broadcasting entertainment is now so familiar and the various forms of radiolocation developed during the war have so captured public interest that its uses as a means of communication between two places tend to be overlooked. This article is therefore intended to describe a few of the ways in which radio is used to supplement or replace the more familiar line systems of communication.

The first practical demonstration of radiocommunication was made by Marconi just over 50 years ago and for 25 years its use was almost limited by the equipment then available to telegraphy.

During World War I some use was made of radio both for telegraphy and telephony, but the work done during these years did not really bear fruit until after the war. From then on progress was very rapid. 1920 saw the first use of radio for regular public telephone service, when a link was set up between Catalina Island and Long Beach, California, and connected into the Bell telephone system. In 1923 the first public demonstration of trans-oceanic radiotelephony was made between Broadway, New York, and New Southgate, England. In 1925 the first ship-to-shore telephony sets were installed in vessels of the whaling fleet in South Georgia.

These three historic achievements exemplify the three important spheres in which radio offers considerable advantages over line as a medium of communication. These can be listed as:—

(a) Long-distance links (international or transcontinental) when distance, physical obstacles, varying transmission standards or political reasons make a straight-through wire connection impracticable.

(b) Short-distance links (up to a few hundred miles) where the nature of the terrain between the terminals makes the construction or the maintenance of a wire route or the laying of a cable difficult or uneconomic.

(c) When one or both of the terminals are mobile.

Fig. 1 (*above*) illustrates these three spheres of use and also shows the parts of the frequency spectrum normally used for each. These are by no means clear cut, as the demand for frequencies far exceeds the supply, but whenever possible

*Standard Telephones and Cables, Ltd., London.

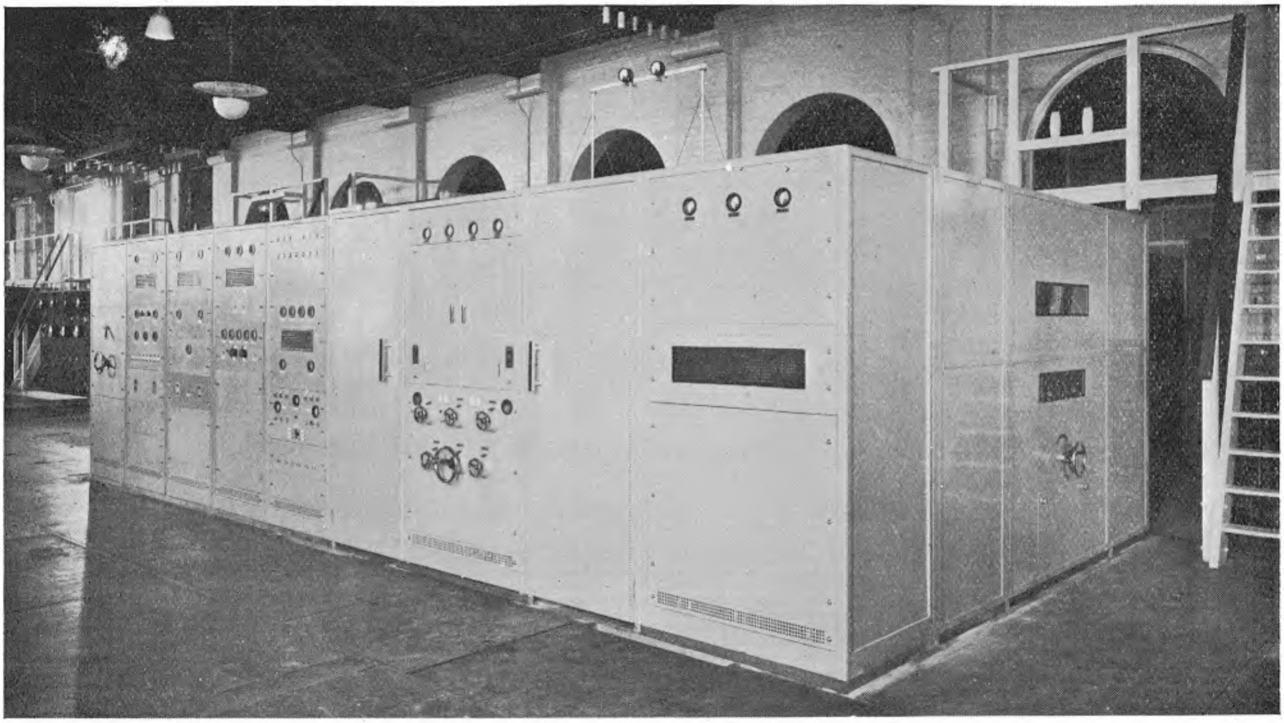


Fig. 2. General view of British Post Office transmitter (Rugby)

parts of the spectrum especially suited to a particular service are reserved for it.

Long-Distance Links

The map in Fig. 1 shows the different parts of the world to which radiotelephone links are operated from this country. In addition, there are a large number of services worked by telegraphy. The telephone circuits are all provided with terminating and privacy equipments to enable them to be connected into the public telephone systems. Many of the telegraph circuits now terminate in standard Post Office V.F. telegraph equipment, though certain forms of specialised high-speed instruments are also in use.

Normally the transmitters and receivers for these long-distance circuits are situated many miles apart in localities particularly favourable for their operation. They are connected by land-lines to a central point at which special equipment is provided, in the case of telephone circuits, for mixing the transmitted and received signals and for connexion to the trunk telephone systems. In this country, the telephone circuits are controlled from the Radio Telephony Terminal which is in process of being moved from Faraday Building, London, to Brent. The outgoing speech is passed by land-line to one of the transmitters at Rugby or Criggion and the incoming speech is brought in from the receiving station at Baldock, Cupar or Cooling Marshes.

The frequencies used for these long links vary very considerably according to the part of the world to which they are working and the ionospheric conditions prevailing at the time. The V.L.F. transmitter (GBZ), for instance, at Criggion operates on 15.46 Kc/s., while the H.F. links may use frequencies of up to 26 Mc/s. Research into the forecasting of the best frequencies to use under given conditions has considerably reduced the amount of time these links are out of communication.

A typical transmitter used by the British Post Office for these links is shown in Fig. 2. It has an output power of about 20 kilowatts and a frequency range from 3 to 21.75 Mc/s.

Normally separate frequencies are used for transmitting in each direction and both transmitters are in operation at the same time, so that the link operates in the same way as a four-wire telephone circuit. However, as the circuit conditions are continually changing due to the inclusion of the two radio paths and as the gain of the path between the subscriber and the transmitter has to be continually varied to maintain the correct modulation level, the simple hybrid transformer terminations used on wire circuits are not satisfactory. Voice-operated switching circuits are therefore provided to ensure that only one transmission path is open at a time, the other path being blocked to prevent "singing." In addition, a technical operator is required to carry out the adjustments necessitated by the continually changing conditions. During recent years much work has been done on the development of an automatic technical operator which ensures that the transmitter is always modulated to the correct depth by the outgoing signal and that the level of the incoming signal is kept at the maximum consistent with stability, with the result that radio terminals are now operated on a semi-automatic basis.

One of the most important

developments in long-distance communication during the past few years is the extension of the use of the single sideband principle of operation. The L.F. circuit between this country and the U.S.A. has been using the single sideband method of operation since 1927, but it is only recently that the method has been applied successfully to H.F. operation. The advantages of the system will be discussed in greater detail in a later article, but they may be summarised as:—

1. Improved signal-to-noise ratio at the receiver for a given transmitter power.
2. Less bandwith occupied per channel.
3. Freedom from the distortion normally caused by selective fading and multi-path propagation.

Receiving equipments for long-distance links usually make use of space diversity reception. Fading commonly occurs as the result of interference between waves which have reached the receiver by different paths, and while this can to some extent be overcome by automatic gain control circuits, these cannot deal with the distortion which is usually present during the weak part of the fading cycle. Greatly improved reception can be obtained by taking advantage of the fact that fading effects are very localised, so that if a number of antennæ are spaced a few wavelengths apart it is probable that one of them will pick up a strong signal. The outputs of the spaced antennæ can be combined in such a manner that the antenna receiving the strongest carrier provides all or the majority of the total output to line. Such receiving systems tend to be rather complicated and expensive, but where high quality circuits are required their use is well justified.

Short-Distance Links

These may conveniently be divided into two types, those which are connected direct into the public telephone or telegraph service and those which merely provide point-to-point communication between the terminals. The latter were originally hand-keyed morse telegraph circuits but are now in this country all "phonogram" circuits, that is to say, they are used to pass messages by speech, but are not available to the public for direct conversation. They are one-way telephone circuits using very simple equipment requiring unskilled operators and are arranged to operate for a specified period in each direction. A number of such circuits are in operation round the coast of Great Britain, providing communication to small islands, where the amount of traffic makes any other system uneconomic.

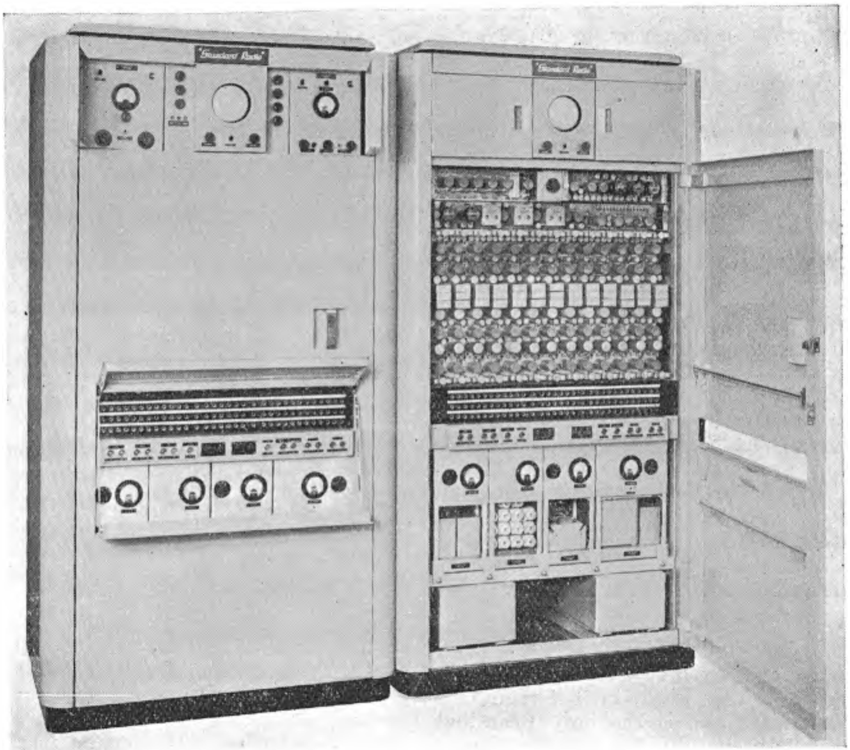


Fig. 3. 24-channel UHF transmitter-receiver

When the links form a part of the telephone or telegraph network the equipment has to be rather more complicated. It must resemble a telephone circuit not only in being duplex (*i.e.*, providing communication in both directions without send-receive switching), but also by having a performance equivalent in all respects to the line circuit which it replaces. It must be completely reliable in operation and require the minimum of attention. The frequency response, the signal/noise and signal/crosstalk ratios, the distortion and the gain stability must all be as good as on an equivalent line system.

In this country such links are used mostly between the mainland and the larger islands and are in many cases multi-channel. The majority of them operate in the V.H.F. band although the advantages of the higher frequencies have been recognised and the trend is towards their use, especially in America. In the V.H.F. band amplitude or frequency modulation is favoured and multi-channel operation is secured by frequency division, whereas in the U.H.F. band time division is often more suitable in conjunction with one of the various forms of pulse modulation, though wide-band frequency modulation is also used. In the U.H.F. band it is not normally possible to obtain direct communication over more than optical distances (about 35 miles), but it is possible to use several repeaters to form a chain of radio links. In the V.H.F. band it has been found possible to operate direct links over considerably greater distances. The longest V.H.F. link in regular operation in Great Britain is from Lerwick in the Shetlands to Kirkwall in the Orkneys, a distance of 98 miles.

The first link to provide as many as nine channels was that installed in 1938 between Belfast and Stranraer, a distance of about 35 miles. Amplitude modulation is used and a frequency division system of multiplex. In the transmitter each incoming signal modulates a separate sub-carrier in the range 150-300 Kc/s. and the whole group of sub-carriers modulates the radiated carrier which lies between 60 and 85 Mc/s. In the receiver the output of the second detector is applied to a bank of nine band-pass filters which select the modulated sub-carrier for each channel. The outputs from these filters are then demodulated, amplified and passed to line. Fig. 3 shows a modern U.H.F. 24-channel transmitter and receiver using a time-division system of multiplex.

It is probable that most new links set up in the future will operate in the U.H.F. band and also that existing links will eventually be transferred to this part of the frequency spectrum, since there is a growing demand for frequencies in the V.H.F. band for the mobile services described in the next section.

Mobile Systems

When communication is required between a fixed station and a mobile craft of any kind, or between two mobiles, radio is the only practical alternative so far to visual or direct aural methods. All mobile systems are similar in principle, but the requirements vary considerably according to the nature of the craft and the service. In the sphere of naval communication some of the large ships may be required to communicate with shore stations many thousands of miles away, with other ships or ports almost within optical range and in some cases also with aircraft flying over a wide area. In many cases it is also desirable that passengers on the ship shall be able to speak over the public telephone service of one or more countries, often a considerable distance away.

In the air the requirements are equally diverse. Apart from the various navigational and landing aids, not only must the pilot be able to receive instructions about taking off and landing, but the plane must also be able to keep in touch with ground stations some distance away. It is now normal to use V.H.F. for airport control, but the long-distance equipment has to cover a wide band of frequencies in the H.F. and M.F. bands. The chief consideration in the design of airborne equipment is the reduction of weight, and to a lesser extent of bulk. This has resulted in the development of the technique of miniaturisation, the success of which is illustrated by the V.H.F. equipment shown in Fig. 4. This is the civil counterpart of an R.A.F. equipment developed by Standard Telephones and Cables, Ltd., during the war to replace the V.H.F. transmitter/receiver type TR.1143. The total weight of the earlier model (the TR.1143) is 79 lb., and of the later model (the TR.1520) 23 lb. Both these equipments have provision for the remote selection of four frequencies, the former using eight crystals and the latter five, one of which has a fixed value. The demand for more operating frequencies has led to the development of the STR.12 equipment shown in Fig. 5. This gives 23 spot frequencies in the band 118-128 Mc/s., all the crystals being located in the control unit, which also contains the first oscillator stages for both transmitter and receiver. All tuned circuits in the main unit are of band-pass design so that no complicated system of remote control is necessary.

In peacetime, the use of radio for mobile communication on land is still rather restricted in this country, the chief users being the police, fire and ambulance services and taxi operators, although the newspapers are beginning to appreciate its possibilities. In America, however, there is a general mobile service operating in more than 50 cities which enables connexion to be made from a mobile unit to any telephone in the public service. This service is being used by ambulances, garages, public utilities, newspapers, doctors, police, fire departments and many others. A typical mobile installation consists of a frequency modulated transmitter of 20 watts output power and a receiver, both located in the luggage boot of a car. A micro-telephone hand-set with a send-receive switch and some calling means such as a bell or lamp are mounted below the dashboard.

Telephone service to train passengers was started between New York and Washington last year. The possibility of separating the aerials and using slightly more equipment than in a car enables duplex working to be used so that passengers can talk as over a normal telephone.

Conclusion

In the space available it has been possible to mention only a few of the ways in which radio is being used in the various fields of communication. For the future it can be said that the use of radio is likely to continue to increase to the limit of frequencies available. Consequently much research is now directed towards extending the useful frequency spectrum and, even more important, making the fullest possible use of the frequencies in that spectrum.

Fig. 4. VHF transmitter-receiver. Type STR.9

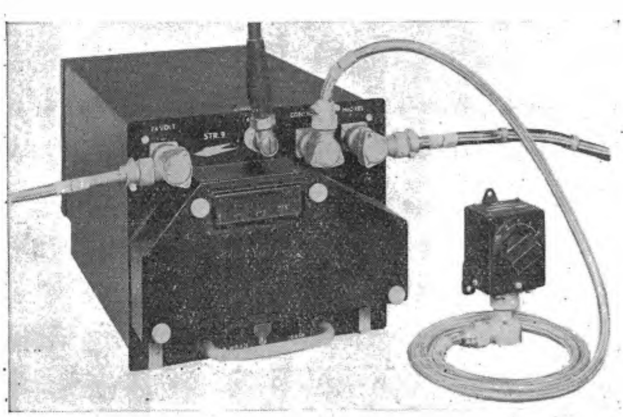
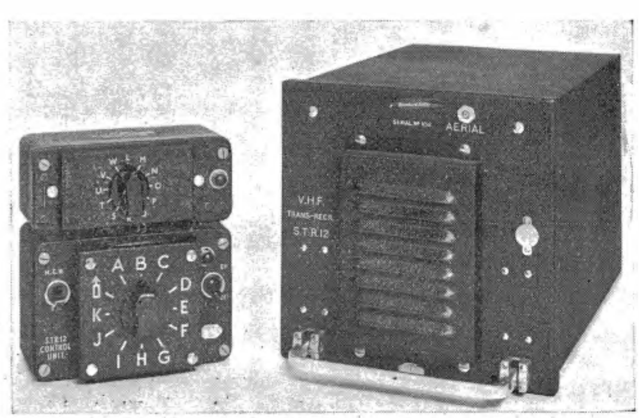
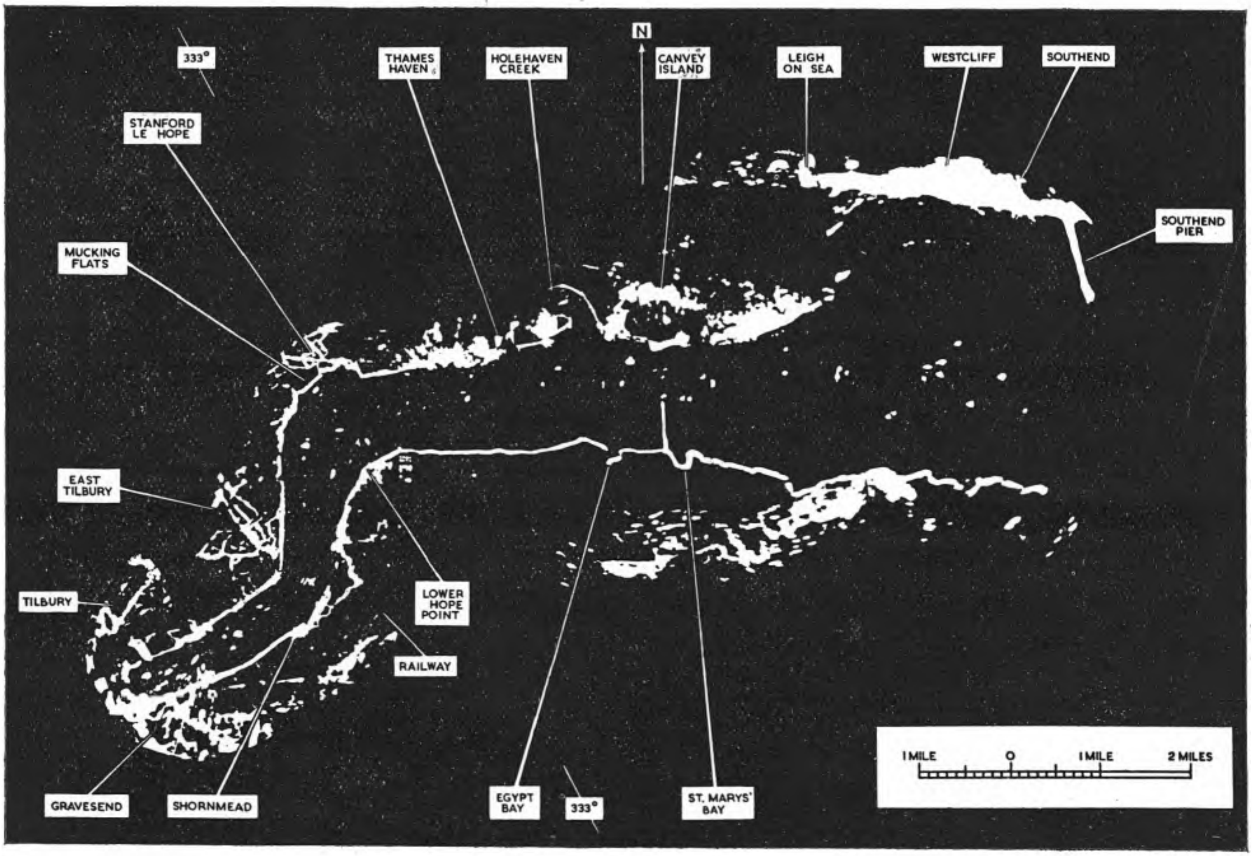


Fig. 5. VHF transmitter-receiver Type STR.12





Radar Mapping

By R. R. LOWTHER, F.Z.S.*

THE illustration shown above is a radar mosaic, reconstructed from a series of photographs of the P.P.I. display on an E.M.I. Marine Radar prototype equipment installed on the T.S.M.V. "Seamew." This mosaic covers that part of the River Thames lying between Southend and Gravesend. The vessel was used for a series of extended sea trials of the above equipment during voyages between the United Kingdom and various Italian seaports.

The Radar Equipment

The radar equipment was built to comply with the specifications laid down in the Ministry of Transport Marine Radar recommendations.

The transmitted pulse is of 0.2 μsecs. duration, the repetition rate 1,500 cycles per second, and the peak power output is 40KW. The transmitter and associated power supplies are shown in Fig. 1.

The scanner rotates at 30 r.p.m. and the beam width is $\pm 1^\circ$ at half-power points. The Plan Position Indicator (P.P.I.) display is produced on a 9 in. diameter cathode-ray tube having a fluoride screen.

Photographic Arrangements

The brightness of the afterglow of P.P.I. tubes is such as to prohibit the use of short photographic exposure times, but the slow rate of travel past the land allows long exposures to be made without any detrimental effect. A fast panchromatic film, type Ilford HP3, was used for the photographs. The camera was a standand Contax II fitted with a 5 cm. focal length, f1.5 lens and employed a supplementary lens to enable the image to be brought into focus when the cross-over point of the optical system is at a distance of approximately 50 cm. from the P.P.I. screen. This arrangement is necessary to permit the whole of the available area of the 35 mm. negative to be used, so as to reduce the degree of ultimate enlargement required if the photographs are to be reproduced with reasonable dimensions.

Exposure times were of the order of 4 seconds, but the results indicate that shorter times could be used and that times slightly exceeding the minimum of 2 seconds, provide adequate density in the negative. Since the scanner rotates at 30 r.p.m. an exposure of less than 2 seconds will not permit the whole scene to be photographed with an equal intensity of illumination over the whole scene.

Because of the comparatively long exposures used, every effort had to be made to ensure a rigid mounting for the camera. In the present instance, the P.P.I. unit (see Fig. 2) was provided with two rails for the operator to use for personal support in rough

* E.M.I. Engineering Development, Ltd.

weather. A bridge-like structure, built of angle iron, for the purpose of supporting the camera was clamped to these rails. This structure carried a platform on which the camera was mounted. The platform was adjusted to the position of optimum focus so that the camera could be removed for reloading and easily replaced in the correct position. The camera focus control remained in the *Infinity* position in order to reduce the number of operations necessary before photography can be commenced.

The camera-clamping arrangement was so designed that it could be swung out of its position over the P.P.I. tube so that normal navigational use of the Radar installation was readily available.

Before the mounted camera was used, measurements were made to verify that the plane of the film was parallel to the screen of the P.P.I. A final verification of the accuracy of the focus was made by means of a piece of finely ground glass, placed at the plane of the film.

Every precaution was taken to prevent extraneous light from falling on the face of the tube. A cone-shaped light screen, lined with black felt on the inside to prevent internal reflexions, was fitted between the camera lens mount and the tube screen. A piece of felt was fitted to the P.P.I. end of the screen to act as a light trap.

Because of the curved shape of the P.P.I. tube face, it was not possible to make use of the full radius of the screen for these photographs. Moreover, the use of the outer edge of the image introduces an apparent lack of definition because of the increased arc subtended by the scanner beam, with increasing range.

For this series of photographs, the relative type of display was in use so that extreme care had to be taken to ensure that the ship was not turning while an exposure was being made. With this display, the heading line, which shows the direction of travel of the ship, is always at the top of the tube (*i.e.*, at 0° on the bearing scale) and any change of the vessel's course produces a rotation of the images of the various targets and so causes a blurred image. This drawback could not be overcome in the present instance as no gyro-compass was available to provide the necessary compass correction for a true† display, in which this disadvantage does not occur.

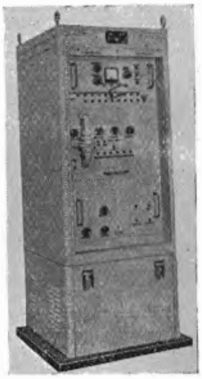


Fig. 1. (*Left*) Transmitter and power supplies

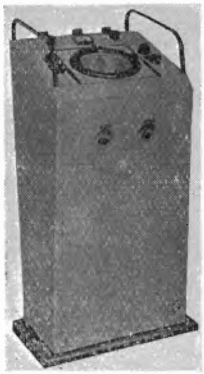


Fig. 2. (*Right*) Plan position indicator (P.P.I.)

The Mosaic

As each photograph, forming part of the mosaic, was taken, some outstanding feature of the image, well ahead of the ship's position, was immediately noted and followed till it was left well astern. By this means, an indication was obtained that the required land distance had been covered before taking the next photograph. This procedure was quite adequate while traversing straight portions of the river, but while negotiating turns extra exposures were made so that adequate coverage was obtained during the turn.

The normal exposure time-sequence was not adhered to for the whole operation, extra exposures being made from time to time to provide good photographs of creeks and inlets which were previously displayed in an inadequate manner owing to the presence of intervening buildings or high ground.

The majority of the photographs were taken on the three mile range-setting of the P.P.I. display, but those off Southend and up to Canvey Island were taken on the six miles setting. The exposures were made during a normal run up-river after returning from the Mediterranean.

The mosaic shown is not highly accurate since it was made without any specialised map-making equipment. Nevertheless, the accuracy is remarkably good when the temporary nature of the arrangement is considered. In future mosaics, it would be possible to add the position of lights and buoys.

Maps have, of course, been made by aircraft using normal photographic methods. In conditions of bad visibility, infra-red photography or airborne radar can be employed for this purpose and, in the latter case, the accuracy is increased when the time base trace velocity is modified to provide the true ground range of each portion of the image as measured from a point directly below the aircraft. The accuracy also increases inversely with wavelength, beam width and the distance travelled by the aircraft during one rotation of the scanner.

† A true display is one in which North is always at 0° on the bearing scale.

Radar Charts

Now that radar is becoming more widely used for marine navigation, mosaics of the type shown can be of inestimable value. The Admiralty has produced charts showing the appearance of radar images which may be compared with those on the P.P.I. The presence of high intervening ground prevents the appearance, on the P.P.I. tube, of images of landmarks behind the high ground. This sometimes make difficult the identification of the ship's position on the chart, particularly when the coastline is not indented. It must be borne in mind that the P.P.I. image is related to that of an imaginary observer at the scanner while a chart is related to an imaginary observer suspended in mid-air directly over the land appearing on the chart. The appearance of the resulting images, therefore, differs considerably and the Admiralty radar charts are designed to assist navigators by providing charts drawn from approximately the same view point as that of the radar scanner. Pilot books and some charts provide sketches showing the appearance of the land as seen from a specified direction but these are useless in foggy weather. The equipment of vessels with accurately-scaled radar charts of busy sea roads and of some of the more important coastlines will certainly assist navigators in their work, in times of poor visibility. These radar charts show points such as Ushant and the South Foreland. The charts shorten the time required for new operators to become accustomed to the interpretation of the images displayed on the P.P.I. tube. Unless a fair knowledge of the possibilities and limitations of radar is possessed by an operator, a certain amount of difficulty is experienced in inter-

(*Continued on p.* 299)

Projective Three-dimensional Displays — Part II

By D. M. MacKAY, B.Sc., A.Inst.P.*

Stereoscopic Displays *(continued)*

NUMEROUS methods have been suggested, the most popular employing orthogonally polarised light to distinguish the two pictures, and some are described in the papers mentioned in Part I. The problem is already a live one in relation to three-dimensional television, and readers interested are referred to the extensive literature which has already appeared on the subject.

From our present point of view the chief problem is that of "aspect-switching," which, of course, arises only when a single tube is used for both pictures. Normally, the rate of switching need not be high—25 c/s. is a reasonable figure—and probably the easiest solution is to use high speed relays.

These can be arranged either to change the X' and Y' connexions from one set of resolvers to another, or (preferably) to alter by small amounts the direction cosines of the line of sight.

The rotation required is about the Y' axis, and corresponds to different admixtures of x' and z'' in the horizontal deflexion. Great accuracy is not essential, and for most purposes an arrangement such as that shown in Fig. 11 is suitable. The relay $B1$ connects a small fraction of z'' alternately to one or other X-plate, giving two lines of sight displaced horizontally by equal angles from the normal to the tube face.

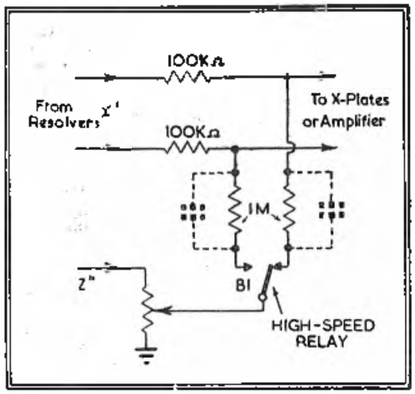


Fig. 11. Stereoscopic switching unit

In practice such an arrangement can be very useful even without stereoscopic facilities, especially if the pattern is fairly "coarsely woven." Generally, however, it would then be advisable to use a much lower switching-rate, to avoid confusion of detail.

Measurement

The whole problem of projective display is greatly eased if the measuring system adopted is a "relative" one, in which any distortion is suffered equally by the subject and the standard by which it is to be measured. Accuracy of projection is then relatively unimportant, and we have been proceeding on that assumption.

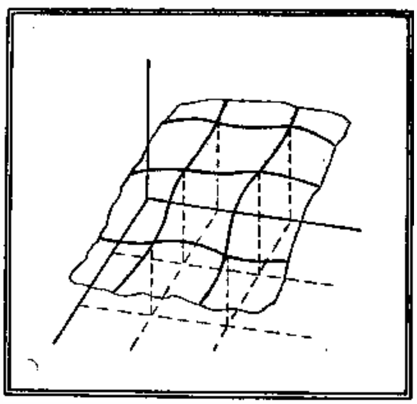


Fig. 12. Electronic grid-lines produced by brightness modulation (see also Fig. 19)

Before dismissing the possibility of direct measurement on the screen, however, we may note that the three "pure" axial views (θ and ϕ = 0° or 90°) are not affected by the accuracy of the resolvers, but only by that of the tube and amplifiers. There may well be cases therefore in which direct measurement will be possible, and sufficiently accurate.

Relative measuring methods using "standard marks" fall roughly into two classes: (a) those in which the standard marks are generated at the instant at which the voltages to be measured have the required value, and (b) those in which the standard marks are generated during a quiescent period and superimposed on the picture in that period. Normally, the first class employs brightness-modulation to denote the standard points, while the second has also to supply standard input voltages to x, y and z terminals during the quiescent interval.

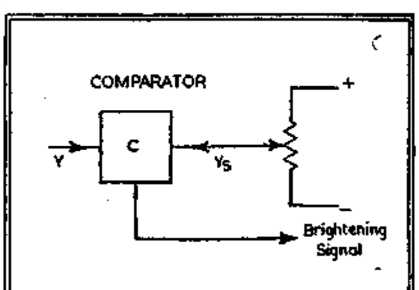


Fig. 13. Basic "standard mark" circuit of class (a)

Where the independent variables x and z vary linearly with time, a particularly simple form of calibration-system is possible, relying on the linearity of the waveforms. The principle is identical with that of the radar range-calibrator,[6] in which a pulse-generator is synchronised with each voltage sweep, and produces a train of pulses equally-spaced along the corresponding time-axis. These are applied as brightening-pulses to the grid of the C.R. tube, superimposed on any other brightening-signals. Now when three dimensions are involved, each pulse along a given axis defines a plane parallel to the other two, and the result is that the trace is brightened whenever it intersects one of the planes so defined. Each pulse therefore is responsible for a bright line on the surface being displayed, representing the intersection of the surface with the plane corresponding to the position of the pulse. With two pulse-generators producing two families of such pulses, along X and Z axes, the result is a mesh of lines covering the surface displayed, defining the intersections of the surface with a rectangular "honeycomb" of co-ordinate planes. (See Fig. 12).

It is a simple matter to make the spacing of the co-ordinate planes

* Wheatstone Physics Laboratory, University of London, King's College.

adjustable, by altering the periodic time of the corresponding pulse-generator. In this way any point can have two co-ordinates accurately assigned to it, if the spacings are adjusted until two lines intersect on it. Knowing the line-numbers and knowing the mesh-interval from the full-scale deflexion, one can easily determine the co-ordinates of the point without any information either on the speed of the timebase or the period of the calibrator.

Measurement of the y co-ordinate is not so simple. One method is to identify our point by two "cross-wires" in the way described, and then measure its height y by selecting a "side view" of the surface, relying on the accuracy of the C.R. tube. Alternatively, we might avoid that uneasy compromise by injecting a calibrated shift-voltage in series with the Y-signal, and measuring the voltage needed to displace the trace by an amount y.

But these are methods in a different class. In order to use our brightness/modulation technique, we should require a circuit which automatically brightened the trace when the voltage y passed through one or more standard values. Such circuits are known,[5] but few are suitable for use down to zero-frequency. The most promising line to follow would seem to be the "gating" of an R.F. signal, since a circuit on that principle would be unperturbed even if required to provide a brightening signal of indefinite duration.

In any case, the basic principle is as illustrated in Fig. 13. The voltage y is balanced against a standard voltage y_s in a comparator circuit C. Whenever y and y_s are equal, or differ by a fixed amount, C sends a "gating" signal to the brightening circuit of the C.R. tube. Thus the displayed surface is now intersected by a plane parallel to X and Z axes, at a height fixed by y_s. By adjusting y_s, as well as the X and Z calibrators, we can thus make three orthogonal planes to intersect in any given point, determining its position completely. In principle, this gating method can be adopted for finding all three co-ordinates of a point; and indeed many cases arise in which, owing to non-linearity of x and z with time, the pulse-calibration technique is useless. The main advantage of the latter, however, lies in the number of reference-lines which it gives simultaneously, and it becomes difficult and cumbrous for a gating method to compete with it in that respect. Class (b) methods are preferable in such cases.

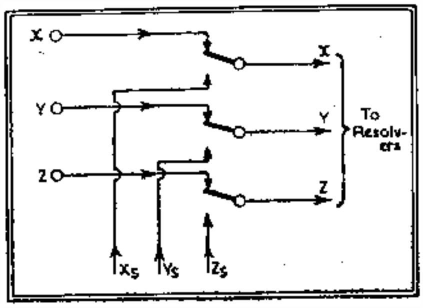


Fig. 14. Simple "standard mark" circuit of class (b)

One of the simplest class (b) methods of co-ordinate measurement is also one of the most accurate, for it eliminates practically all sources of error by making direct connexion between the x, y and z terminals and three standard voltages. The arrangement is shown in Fig. 14 as an attachment inserted in the leads to the x, y and z terminals of Fig. 5. Three high-speed relays are pulsed, during a quiescent period of each cycle, so that the inputs are momentarily given values x_s, y_s, z_s, which are under the control of potentiometers, and can be measured accurately.

The trace is normally blacked-out during the quiescent period, but is momentarily brightened, after all relays have had time to close, by a pulse from the relay-driving circuit The result is a "standard spot" (with three degrees of freedom) which can be moved into coincidence with any selected point, checked for parallax under rotation, and then identified in position from the values of x_s, y_s and z_s.

More complicated, but quite feasible, is the possibility of using the quiescent period to lay down a complete three-dimensional gridwork, obtained in the fashion indicated previously with the aid of three auxiliary timebase-generators, connected in place of x_s, etc., in Fig. 14. This would make it possible to assign three co-ordinates immediately to any point in the display.

Finally, let us consider briefly two possibilities which can be described as "concurrent" calibration methods. The first is simply to use a double-beam tube, with one beam continually engaged in drawing axes and reference lines. This is pictorially convenient, but is not particularly accurate. The beams must, of course, have separate deflecting systems.

The second has much to recommend it, in cases in which D.C. amplification has been retained in the rotation-networks. It involves injecting, in series with x, y and z, three steady standard voltages x_s, y_s and z_s, which displace the origin of the picture.

We might think that this is of little help in a "general view" unless we remember that the *axes of rotation* go through the origin. If therefore we arrange to "rock" the picture continuously about the axes of rotation, it is possible to see at once which point in the picture stays at rest.

Suppose now that we wish to measure the co-ordinates of a certain point in the picture. We set our "rocking" mechanism in operation at a fairly high speed. The point becomes a moving blur, which we find that we can bring to a position of rest by applying shift voltages x_s, y_s, z_s in series with the inputs x, y, z. In this position, clearly, $x+x_s=y+y_s=z+z_s=0$, so that the co-ordinates of the point are $(-x_s, -y_s, -z_s)$.

The rocking can conveniently be done by means of relays or commutators on the principle already discussed.

Accessory Circuits

The applications of this type of display are so many and varied that it would be impossible to describe a drive unit suitable for all purposes. It may be of interest, however, to discuss briefly the design of a simple general-purpose unit.

The circuits necessary are quite standard in type,* but will vary according to the application, so that only block-schematic diagrams are shown, and the various frequencies and magnitudes are chosen only as illustrations. Fig. 15 shows one possible arrangement suitable for use with the transformation-circuit of Fig. 5. It generates two sawtooth voltages v_1 and v_2, which are locked in the frequency-ratio of 100:1. v_1 is a normal sawtooth, but v_2 has a "waiting period" between each linear sweep, during which any relays or re-setting devices used can operate.

Much of the complexity is due to the various calibrating pulses which are provided. These could be re-

* Many examples will be found in reference 5, or back numbers of *Electronic Engineering*.

garded as luxuries and omitted if desired, though the lines they produce will often be found useful for guiding the eye over a complicated surface, quite apart from their normal function.

Base Circuit

The waveforms produced are shown in Fig. 16, and are all synchronised, though not shown to scale. The "master-oscillator" is a 25 Kc/s. blocking-oscillator BO_1, generating positive pulses (a) of 2 µsec. duration across an impedance of about 2,000 ohms. These pulses are used to brighten the trace and to synchronise the time-base generator TB_1, running at 2.5 Kc/s. (b). If coupling is tight enough, the 25 Kc/s. rate can be altered for calibration purposes without seriously affecting the frequency or amplitude of the 2.5 Kc/s. sweep. The latter will "lock" on the pulse nearest to the instant at which it would fire when running freely.

BO_2 is synchronised by TB_1 so as to generate one pulse (c) in approximately every eight to ten sweeps. Each pulse lasts for the duration of one sweep of TB_1. Thus just one complete line is brightened by each pulse. Finally BO_2 synchronises the 25 c/s. time-base generator TB_2. For calibration purposes the frequency of either BO_2 or TB_2 can be varied, though it is preferable on most counts to adjust BO_2.

The waveform of v_2 is illustrated at (*d*). A waiting-period τ_r is provided between sweeps to give time for any relay-circuits to operate.

Relays may be driven by the over-biased amplifier valve *A*, controlled by the differentiated version (*e*) of the output of TB_2. The anode of *A* passes current to the relays for only about one-half of τ_r. The remainder of τ_r is left blank to enable any "chatter" in the relays to die away. For the same reason, the trace is not brightened until the relays are just about to open. This is most easily ensured by deriving the brightening pulse (*g*) from the trailing edge of the anode-voltage pulse (*f*), via a blocking-oscillator, BO_3.

Brightening Circuit

The grid of the C.R. tube has a great deal of work to do, and the mixing of the various brightening voltages must be carefully done to ensure the right order of priority.

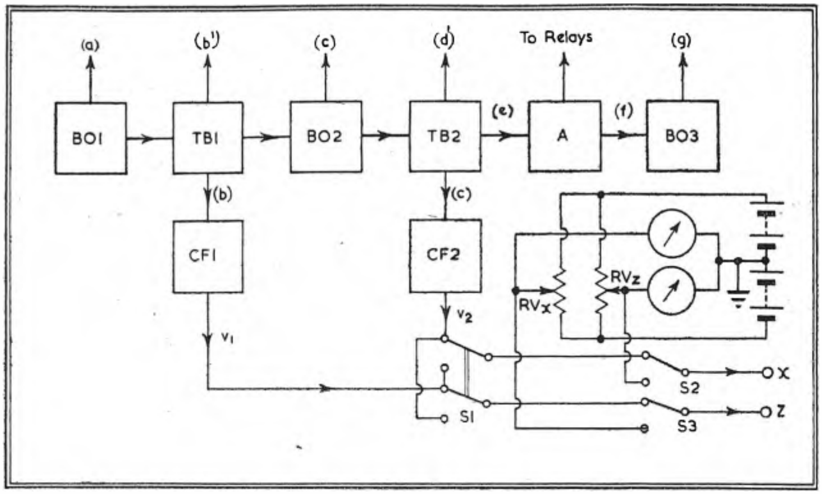


Fig. 15 (*above*). A general-purpose drive unit

Fig. 16 (*below*). Waveforms in the circuit of Fig. 15

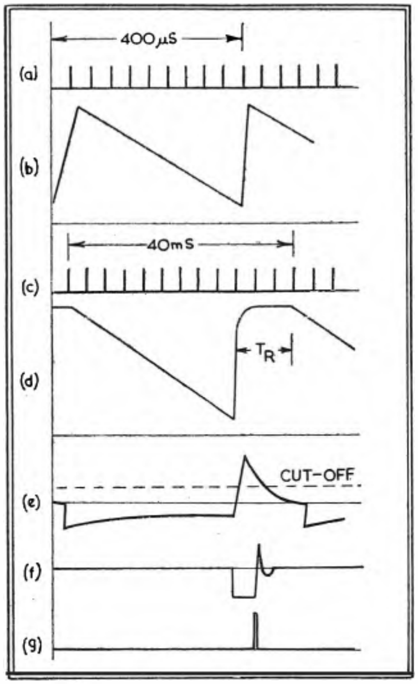
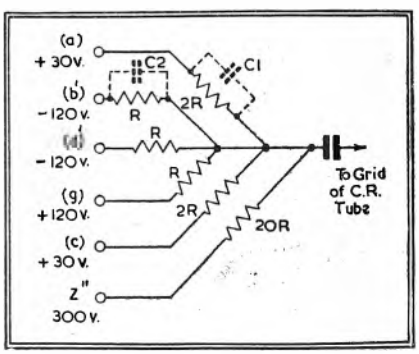


Fig. 17 (*below*). Simplest type of pulse-mixing circuit for brightness modulation



The trace must be:

(i) suppressed during τ_r, but

(ii) brightened momentarily by pulse (*g*);

(iii) brightened by pulses (*a*) and

(iv) brightened by pulses (*c*), but

(v) suppressed during the flyback of v_1;

(vi) modulated by the "perspective voltage" *z*".

Of these, (ii) must be over riding, and (i) and (v) have priority over the rest, which are more or less on equal footing. The simplest way to ensure these priorities is to adjust the relative amplitudes of the various pulses, which can be mixed in quite a conventional way. Fig. 17 shows the simplest possible mixing circuit, with typical values for the amplitudes of the pulses. (*b'*) and (*d'*) are negative blackout pulses derived in the usual way from the time-base generators TB_1 and TB_2. In a self-running Miller time-base, for example, the screen-grid waveform is suitable, if "trimmed" by a limiting diode. The proportions of the mixing resistances should ensure (i) that the pulse (*g*) from the blocking-oscillator over-rides (*d'*), it is made long enough to outlast (*b'*); (ii) that (*b'*) and (*d'*) each develop pulses of −30 V at the grid of the tube; (iii) that (*a*) and (*c*) each develop about +4 volts; and (iv) that the perspective voltage *z*" is able to vary the grid voltage by about 4 volts.

These values are suitable for a small C.R. tube running at a gun voltage of about 2 KV. If the cut-off voltage of the tube is greater than −45 V or so, it may be necessary to amplify the pulses either before or after mixing.

To improve the sharpness of the shorter pulses, the by-pass capacitors C_1 and C_2 are useful. They need only be of a few pF each, and can conveniently take the form of adjustable trimmers. They should be set to the minimum values found necessary to give clean blackout—and calibration—pulses. The lead to the C.R. tube grid must, of course, be as short as possible.

More elegant (and complicated) mixing circuits could be designed to be less affected by stray capacitances, etc.; but the author has found the simple circuits to be quite satisfactory for the unexacting purposes of brightness-modulation—if something in the nature of intelligent "cutting-and-trying" can be tolerated!

Perspective

Quite a good impression of depth can be given by the "perspective shading" controlled by z''. The extra trouble needed to add "perspective convergence" seems scarcely worthwhile, for the circuit of Fig. 10(c) cannot very conveniently be used here, while that of Fig. 10(a) is liable to cause some astigmatism. If convergence is also required, however, probably the easiest solution is to use pulse transformers for the series-injection of brightening pulses, as shown, for example in Fig. 18. The pulses should be mixed in at least two separate groups according to duration; quite different types of pulse-transformer are required to deal with the different durations.

Operational Features

Much of the usefulness of a general-purpose unit of this sort depends on the "minor details" of design. It may perhaps be helpful to mention some of those which can be incorporated with a minimum of trouble. Some are indicated on the block diagram of Fig. 15.

(a) *x and z Controls.*

Cathode-followers CF_1 and CF_2 help to prevent interaction between the rotation controls and the time-base-generators. Their outputs v_1 and v_2 can be interchanged at will by means of switch S_1, making it possible to compare the effects of fast and slow sweeps of x or z. It is also useful to be able to stop x

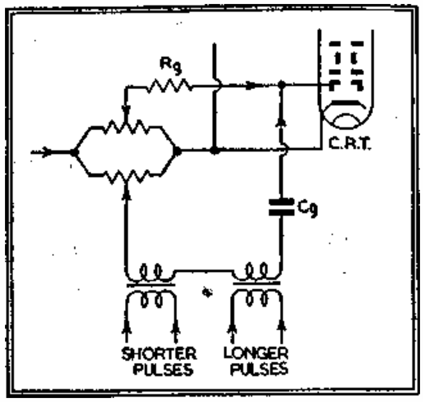


Fig. 18. Modification of Fig. 10 (c) to enable calibration marks to be superimposed on perspective modulation

and/or z from sweeping, and give them fixed values, under the control of potentiometers RV_x and RV_z. S_2 and S_3 are independent switches for this purpose.

(b) *Calibrator Controls.*

The line-spacing controls have been mentioned already, they may take the form of variable grid-leaks in the blocking oscillators. As a luxury, brightness-controls for the calibration lines could also be provided, by making the mixing-resistances variable.

(c) *Meters.*

It is desirable to incorporate at least one high-resistance centre-zero voltmeter. For accurate work each circuit should have its own meter permanently connected, to avoid errors due to the meter-current.

Applications

Electronic Computation

The author's apparatus was designed primarily as an aid in the solution of differential equations by analogue methods. It is often necessary to search systematically for a graphical solution of given type, by varying initial conditions or coefficients in an equation and observing the results. The apparatus makes it possible to display whole families of trial solutions as a series of graphs lying side-by-side and defining a "solution-surface." Much tedium is thus avoided, and *trends** in solutions can be detected at an early stage—a valuable addition to the intuitive qualities which guide a mathematician to a quick solution. When the correct values are approximately determined, the searching can be stopped, and accurate adjustments carried out by hand.

* Note for example how easily the trend towards secondary emission can be followed in Fig. 19.

Valve Characteristics

Of more general interest is the application to problems such as the display of valve-characteristics. The illustrations in Fig. 4 and Fig. 19 (see p.252 and 253 of the July issue) will give some idea of what can be done with simple equipment. They are actually photographs of a display demonstrated at the recent Physical Society Exhibition, and do not by any means represent the best that is possible under laboratory conditions.

The surfaces shown in Fig. 19 represents five stages in the growth of a secondary-emission "valley," in the anode current/grid voltage/screen voltage characteristic of a tetrode. As the anode voltage is increased, the surface can be seen to change progressively from (*a*) to (*e*), the valley deepening and gradually moving off the picture in the direction of higher screen voltage, until at (*e*) the y-amplifier is saturated. It is important to note that the surface is transparent: the valley in (*c*) can be seen quite plainly through the shoulder of the curve.

Current Measurement

Anode current was here measured by amplifying the P.D. across a small anode load resistance. 1 KΩ is small enough to have negligible effect on anode voltage, if only "demonstration accuracy" is required. For more general purposes, however, it may be necessary to display the current drawn by an electrode, as a function of its own potential, and the simple load-resistance circuit cannot be used. Probably one of the best solutions is to use a current transformer (with a satisfactory frequency response). See Fig. 20(*a*). The load-resistance on the secondary, as seen from the primary, should not exceed a few hundred ohms, except perhaps in the case of grid-current measurement. The damping which the load produces can help to secure a level frequency-response in the transformer.

Another method is to supply the sweep-voltage through a transformer, and insert a small current-monitoring resistance in the earthy lead to the secondary. (Fig. 20(*b*)). Both methods have their disadvantages. The second will generally require a larger transformer, but the latter's frequency-response need not be so wide, since it has only to handle the frequency-components of one sawtooth; the current in the first case generally will contain frequency-components corresponding to both modulating voltages.

Brightness-modulation

The much-overworked grid of the C.R. tube can be pressed into yet further service. "Qualitative facts" such as the presence of grid-current, or of anode-dissipation exceeding a critical value, can easily be represented by a brightening or darkening of the trace in the appropriate region. Thus a Class A power-amplifying valve, for example, could be made automatically to display its characteristic only between the limits set by grid-current and anode-dissipation.

This is an equally valuable facility in other fields of application. For instance, the values of parameters x, y and z which together satisfy a given condition in a differential equation can be defined by a brightened locus in a volume scanned in the three directions x, y and z.

Other Applications

Only brief mention need be made of some of the many other possible uses of this technique. A number are suggested in the references quoted, including items as varied as the display of fine detail of metal surfaces, complex impedance-characteristics, frequency-response-curves as a function of a coupling factor, and X-ray "pictures-in-depth." In spectroscopy, to take just one other example, photo-electric scanning is becoming common, and can be made to yield multi-dimensional information—for example on the change in a spectrum with time. Reference has already been made to the revolution which has been wrought in the technique of radar display.

In some of these applications the detail may well be too great to be shown usefully on one tube. This represents an especial danger in teaching work. In such cases it is better to have two tubes, one giving a "coarse" overall picture, and the other an expanded view of any selected portion of the coarse display. In all cases there is the problem of making the cycles recur rapidly enough for persistence of vision, though afterglow screens can help to lower the minimum frequency. These also make it easier to have electro-mechanically varied quantities (e.g. capacitances or coupling-factors) as independent variables.

In teaching, the uses of a three-dimensional "blackboard" are manifold, and are not confined to Physics and Engineering. The entertainment value which it could add to lectures on such "solid fare" as three-dimensional geometry, for example, makes one almost envious of the student of the future.

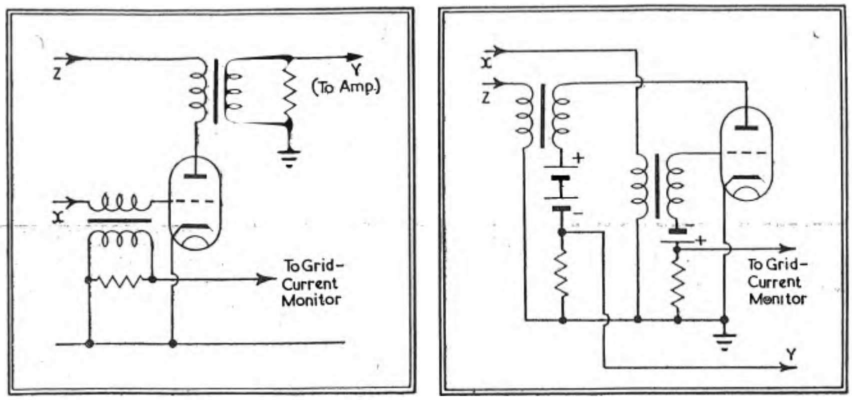


Fig. 20 (a) Fig. 20 (b)

Two methods of measuring anode and grid current

Conclusion

The reader will have realised that the subject-matter of these articles represents a deliberately restricted choice. Nevertheless it must be said now that the omission of all mention of *television* has been intentional. Most people instinctively think of television when three-dimensional displays are mentioned, not realising perhaps that the aim of a normal projective three-dimensional display is to produce just the type of picture which television already produces perfectly successfully—a two-dimensional representation of a three-dimensional object. The problems of presenting such a display with television data in suitable form would be very great, and the transparency of the picture already noted would normally be a serious embarrassment.

The goal of "truly three-dimensional" displays is common to both techniques, and these projective methods merely bring the art of curve-drawing up to the level already reached by that of picture-reproduction.

Acknowledgments

Although the author's apparatus differs, in the methods adopted in its applications, from the three-dimensional radar displays developed at A.S.R.E. (Whitley) during the war, it is a pleasure to return thanks for the inspiration derived from former colleagues engaged on that work, particularly Mr. Eric Parker.

In construction of the apparatus at King's College the competent assistance of Messrs. S. Cranston, K. Meyer and C. Yhap is also gratefully acknowledged.

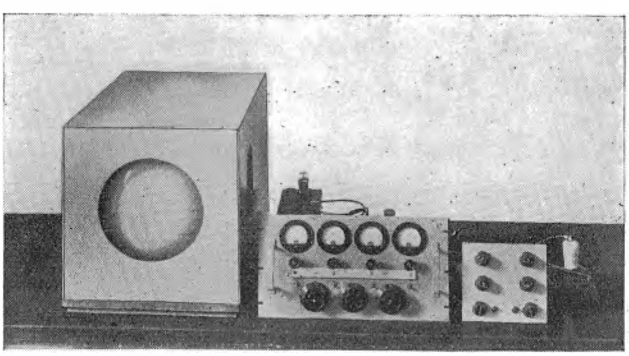


Fig. 20. Demonstration apparatus used to give tetrode characteristics of Figs. 4 and 19

Reference

[5] See, for example, *I. E. Radar Convention Papers* 1946.

(*Further illustrations are shown over the page*)

MACKAY . . . PROJECTIVE THREE-DIMENSIONAL DISPLAYS

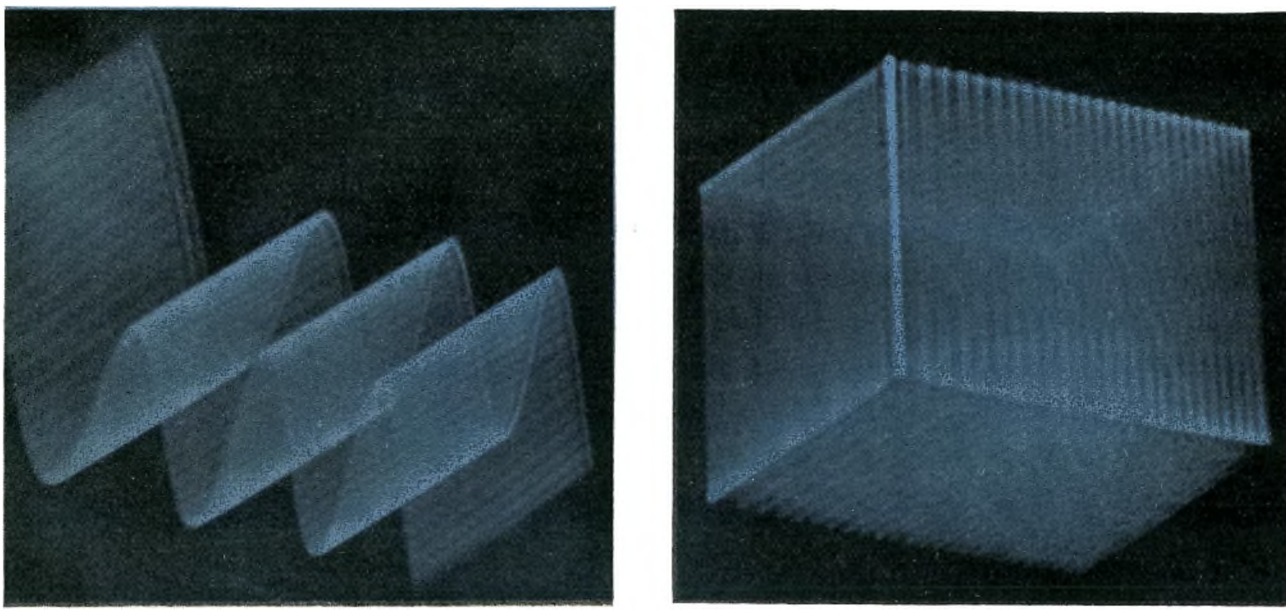
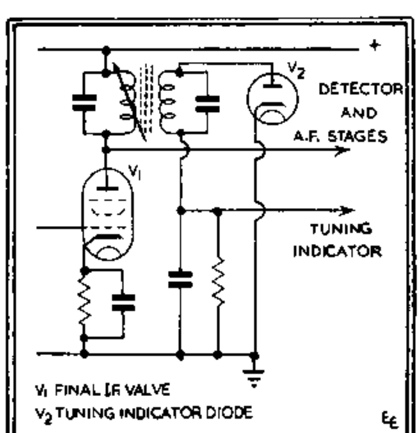


Fig. 21. Some more typical patterns produced on a projective display

Tuning Indicators in High-Quality Receivers

A DIFFICULTY associated with high-quality radio receivers is the accurate indication of correct tuning. The problem arises when the I.F. tuned circuits have broad band (double humped) characteristics so that they may pass the higher audio frequency sidebands without attenuation. This means that a tuning indicator fed from these circuits will give a steady indication throughout the pass-band and will not show when the tuning is at the mid-frequency.

The difficulty may be overcome by including an additional sharply-tuned circuit immediately preceding the tuning indicator so that it will give a sharp response at the middle of the band, and thus show when the receiver is correctly tuned. The Figure, which indicates the final I.F. stage of the receiver, illustrates a practical method of doing this. The signal detector and A.F. stages are fed from the primary of the I.F. transformer in the anode circuit of this stage, while the loosely-coupled and lightly-damped tuned secondary winding provides the additional selectivity required for accurate indication of tuning.



Sharply-tuned circuit fed from last I.F. stage for tuning indication

If a transformer-coupling is considered desirable for feeding the I.F. waveform to the signal detector, a third loosely-coupled winding may be employed to control the tuning indicator.

—*Communication from E.M.I., Ltd.*

The Physics of Cathode Ray Tube Screens

By G. F. J. Garlick, B.Sc., Ph.D., A.Inst.P.*

THERE is no doubt that the function of the cathode ray tube screen is of paramount importance in any application of such tubes. However, it is not always appreciated that the present day standards of screen performance have depended on an extensive background of more basic research on the luminescent substances employed. We shall therefore be concerned with such research in the present instance. We shall describe the physical characteristics of the screen materials and also discuss the theoretical concepts of the processes involved. As a preliminary step we may summarise the general practical requirements of the cathode ray tube screen:—

(a) The screen must have a high efficiency for the conversion of cathode ray beam energy to light energy. In practice efficiencies greater than 10 per cent are not often attained.

(b) The spectral emission characteristics must be suitable. For television a white emitting screen is desirable. In most other applications colour is not of the same importance.

(c) The screen must possess a suitable degree of phosphorescence. In television applications the maximum permissible duration of phosphorescence is of the order of milliseconds but in some radar applications durations of many seconds are required. The form of the phosphorescence decay with time is also important.

(d) The screen must have good electrical characteristics. In particular it must exhibit adequate secondary electron emission under the given operating conditions.

(e) The screen material must be stable during the processing of the tube, and during its operational lifetime.

These requirements severely limit the choice of materials and it is impossible, at present, to satisfy all of them in one screen material. In the next section we give a brief account of the types of luminescent material suitable for use as cathode ray tube screens.

Classes of Screen Materials

The microcrystalline luminescent powders used for cathode ray tube screens are usually known as *phosphors.* They are prepared from carefully purified basic constituents and this preparation always involves synthesis of these components by heat treatment at high temperatures (900-1300°C). In most cases the luminescence characteristics are largely determined by the inclusion of small amounts of specific metallic impurities in the host substance during preparation. The heat treatment then not only forms the crystal lattice of the *phosphor* but enables the impurity, usually known as the *activator,* to diffuse throughout the crystal grains. Sometimes these processes are assisted by including a few per cent of a suitable flux material. As examples, silver, copper and manganese impurities in zinc sulphide produce blue, green and yellow-orange emitting phosphors respectively. In these phosphors alkali halides (exclusive of fluorides) can function as fluxes.

In some cases heat treatment of the pure materials alone produces good phosphors. Tungstates of calcium, magnesium, cadmium, zinc, etc., are examples of this class of phosphor. Table I (overleaf) gives in summarised form the various classes of phosphors used as cathode ray tube screens and their general characteristics:—

In Fig. 1 the emission spectra of several different zinc sulphide phosphors and a zinc oxide phosphor are given for cathode ray excitation, while Fig. 2 gives the spectra for silicate and tungstate phosphors. In Fig. 3 we give spectra for the two components of a white emitting television screen and the composite spectrum which gives a white appearance to the viewer. Screens formed by mechanical mixtures of two or more different phosphors giv-

* Physics Dept., University of Birmingham.

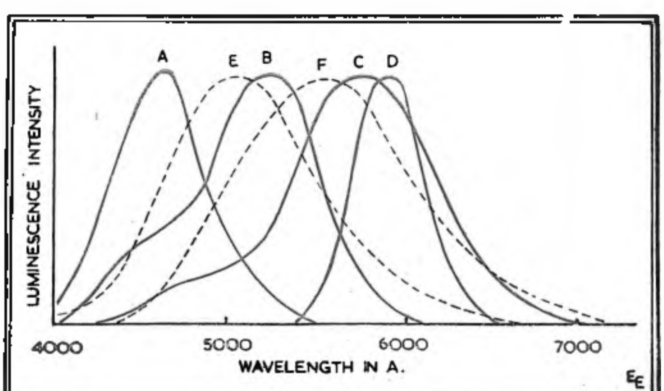


Fig. 1. Emission spectra of ZnS and ZnO phosphor screens. A. ZnS-Ag B. ZnS-Cu C. ZnS-CdS (40%)-Ag D. ZnS-Mn E. ZnO F. ZnS-ZnSe (40%)-Ag

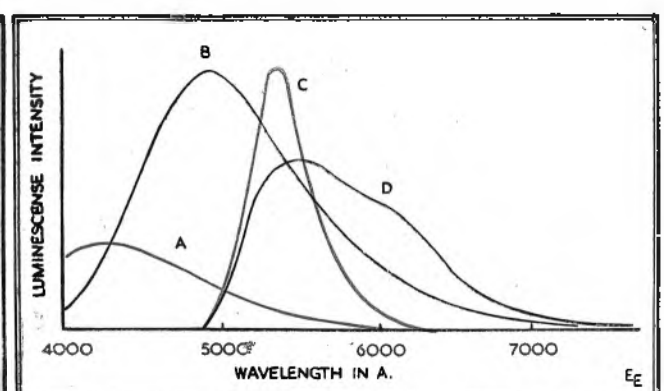


Fig. 2. Emission spectra of silicate and tungstate phosphor screens. A. $CaWO$ B. $MgWO_4$, $CdWO_4$ or $ZnWO_4$ C. Zn_2SiO_4-Mn D. $ZnBeSiO_4$-Mn (7 mol% BeO)

Table I

Phosphor	Activators	Emission	Phosphorescence	Type of decay	Application
ZnO.	None	Green	~1μsec.	Exponential	Television film scanning
ZnS.	Ag.	Blue	Up to a few secs.	Hyperbolic	Television and Radar
	Cu.	Green	Up to hours	Hyperbolic	Television and Radar
	Mn.	Orange	Up to a few secs.	Initially exponential later hyperbolic	—
ZnS-CdS.	Cu or Ag.	Blue to red acc. to CdS%	Dependent on CdS%	Hyperbolic	
ZnS-ZnSe	Cu or Ag.	Can be near white	~μ sec.	Hyperbolic	Television
Zn_2SiO_4	Mn.	Green	~10m. secs.	Exponential	Monitoring and radar projection television
$ZnBeSio_4$	Mn.	Green to red acc. to Be%	~m. sec.	Exponential	Television before 1940
$CaWO_4$	—	Blue	~3 μ sec.	Exponential	Not used much now
$MgWO_4$	—	—	,,	,,	,, ,,
$ZnWO_4$	—	Near white	,,	,,	,, ,,
$CdWO_4$	—	—	,,	Exponential	,, ,,
ZnF_2	Mn.	Yellow	100 m. sec.	Exponential	Radar
MgF_2	Mn.	Orange	100 m. sec.	Exponential	Radar

ing approximately white emission suffer from the following disadvantages:—

(a) If the different phosphors have different grain sizes, then in deposition the smaller grain size phosphor settles in a different layer from a large grain size specimen. This introduces different excitation conditions for the different phosphors.

(b) There may be colour changes in the television image if one phosphor emission changes in a different way with modulation density from that of another phosphor.

(c) If the component phosphors have different degrees of afterglow then trailing colour effects may occur behind images of moving objects.

The desirable screen is thus one composed of a single material, but this is difficult to realise in practice. Some success has been achieved with zinc sulpho-selenide phosphors in recent years. We now consider some of the physical characteristics of conventional phosphor screens.

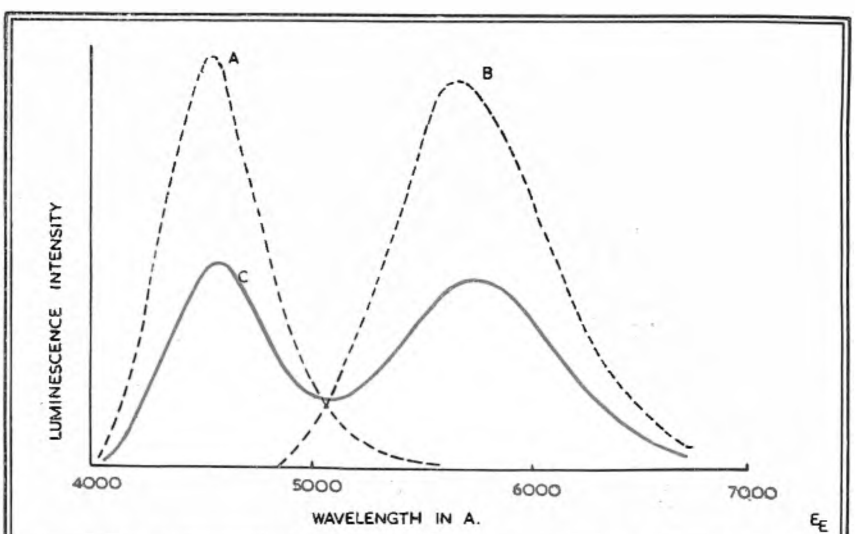


Fig. 3. Emission spectra of phosphor components of a " white " television screen
A, ZnS-Ag B, ZnS-CdS-Ag C, Composite spectrum for " white " emission

Dependence of Luminescence on Cathode ray beam density and energy

(a) *Variation of luminescence with beam current density.*

At sufficiently low beam current densities the luminescence of conventional phosphor screens is proportional to the current density, but at higher densities saturation effects may occur. Zinc sulphide phosphors, such as ZnS-Ag and ZnS-Cu, do not show saturation until densities of 100 μa/cm.² are reached, but zinc silicate phosphors begin to show saturation at densities as low as 10 μa/cm². At higher operating voltages and current densities, such as obtain for projection cathode ray tubes, the behaviours of these two classes of phosphor are reversed. In Fig. 4 the current saturation effect for a zinc silicate phosphor is given for two different tube potentials (4 KV and 10 KV). The curve B may be fitted to curve A if its ordinates are multiplied by a suitable factor. This indicates that current saturation effects are independent of the tube voltage. These results and other were obtained by Strange & Henderson (1946) and indicate that the lack of dependence of current saturation on tube voltage is a usual feature for conventional screen materials.

(b) *Variation of luminescence with cathode-ray beam energy, or cathode-screen potential.*

A power relation is found between the luminescence emission of a screen and the energy of the electron beam producing it (measured as cathode-screen potential). This may be expressed by the following empirical formula:—

$$L = \text{constant.}\ (V - V_o)^q \quad \ldots\ldots (1)$$

where L is the luminescence output for a given current density, V is the screen-cathode potential, V_o is a potential known as the " dead " voltage of the screen and q is a constand for a given screen. If the screen is carefully processed and free from contamination, in the form of absorbed surface layers of other materials, then it has been shown that the " dead " voltage is negligible. Thus for clean phosphor screens and over certain ranges of potential the luminescence is proportional to the qth power of the cathode-screen potential. This relation breaks down when the potential is increased beyond that at which secondary emission becomes inadequate to prevent negative charging of the screen (known as the " sticking " potential). We thus see that the luminescence efficiency (i.e., luminescence output per unit input power V.i. where i is the current density) increases as the (q-1)th power of the tube voltage. In Fig. 5 we give the luminescence *vs.* cathode-screen potential characteristics of different phosphors showing the validity of Equation (1) above. The curves A and B of this figure show that the power index q

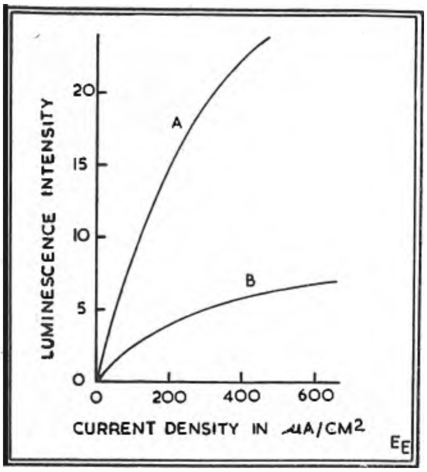


Fig. 4. Variation of luminescence of Zn_2SiO_4-Mn phosphor screen with beam current density. A, Tube voltage 10KV. B, tube voltage 4KV

is independent of current density. Its value depends on the particular screen material but it usually lies between one and two. The increase in efficiency with tube voltage is obviously of considerable practical importance. As we shall see later, it may be explained by the increased penetration of the primary electron beam into the phosphor grains as the electron energy is increased.

(c) *The efficiency of energy conversion in luminescent screens.*

Although the luminescence efficiency of a screen increases with tube voltage it reaches a limiting value. At this value only about 10 per cent of the energy appears as luminescence. Most of the remaining 90 per cent is dissipated as heat in the screen. In the surface layers of phosphor grains the probability of luminescence being excited will be relatively low, since in these regions the crystal structure is very distorted and this perturbs the impurity atom centres which normally give rise to the emission. As the primary electron energy increases luminescence is produced at greater depths below the grain surfaces and here the probability of excitation is higher. However, even in this case, the efficiency value of 10 per cent leads us to assume that non-radiative processes predominate over luminescence processes. Precise information about these non-radiative processes will be more likely to be obtained by exciting large optically polished single crystals of phosphors than by using conventional screens having very complex surface conditions. Such experiments are being planned in the author's laboratory. Preliminary studies indicate that for single crystals of blue luminescent alkali halides the index q of Equation 1 is unity at all except very low electron energies (tube potentials below 1 KV).

The Phosphorescence of Cathode ray Tube Screens

Phosphors may be divided into two main classes with respect to their phosphorescence characteristics after cathode ray excitation. The first class comprises phosphors whose emission decays exponentially with time and at a rate that is independent of excitation conditions (i.e., nature and intensity of the exciting radiation) and of temperature. Phosphors of this type are indicated in Table I and their mean decay times given. These range from a microsecond or so for tungstates to one tenth of a second for some phosphors. Phosphors of the second class exhibit a hyperbolic decay of emission with time and one which is markedly dependent on the excitation conditions and on the temperature. The long persistence phosphors used as screens in radar cathode ray tubes belong to this class. In these phosphors phosphorescence is due to the storage of excited electrons in thermally metastable energy states, known as electron traps. Change of excitation conditions and of temperature alter both the life times of trapped electrons and the number of trapped electrons. As an example of this type of decay we give in Fig. 6 its form for a copper activated zinc sulphide phosphor after excitation by cathode rays (6 KV) and after excitation by ultra-violet light of 3650A wavelength, the initial intensity of luminescence reached before decay being the same in both cases. It is evident that after cathode ray excitation the initial decay of emission is much more rapid than that after excitation by ultra violet radiation and the later stages of phosphorescence are of correspondingly less intensity. The difference largely arises from the smaller volume of phosphor excited by cathode rays which causes the filling of many more "shallow" electron traps than "deep" ones. For a detailed explanation of these effects see (b) of general references.

The Secondary Electron Emission of Phosphor Screens

If a phosphor screen is not to charge up by bombardment with electrons, and thus to repel further electrons, then it must emit one secondary electron for each primary electron absorbed. If we denote by η the ratio of secondary electron emission current to primary electron current then the condition for the efficient electrical behaviour of the screen is that η is greater than, or equal to, unity. In Fig. 7 we give the way in which η varies with primary cathode ray voltage for a

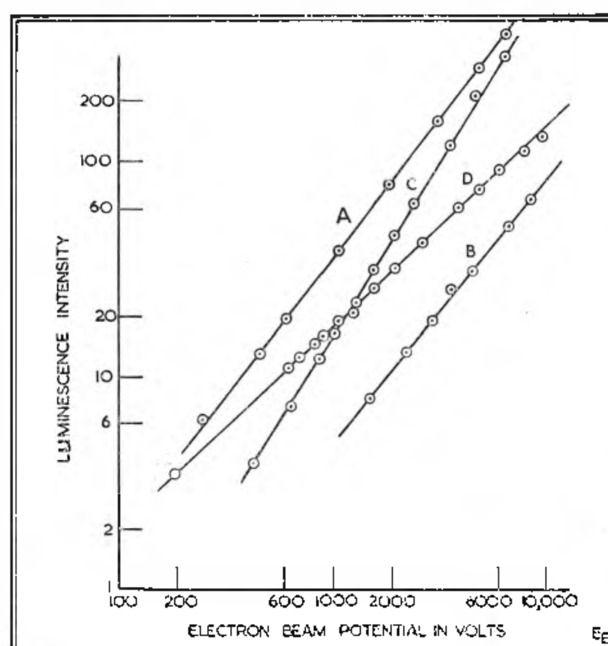


Fig. 5. Variation of luminescence with cathode ray beam energy (cathode-screen potential) for different phosphors.
A, ZnS-Ag (10μA/cm)
B, ZnS-Ag (550μA/cm²)
C. Zn_2SiO_4-Mn (5μA/cm)
D, ZnS-Mn (10μA/cm²)

typical metal and for a phosphor or other similar insulator. We notice that the general characteristics are the same for metals and insulators but that the orders of magnitude of the critical voltages at which $\eta = 1$ are different for metals and insulators. We can give a qualitative explanation of these behaviours and also point out the complex conditions which hold for phosphor screens.

When a primary electron penetrates into a substance it loses its energy by the production of secondary electrons. The secondary electron emission is then dependent on the ability of the secondary electrons so produced to reach and leave the surface of the material; the probability of their reaching the surface depends on their mean free path in the material, which depends on their energy. When the primary electron energy is small few secondary electrons are produced and even fewer will have the chance of reaching a surface. Thus at low cathode ray energies the secondary emission is too small to prevent a phosphor screen from acquiring a negative charge. At higher primary electron energies the secondary emission becomes adequate. It reaches a higher maximum and at higher voltages for insulators than for metals. This we must attribute to the difference in mean free path in the two cases. In metals, secondary electrons of 5 or 10 eV energy will make collisions with other electrons forming the "electron gas" of the metal and their free path is of the order of 10^{-6} cm. However, in insulators electrons of the same energy are likely to have mean free paths larger by an order of magnitude than those in metals because of the absence of an electron gas and because with such energy (i.e., greater than thermal electron energies 1/40 eV) their interaction with crystal lattice atoms is very small.

At higher voltages secondary electron emission again becomes inadequate because the secondary electrons are produced at depths below the surface greater than their mean free paths. The limiting or "sticking" potential is different for different phosphors and determines the useful range of operating voltages for tubes with particular screens. We shall describe recent developments which overcome the disadvantages of poor secondary emission from phosphors at high operating voltages.

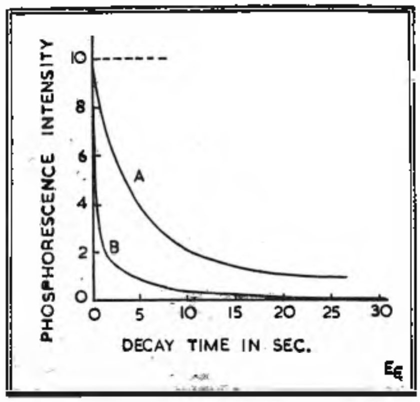


Fig. 6. Decay of phosphorescence of a ZnS-CdS after excitation by ultra-violet light and by cathode rays to the same initial brightness. A, U.V. excitation (3650A). B, Cathode ray excitation (6KV)

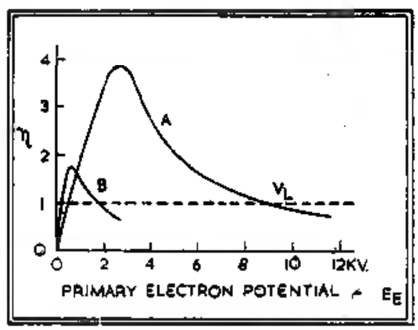


Fig. 7. Secondary electron emission characteristics of insulators (inclusive of phosphors) and metals. A, Insulator B, Metal

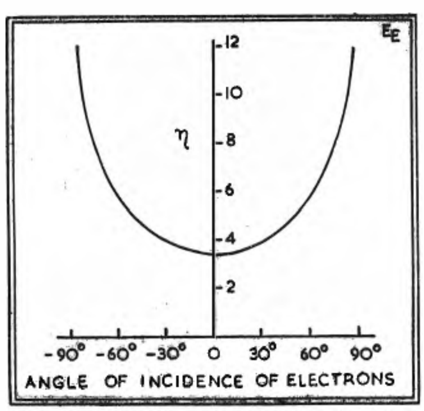


Fig. 8. Variation of Secondary electron emission ratio η with angle of incidence of primary cathode ray beam

The secondary emission from a surface depends markedly on the angle of incidence of the primary electrons, as shown by Fig. 8, since this determines the depth below the surface at which electrons are produced. For glancing angles of incidence the ratio can reach very high values. Since a phosphor screen is composed of crystal grains with faces orientated at all angles to the incident electrons we see the difficulty of making fundamental deductions from secondary emission measurements on such systems. What are needed, both here and for the study of the variation luminescence with electron penetration as discussed, are experimental studies using large single crystals of suitable luminescent materials.

The Stability of Phosphor Screens

Phosphor screens in cathode ray tubes lose their luminescence efficiency with use, but this deterioration varies with the particular screen material. We shall first discuss the effects of electron bombardment and then mention the effects of heavier particles (ions).

(a) *Effects of electron bombardment at normal voltages.*

We often notice at low tube voltages that the luminescence efficiency of those areas of a monitor cathode ray tube screen which are frequently scanned decreases and that a visible darkening of the screen material occurs. These effects are most common for the green zinc silicate screens used in such tubes and at tube voltages of about 1 KV. This deterioration is often loosely termed "electron burn." "Electron burn," for a given exposure to electron excitation, decreases as the cathode ray tube voltage is raised. Qualitatively this is explained by the increased primary electron penetration and the corresponding decrease in volume density of excitation. The detailed nature of the "burning" process is still obscure but the final result is the formation of colloidal metal in the screen. Electrons bombarding most insulators behave as reducing agents but at low voltages their effects appear to be greatest in phosphors having manganese as activating impurity in concentrations of about 1 per cent. Copper and silver activated zinc sulphides or sulpho-selenides seem much less prone to electron burn at ordinary cathode ray tube voltages.

(b) *Deterioration of cathode ray tube screens at high operating voltages.*

At tube voltages, such as those used for projection television, the electron beam has a marked destructive effect on the phosphor screen, but, in contrast to their behaviour at ordinary voltages (0 - 10 KV), the sulphide screens are much less stable than silicate or oxide screens.

Again, prolonged bombardment causes a chemical reduction of the screen material. When we remember that about 90 per cent of the bombardment electron energy is thermally dissipated in the screen we see that an electron beam of a fraction of a millimetre diameter, of energy 25 KV and of current 2 or 3 mA, will provide enough energy for considerable thermal destruction of the phosphor screen.

(c) *Effect of electron burn on secondary electron emission.*

It has been found that electron burn of phosphor screens adversely affects their secondary electron emission by reducing the ratio η and also the sticking potential. If we assume that electron burn produces specks of colloidal metal or other irregularities in the crystal lattice of a phosphor by reducing it, then the fall in secondary emission may be explained by the decrease in mean free path of secondary electrons within the screen particles as the number of collisions with colloidal aggregates in the phosphor grains increases.

(d) *Ion burn of phosphor screens.*

The formation of the ion spot in the centre of the screens of magnetically deflected cathode ray tubes is a familiar sight to television viewers. In this region bombardment of the screen by ions destroys its luminescence. In some cases the ion spot is thermally metastable and is largely removed by careful heat treatment of a screen. In such cases the ions are probably only adsorbed on the screen surface. It is likely that they distort the luminescence centres in their neighbourhood and thus decrease the luminescence efficiency.

Metal Backed Cathode Ray Tube Screens

It is of interest to include at this point a description of recent developments which make it possible to improve the working efficiency of cathode ray tube screens, in particular the amount of light emitted towards the viewer and the removal of the effects of poor secondary emission at higher operating voltages (10 KV). In conventional screens about 50 per cent of the luminescence is emitted in the primary electron beam direction and is then scattered or absorbed, resulting in loss of useful emission and also in an adverse effect on picture contrast, by scattering back on to the screen. If the screen is backed by a reflecting metal layer thin enough to allow efficient excitation of the phosphor by the primary cathode rays then most of the 50 per cent of light usually lost can be reflected towards the viewer. In addition the metal backing prevents the screen from charging up at high operating voltages, when the secondary emission becomes inadequate. Picture contrast is improved at all voltages and minimising of ion burn has also been claimed to be a feature of metal backed screens.

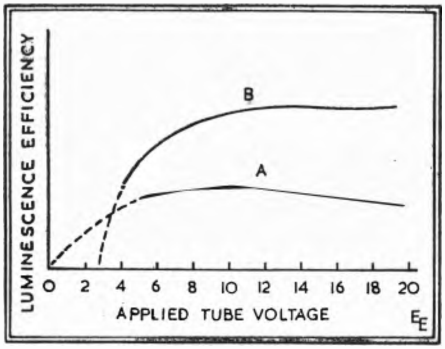


Fig. 9. Luminescence efficiency vs. tube voltage characteristics for backed and unbacked phosphor screens (Epstein and Pensak). A, Unbacked screen B, Al backed screen

The backing is usually provided by evaporating aluminium on to the screen. However, a straightforward evaporation only coats the phosphor grains and does not give either a good reflecting backing or one of high electrical conductivity. To achieve these properties the aluminium is evaporated on to a tight skin of an organic lacquer film previously formed on the screen. By baking after evaporation the organic film is removed and leaves a stretched skin of aluminium which is a good conductor and also gives good optical reflexion. The thickness of the aluminium layer is quite critical. It must not be too thin for then it is not opaque and has poor conductivity. If too thick it absorbs too large a fraction of the primary electron beam and reduces its energy. In practice the optimum thickness is of the order of 10^{-5} cm. In Fig. 9 the luminescence efficiency *vs.* tube voltage characteristics are given for backed and unbacked cathode ray tube screens. Even at low operating voltages where the efficiencies are about equal the backed screen offers better picture contrast, due to the lack of light scattering.

Conclusion

The basic processes of luminescence in cathode ray tube screens are as yet little understood. It may be necessary for their elucidation to simplify the conditions by using large single crystals. The difficulty in this respect is that almost all phosphors of reasonable luminescence efficiency cannot be obtained in such a form. There are possibilities of using evaporated phosphor layers on plain metal surfaces for basic studies. Until such studies have been made it will not be possible to indicate whether or not the 10 per cent conversion efficiencies for phosphor screens set a fundamental limit to screen improvement.

Investigations of luminescence produced in small single crystals of phosphors by single α particles, now in progress, have provided a new method of investigating the intermediate stages between the absorption of primary particles and the appearance of luminescence.

With respect to practical or developmental research, interest is turned towards such materials as the zinc sulpho-selenides whose emission spectra can be controlled to give a good approximation to a white emission and which possess suitable phosphorescence characteristics. With the development of the flying spot film scanner and of projection television, the conditions imposed on the choice of suitable phosphors become more stringent. This will be further evidenced by future development of colour television systems in which three or more different phosphor screens provide the basic colour components of the final picture.

General References

In *lieu* of detailed references to each phenomenon above a list of general references is given below from which these and others may be obtained.

(a) *Luminescence due to cathode rays.*

[1] H. W. Leverenz, *R.C.A. Review*, 5, 131, 1940.
[2] J. W. Strange and S. T. Henderson, *Proc. Phys. Soc.*, 58, 369, 1946.
[3] G. F. J. Garlick, "Advances in Electronics—II," Academic Press, New York, 1949.

(b) *Luminescence.*

[1] G. R. Fonda F. Seitz (Ed.), *Solid Lum. Mat.*, John Wiley, New York, 1948.
[2] G. F. J. Garlick, *Lum. Mat.*, Oxford Univ. Press, 1949.

(c) *Cathode ray tube screens for radar.*

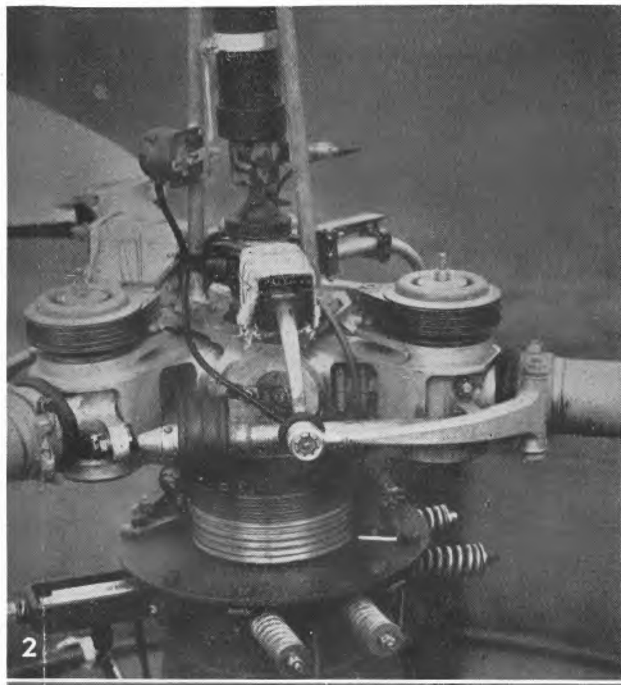
[1] "Radar Convention Proceedings," IIIA, Pt. I, *Journ. I.E.E.*, 93, 1947.
[2] H. W. Leverenz, *R.C.A. Review*, 7, 199, 1946.

(d) *Secondary electron emission.*

[1] H. Bruining, "Secondary Electron Emission of Solids," Berlin, 1942.
[2] M. Knoll, O. Hachenberg and J. Randmer, *Zeit. Phys.*, 122, 137, 1944.

(e) *Metal-backed cathode ray tube screens.*

[1] D. W. Epstein and L. Pensak, *R.C.A. Review*, 7, 5, 1946.



Electronic Equipment for a Helicopter Testing Tower

A Helicopter Rotor Testing Tower has just been installed at the Bristol Aeroplane Company's works, and full details of its design and development have been given in reports by R. F. Tayler, A.M.I.M.E., and issued by the Company.

The testing tower, a general view of which is shown in Fig. 1, was erected to provide a means of testing rotor hubs and blades independently of helicopter aircraft.

The tower itself is about 3 ft. in diameter and 25 ft. in height, with an observation platform just below the rotor.

The rotor is driven by a 700 h.p. electric motor situated in a steel framed building at the foot of the tower and the drive is taken by a vertical shaft through universal joints so as to provide torque but no end-thrust.

A ring of wire-braced pylons surrounds the tower and supports a screen of heavy steel netting, 84 ft. in diameter, for protection in case of breakage of the rotor blades.

Of main interest is the electronic equipment designed to measure the following:

1. The total lift of the rotor.
2. Two quadrature horizontal forces at the rotor hub.
3. The angular position of the rotor.
4. The individual pitching moments of the three rotor blades.

Further details of the testing tower and the electronic testing equipment may be obtained from The Bristol Aeroplane Company, Ltd.

Acknowledgement is made to the Royal Aeronautical Society for permission to publish this information.

Fig. 2. General view of hub showing, from top to bottom, collective pitch changing actuator and desynn transmitter, blade moment gauges on spider arms, rotor hub, slip-rings and brushes, and out-of-balance gauges and springs

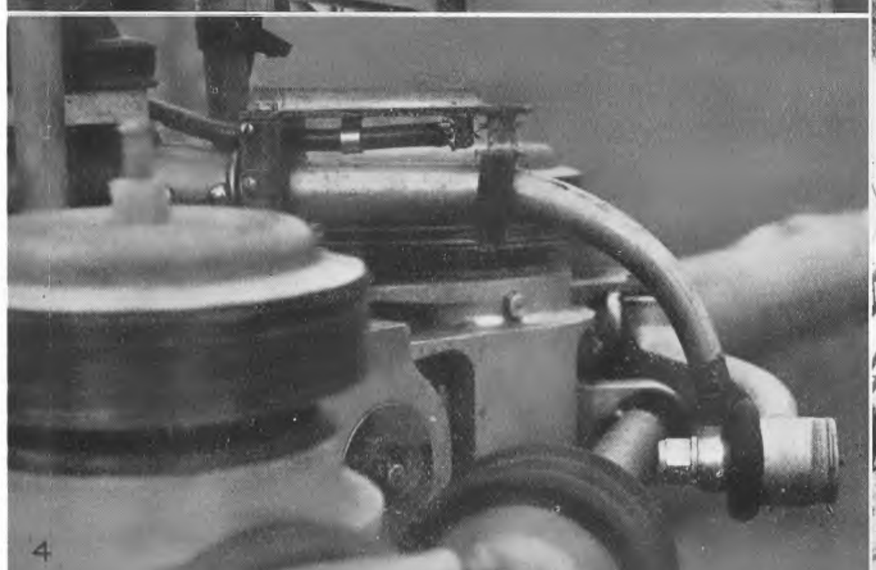
Fig. 3. Control and recording equipment. From left to right: Frequency modulation units for blade moment measurement; five channel oscilloscope unit, with strain gauge bridges on top and recording camera in front; motor control panel

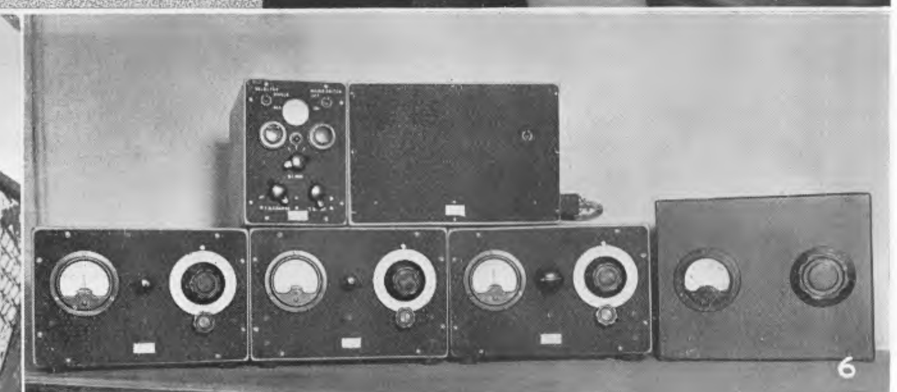
Fig. 4. Method of measuring bending of spider arm with inductance gap gauge (lower right of photo)

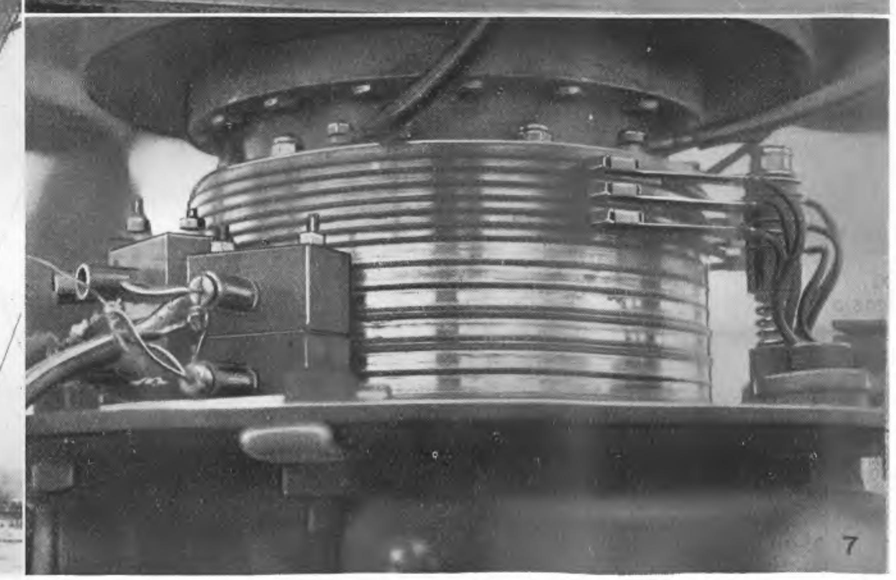
Fig. 5. Hub assembly of the rotor with oscillator unit mounted on the right-hand rotor arm

Fig. 6. Amplifier units at the base of the tower

Fig. 7. Slip-rings. Upper rings supply actuator and carry signal from desynn indicator. Lower rings are for frequency-modulated circuits







The Electromagnetic Horn

—Part II

By W. D. OLIPHANT

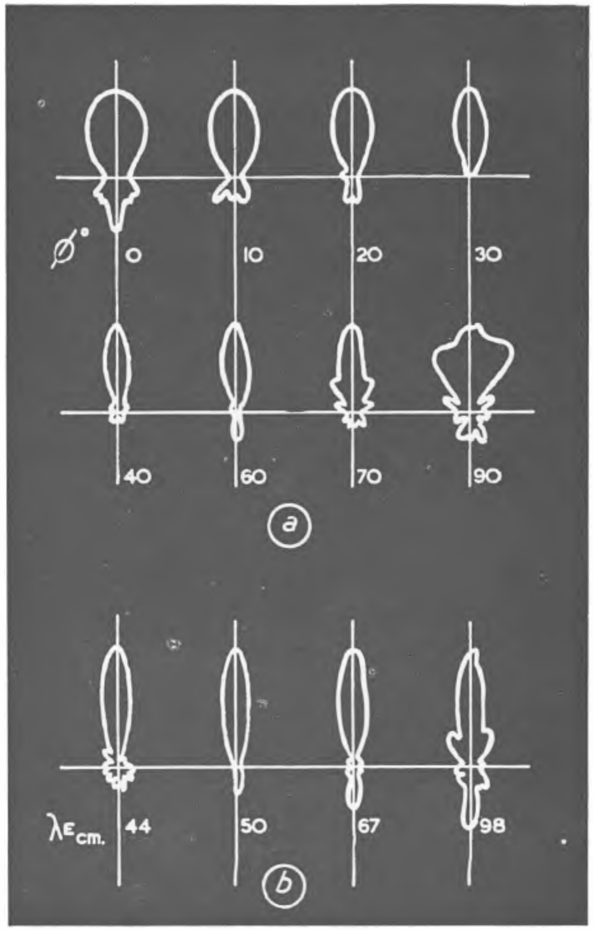


Fig. 4. Radiation patterns for sectoral horn (*After Barrow & Lewis*)—Ref. 6

Experimental Evidence

BARROW and Lewis[6] have discussed the results obtained from tests carried out on experimental horns of the sectoral type to investigate the manner in which the flare angle (ϕ_0) and the excitation wavelength (λ_E) define the radiation characteristic, and a brief account of their findings will now be given.

In order to investigate the effect of flare angle on the radiation characteristic, a sectoral horn, constructed of galvanised-iron sheeting, was conductively joined at its throat to the open end of a 2.44 m. length of rectangular hollow tube guide wherein a and b were respectively 15 and 50 cm. The axial length (r_1-r_0) of the horn itself was 1.43 m. and in order to provide for a variable flare angle, the vertical sides of the horn (a dimension) were hinged at the throat and means were provided for maintaining conductive continuity of the horn structure for all angular settings. The method of H_{01} wave excitation employed was as already shown in Fig. 1, and the tube guide was conductively closed at the end remote from the horn by means of a piston reflector. For each setting of the flare angle, the distance between the exciter electrode and the piston was adjusted for maximum radiation along the principal axis and, in general, the separation was of the order of an odd multiple of a quarter wavelength of the tube wave (λ_T). Tests were carried out at an excitation wavelength of 50 cm., and the E-field intensity in the horizontal (or xz) plane was measured at a large number of points around a circular path of constant radius (100 ft.) about the mouth of the horn.

The resulting polar diagrams of horizontal E-field intensity distribution for various values of ϕ_0 are reproduced in Fig. 4(a), and in assessing the performance of any given arrangement, attention is given to the nature of the principal lobe and to the presence of spurious radiation. Spurious radiation comprises backward radiation due to diffraction around the mouth of the horn, and secondary lobes which tend to distort the principal lobe.

The diagram appropriate to a simple open-ended guide radiator is shown at $\phi_0 = 0°$. The backward radiation is here quite considerable, both in angular width and amplitude, while the forward radiation takes the form of a more or less undistorted, but very wide, principal lobe. As ϕ_0 is increased, the principal lobe becomes sharper and the backward radiation is reduced both in angular width and amplitude. For $40° < \phi_0 < 60°$, the principal lobe is at its narrowest, and this represents the optimum range for ϕ_0 for a highly directive beam system. As ϕ_0 is increased beyond 60°, secondary lobes appear with increase in backward radiation, until at 90° the secondary lobes are almost as large as the principal lobe, which thereby suffers severe distortion with resulting increase in beam width.

The relative power gain (already defined) was computed from the ratio of the area of the circle of radius equal to the maximum ordinate of the pattern to the area of the pattern itself, and its relation to ϕ_0 is shown in Fig. 5. Thus the optimum flare angle is again seen to be (50 ± 10) degrees.

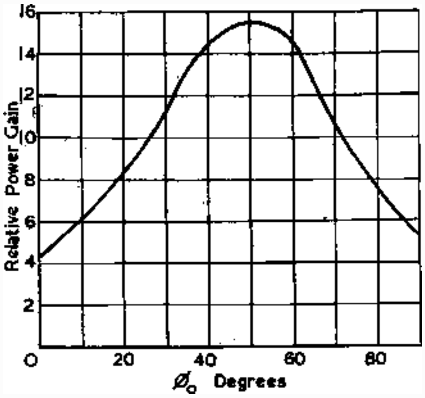


Fig. 5. Relative power gain plotted against ϕ_o (*After Barrow & Lewis)—Ref. 6*

In order to explain the presence of secondary lobes for values of $\phi_o > 60°$, a series of experiments was conducted to determine the *E*-field distribution across the horn mouth, and it was conclusively demonstrated that departure from a more or less true sinusoid was associated with secondary lobe formation. Apart from this observation, it must be borne in mind that horn wave guidance is essentially radial in character and so for the large flare angle a horizontal spread of the wave energy is to be expected. Large flare angle is thus associated with the presence of harmonics in the mouth field intensity distribution and with radial spread of the wave energy.

The narrowing of the beam angle with increase in ϕ_o up to 60° is essentially the result of increase in the horizontal aperture (W_H), a point which has already been discussed in connexion with the theory of the hollow tube guide radiator.

Reference has already been made to the use of Equation (8) for calculating the forward field characteristic for $\phi_o < 50°$ and for $W_H > 3$. Since its derivation is based on the assumptions that the field distribution across the mouth is an equiphase sinusoid and that the wave propagation within the horn is axial and not radial, it follows that departure from the experimental values must be expected for $\phi_o > 50°$. The experiments of Barrow and Lewis confirm the validity of Equation (8) within the prescribed limits, and it is further possible (within the same limits) to calculate the horizontal and vertical beam angles for any sectoral horn by means of Equations (10). These equations are reproduced graphically in Fig. 6, thus affording a ready means for determining the necessary apertures to satisfy a given beam requirement in both the horizontal and vertical planes.

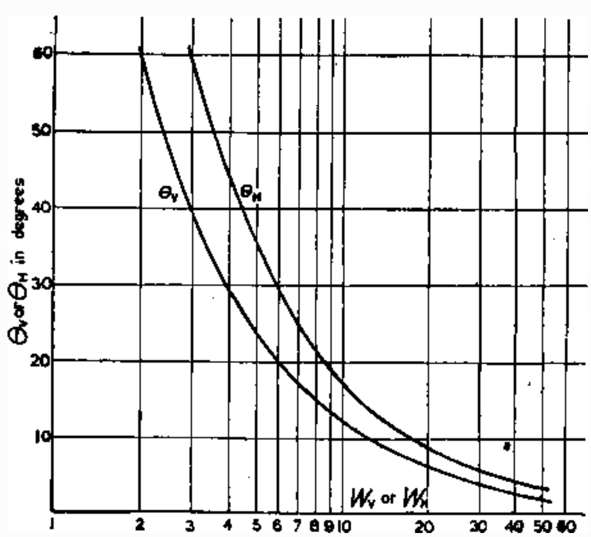
The experimental horn was now set at $\phi_o = 40°$ and the axial length was increased to 3.44 m., the excitation wavelength being still 50 cm. The new axial length provided a greater horizontal aperture, and a resultant sharpening of the principal lobe, appropriate to $\phi_o = 40°$ in the earlier experiments, was observed. This result demonstrates the fact that increase in horn length is associated with a sharpening of the beam and this is accomplished without any departure from the smoothness of the principal lobe or by the increase in backward radiation.

The excitation wavelength was now varied from 44 cm. to just below the critical wavelength (100 cm.) for the tube guide, and the horizontal field intensity distribution determined. The results are reproduced in Fig. 4(b). It is at once apparent that the principal lobe remains more or less unchanged apart from series distortion at the upper wavelength limit, and that the backward radiation increases with increase in wavelength. As before, the existence of secondary lobes was found to be associated with non-sinusoidal field distribution across the mouth of the horn. The optimum operational wavelength for the given horn is seen to be 50 cm., and it is evident that a change in wavelength of the order of ± 25 per cent does not materially affect the directive properties of the horn. This characteristic is of considerable practical advantage in the application of the horn to wideband systems, or where it is necessary to be continually changing the operational wavelength. The relative power gains for the ascending wavelengths employed were found to be 17.5, 21.0, 18.3 and 11.3 respectively. The effect of increase in radial length on a power gain basis is quite marked; the power gain for $\lambda_E = 50$ cm. increasing from 14.5 to 21.0.

Further experiments were carried out with direct horn excitation in the larger case. To do this, the tube guide was removed and the excitor electrode was placed at the throat. As before, a piston reflector (working in a short stub) closed the back of the horn, and it was found that the radiation characteristic was not materially affected by the alternative method of excitation. Indeed, the excitor electrode could be moved about along the axis within the horn structure without any evident change in the characteristic. Furthermore, the shape of the reflector, whether it be planar or parabolic, did not affect the pattern and the conclusion which can be drawn from these experiments is that the radiation characteristic is dependent entirely on the configuration of the horn structure and is not controlled in any marked manner either by the method of horn excitation or by the shape of the associated reflector piston.

An electromagnetic horn has no focus and the excitor electrode can

Fig. 6. To determine apertures for given beam requirement in horizontal and vertical planes (*After Barrow & Lewis—Ref. 6*)



be placed anywhere in the throat region. The beam concentration arises as the result of horn wave guidance and not by reflexion. In this respect it differs from the operation of a dipole working in conjunction with a cylindrical parabolic reflector and possesses a very considerably reduced spurious radiation. The separation between dipole and reflector requires critical adjustmentment for each wavelength, whereas this is not necessary in the case of the horn where a comparatively rough adjustment of the piston will accommodate optimum operation over a wavelength range of 2 to 1 or even more. It is pointed out that if the piston is replaced by a non-reflective medium, the horn is thereby made practically equally responsive over a wide frequency range, but this must necessarily be accompanied by an increase in power loss within the horn itself.

A comparison is made between the horn radiator and orthodox aerial arrays and the serious difficulties associated with the design, adjustment and operation of the latter at wavelengths less than 1 m. are cited. In adjustment and maintenance, the normal methods for current measurement and phasing are inaccurate at the very high frequencies and resort has to be made to the use of field strength measurement equipment to obtain the field polar diagram. Furthermore, highly directive arrays are critically resonant so that any departure from the wavelength for which the array has been designed and adjusted will result in a drastic reduction in the power gain of the system. The simplicity of design and operation of the electromagnetic horn, with its inherent wide-band properties, is strong recommendation for its use in practice in preference to an array for micro-wave services, and it has the further advantage that spurious radiations are negligible when compared with those associated with, say, a broadside array.

Design Data

The inner surfaces of the horn structure must be made of some high conductivity material, such as copper or aluminium, but in the experimental horns just described use was made of galvanised-iron sheeting. In very large models, where weight might be a serious factor, it is permissible to construct the horn of plywood and then line the interior with copper foil; or again the throat region may be constructed in the manner indicated, but increase in radial length may be achieved by the use of a fine-mesh gauze. By whatever means the conductive sheath is realised, it is important to ensure that the inner surfaces are smooth and free from discontinuities, and furthermore, efficient conductive bonding is essential at all seams and joints in the material. In order to reduce the power loss within the horn to a minimum, dielectric supports and other bracing members should not be positioned inside the structure; in the majority of designs the horn structure can be made self-supporting and thus not require secondary support. When horns are exposed to the elements adequate weather protection can be obtained by closing the mouth with a sheet of high quality thin dielectric material; wind pressure, if troublesome, can be reduced by the use of gauze as already indicated.

In general, a horn can be installed in any position relative to the transmitter or receiver and connexion can be made either by wave guide or concentric line. In compact portable micro-wave equipment, the horn can be mounted directly above the transmitter or receiver, the whole being supported on a tripod.

The production of a single lobe vertically polarised radiation characteristic is realised when a sinusoidal E intensity distribution exists across the mouth of the horn and this is dependent on the propagation of a pure H_{01} wave along the horn. In general, a number of possible wave modes are generated by the excitor electrode and if these were allowed to propagate along the horn serious distortion of the distribution sinusoid would result. In order to eliminate this effect, use is made of the throat attenuation qualities to the higher order waves and this is governed by the cut-off length r_0 or by the quantity $x_0 (= r_0 / \lambda_E)$. By suitable choice of x_0, it is possible for a given flare angle to afford a more or less non-attenuative propagation to the H_{01} wave, but at the same time to provide almost complete attenuation or filtration to the waves of higher order, of which the lowest is the H_{03} wave. In practice, horns should be constructed so that the cut-off lengths are not too different from the optimum value for the H_{01} wave so that the maximum possible higher order attenuation is available. In Fig. 7 is reproduced a curve from which this value may be read for any chosen value of ϕ_0. The H_{03} wave curve is included to show the radial extent of the attenuation region to which the H_{03} wave is subjected. The optimum cut-off length and the extent of the attenuation zone are not influenced by the vertical dimension a provided this quantity is not considerably greater than λ_E. In

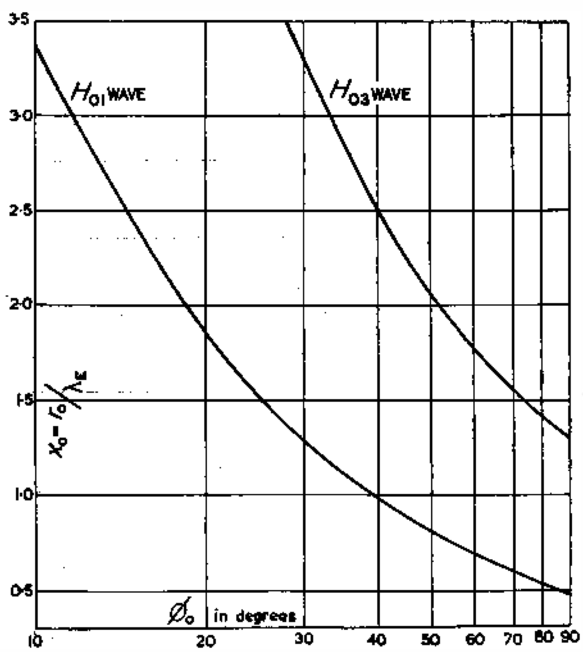


Fig. 7. Plot of ϕ_0 for sectoral horn to obtain optimum value of H_{01} for maximum higher order attenuation

other words the curves of Fig. 7 hold for all truly sectoral horns, but when pyramidal horns are considered account must be taken of the increased vertical aperture.

Having noted the conditions necessary for the ideal mouth distribution of intensity, it is now necessary to consider how any desired radiation characteristic may be obtained and to this purpose a number of design curves have been published by Chu and Barrow.[7] A selection of these curves is reproduced here to illustrate the design principles.

It has been shown that the radiation characteristic may be assessed on either a beam angle or a power gain basis and that the variables involved are the flare angle and the radial length, which latter, in terms of the excitation wavelength, has been here given the symbol $X_R (= r_1/\lambda_E)$. In the curves which follow it should be noted that: (a) the beam angle is taken to be twice the angle measured from the forward axis to the radial ordinate in the pattern whose magnitude is 10 per cent of its maximum (or forward axis) value. This is taken to be the practical method in stating beam angle or width and differs only slightly from the theoretical definition previously given in connexion with Equations (10); (b) the power gain is everywhere plotted for unity vertical aperture, thus the actual power gain is obtained by multiplying the curve value by $W_V = a/\lambda_E$

In Fig. 8 are shown two families of curves for various values of X_R showing the manner in which θ_H and power gain vary with ϕ_o. For a given value of X_R, there is seen to be an optimum value of ϕ_o, for which θ_H is a minimum and for which the power gain is a maximum. Again, increase in X_R coupled with a slight adjustment in ϕ_o, results in a sharpening of the beam angle and in an increase in power gain. It is to be noted, however, that the curves in the two families become more crowded together with continued increase in X_R and so there is a practical limit to the improvement which can be achieved by increase in radial length.

Arising out of the curves of Fig. 8, it is possible to draw optimum design curves for the H_{01} wave on a beam angle and on a power gain basis, and these are reproduced in Figs. 9 and 10.

In Fig. 9 are redrawn the $\theta - \phi_o$ curves for various X_R (shown dotted) and through the values of minimum θ_H is drawn the solid straight line, from which can readily be determined the value of ϕ_o suitable for a given θ_H. A scale of X_R, drawn in conjunction with the values of minimum θ_H, is also provided so that the shortest radial length for a given value of θ_H can also be determined.

By way of an example, it is assumed that a horizontal radiation field is required whose beam angle is to be 40°. From Fig. 9, it is evident that the flare angle must be 25° and that the minimum radial length is of the order of 17 per wavelength. If the excitation wavelength is to be 10 cm., then r_1 is 170 cm. Referring back to Fig. 7, it is seen that the optimum value for x_o is about 1.5, from which it follows that r_o will have to be 15 cm., giving an axial length of actual horn structure of 155 cm.

In Fig. 10 are redrawn the power gain $-\phi_o$ curves for various X_R (shown dotted) and through the values of maximum power gain is drawn the solid curve. It is thus evident that the maxima occur at smaller ϕ_o for increase in X_R. As in Fig. 9, a scale of X_R is also constructed so that for a given power gain it is possible to determine the shortest radial length as well as the appropriate flare angle.

In the example already given, where $\phi_o = 25°$, the corresponding power gain per unit vertical aperture is found to be of the order of 43. If $a = 20$ cm., then $W_V = 2$, and so the absolute magnitude of the power gain is 86.

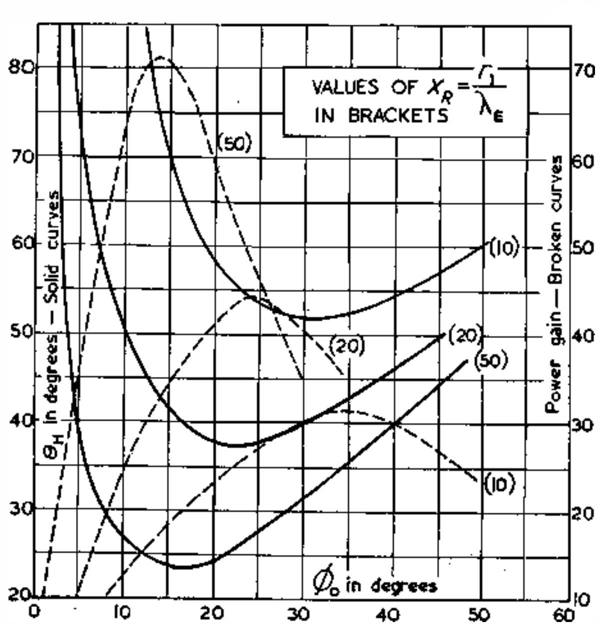
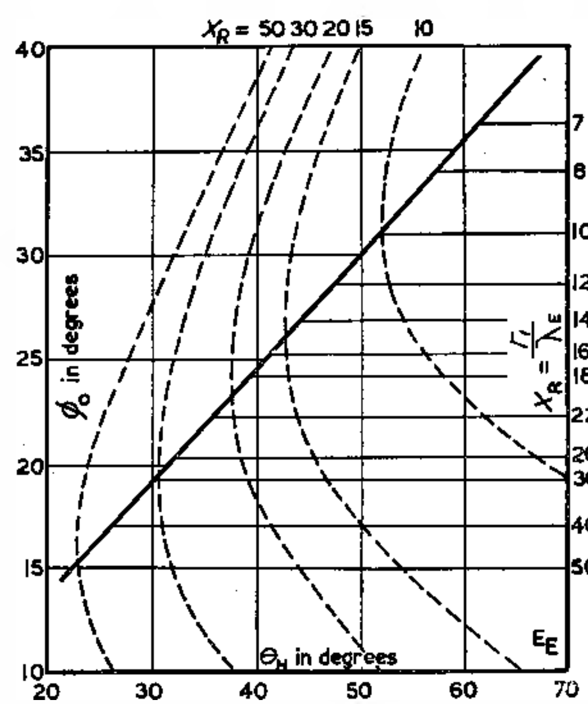


Fig. 8 (above). Power gain and θ_H plotted against ϕ_o

Fig. 9 (right). Curves of ϕ_o and θ_H for various values of X_R
(From data by Chu & Barrow—Ref. 7)



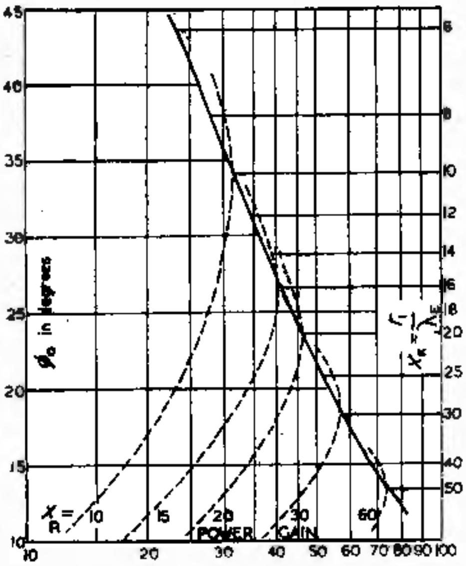
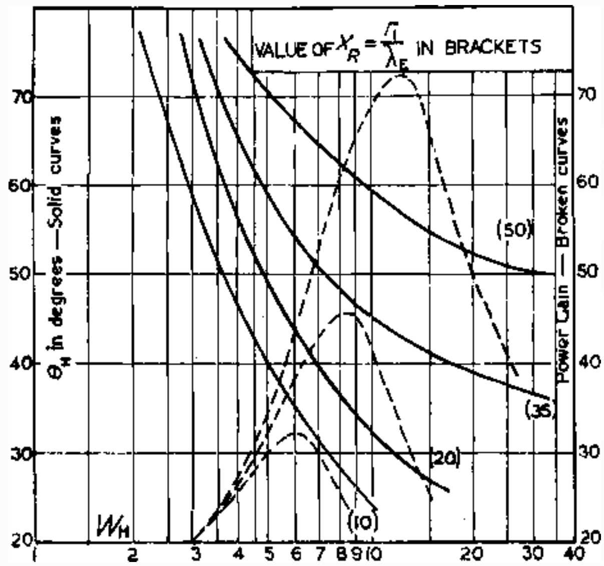


Fig. 10 (left). Power gain plotted against ϕ_0

Fig. 11 (right). Relation between beam angle or power gain and the horizontal aperture for various values of X_R

(From data by Chu & Barrow—Ref. 7)



In Fig. 11 are reproduced curves showing the relation between beam angle or power gain and the horizontal aperture for various values of X_R. From this it is seen how, for a given radial length, the beam is progressively sharpened with increase in W_H, and, furthermore, that there is an optimum value for W_H for maximum power gain with a given value of X_R.

The vertical field characteristic (xy-plane) can be obtained from Equation (7), being the same as that for a simple hollow tube guide radiator, and a plot of vertical beam angle (θ_V) against vertical aperture (W_V) is shown in Fig. 12 for the H_{01} wave. Within limits, the design data already given can be extended to the case of the pyramidal horn, where flaring also takes place in the direction of the y-axis. In this case a smooth vertical characteristic is only possible provided W_V is not made too large. This restriction is also necessary from the point of view of optimum cut-off length and of effective higher order attenuation at the throat.

The quantities W_H, W_V, x_0 and x_R are all directly related to the excitation wavelength λ_E, so that if the wavelength is altered by some factor, then it is only necessary to apply the same numerical factor to all the linear dimensions to give the same radiation characteristic at the new wavelength. Thus, the principle of models can be made use of in horn development when a set of data obtained for any particular wavelength can be applied directly to the design of a similar horn at some other wavelength.

The sectoral horn, by virtue of its highly directive properties, may be used in point-to-point microwave communication systems when the relatively narrow channel ensures secrecy and a minimum of interference from other sources. The wide-band character allows of rapid wave change without attendant trouble in radiator adjustment. Its use in direction-finding is also indicated as well as in the application to microwave field strength measurement when spurious reflexion effects will be reduced to a minimum.

A number of sectoral or pyramidal horns may be mounted together to form a planar horn array, and this possibility has been fully investigated by Barrow and Shulman.[9] Multi-unit electromagnetic horns, in addition to the above-mentioned applications of the single horn, possess two very important properties, namely, electrical steerability and relatively small radial length compared with the length of a single horn of equivalent effectiveness. The mutual impedance between two or more adjacent horns whose mouths are in the same plane and whose apertures are several wavelengths, is substantially zero even if they are placed edge to edge. Horns may thus be treated as pure self-impedances and so the radiation characteristic and operation of one horn is unaffected by the presence of its neighbours. The field configuration at a considerable distance from the plane of the array may be determined from a knowledge of the component characteristics, and, by suitable phase and amplitude adjustments, the principal lobe of the array may be steered in the usual way. Such arrays may be fed either by concentric lines or by tubular wave guides fitted with appropriate phasing devices.

In a design of the simple sectoral horn, several modifications may be incorporated to improve the efficiency. For example, the surface discontinuity which exists at the throat, where the flared horn structure joins the tube guide or stub, may be curved to give a hyperbolic contour. Again, the edge of the mouth may take the form of an arc of a circle, whose centre is the apex of the horn structure, thus conforming to the essentially radial nature of the horn wave propagation.

High conductivity tubes of circular section are probably the most readily obtainable in engineering practice and thus a hollow cylindrical tube guide can readily be constructed. It is logical, therefore, to terminate such a guide in a flared mouth of circular section, the profile being either linear or hyperbolic. The associated theory, however, does not lend itself to such simple analysis as does the tube and horn of rectangular section.

The conical horn has received some considerable theoretical and practical investigation, particularly in its application to broadcast coverage, when the radiator has come to be known as a biconal electromagnetic horn.[10] The radiation field is here uniformly distributed in a plane. Such a horn comprises two smooth and symmetrical surfaces of revolution, which may be either planar or curved and which are placed apex to apex to form a pair of divergent boundary surfaces of varying degrees of flare. In the paper mentioned, the linear profile is chosen and a full theoretical and practical configuration of such a horn is shown in Fig. 13, consisting of two similar members (A and B). As before, excitation is produced at the throat and the two types of wave which have practical application are the E_{00} and H_{01}, the former producing vertical polarisation and the latter horizontal polarisation when the principal axis (or axis of revolution of the surface generators) is vertical.

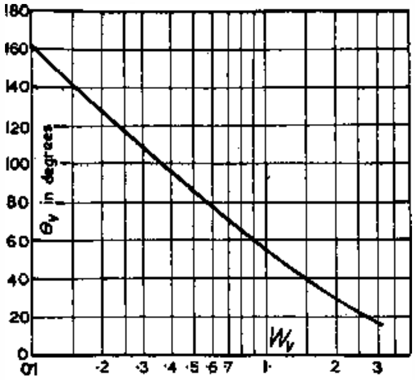
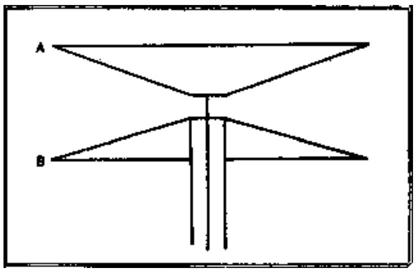


Fig. 12. Plot of θ_v against W_v

Fig. 13. The Bi-conical E.M. horn



Acknowledgment

The object of the present paper has been to present in summary form the basic principles of the theory and design of the electromagnetic horn. To this end, free use has been made of the available literature and the author wishes to express his indebtedness, in particular to the Department of Electrical Engineering of the Massachusetts Institute of Technology, from whose publications much data has been abstracted. (References [3] to [10] inclusive.)

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Radar Mapping

By R. R LOWTHER, F.Z.S.

(*Continued from page* 280)

preting the displayed image accurately and rapidly.

In periods of bad visibility, radar mosaics or charts become increasingly useful since the surrounding terrain as displayed on the P.P.I. screen is readily recognisable when compared with the mosaic. In fact, it is more easy to recognise land features in this way than it is when they are viewed visually and compared with an orthodox chart. This is borne out by statements made by navigators that marine radar is often used for general navigation purposes within sight of land in clear weather because accurate ranges are constantly available and because lighting conditions affect the configuration of the land as seen by the human eye. It has been demonstrated that difficult pilotage, in foggy conditions, can be mastered by

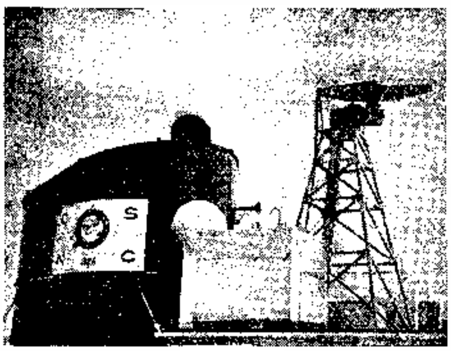

Fig. 3. Scanner mounted ahead of funnel on General Steam Navigation Company's T.S.M.V. "Seamew"

the use of a marine radar equipment in the hands of a skilled operator. Such an operator must be familiar with the apparatus he is using and he must have thorough knowledge of the area through which he is passing and of the type of information required by the pilot, at every point along the route. This knowledge is acquired only after long experience in the area concerned. It is suggested that considerable time could be saved in foggy conditions if these charts were studied during conditions of clear visibility and compared with the outlines as they appear on the P.P.I. in order that the navigator could become thoroughly conversant with the relation between the radar image and the visual image.

Inspection of the illustration will show that many salient features such as Southend Pier, the pier at St. Mary's Bay opposite Canvey Island, the oil tanks at Lower Hope Point and the Docks at Tilbury are readily discernible.

VOLTAGE STABILISERS
—Part IV

By F. A. BENSON, M.Eng., A.M.I.E.E.*

Alternative Bridge Stabilising Circuits

APART from the Metrosil bridge circuit already described, many similar ones have been suggested from time to time.

Bridge circuits employed by Lewis[30] and Higgs[31] have two diagonal arms comprised of metal-filament lamps, the other arms containing constant resistances. The supply voltage is applied across one diagonal and the output voltage is taken from the other. The action of the circuits depends on the fact that the resistance of a metal-filament lamp rises as the current rises, increasing rather quickly just before the glow point is reached. Thus, if the input voltage increases, the lamp resistances increase due to the extra current through them and the output voltage tends to remain constant.

The principles underlying the design of bridge stabilisers have been described by Morton[32] and the balance conditions for a number of circuits have been studied by Patchett,[33] Brownlee[34] and Baker.[35] The bridge may have any number of arms, from one to four, composed of resistances with non-linear volt-ampere characteristics. The lamps used by the early investigators may quite advantageously be replaced by barretters, gaseous discharge tubes, thermistors, copper and selenium rectifiers or materials such as Metrosil. The current-voltage characteristics of suitable bridge elements may, as Morton shows, be divided into two classes, as shown in Fig. 33. Materials such as Metrosil come into class 1, as do gaseous discharge tubes in series with a high resistance. The relation between V and I for a class 1 characteristic may be written $V = rI + v$ where r is the reciprocal of the slope of the curve and has the dimensions of resistance. Similarly, the relation between V and I for elements which have characteristics of class 2, such as metal-filament lamps and barretters, can be written $V = r'I - v'$. Morton has analysed a bridge network in which two diagonal arms are composed of elements which have class 1 characteristics and the other arms consist of elements with class 2 characteristics (Fig. 34).

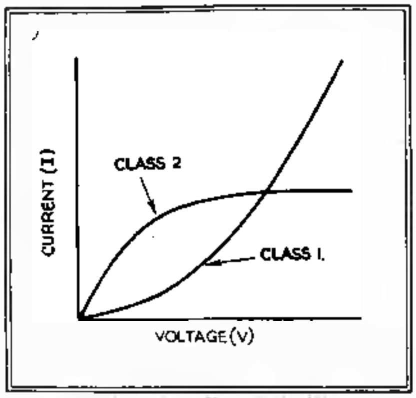

Fig. 33. Current-voltage characteristics for bridge elements

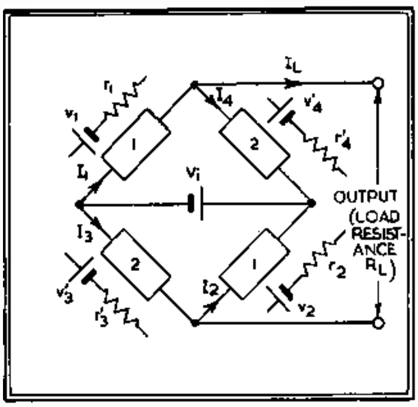

Fig. 34. Bridge circuit employing Class I and Class 2 elements. (Morton)

These elements can be replaced by their corresponding values of internal E.M.F.'s v and v' and resistances r and r'. Let the input voltage be V_i, the load resistance R_L, and the load current I_L. Let the currents in the arms of the bridge be I_1, I_2, I_3 and I_4 as shown.

Then it can be shown that

$$I_L = \frac{r_1(v_2 + v_4') + r_4'(v_1 + v_3')}{r_1(R_L + r_2) + r_4'(R_L + r_1)}$$

if $r_1 r_3 = r_3' r_4'$

which is independent of V_i. It is necessary to add resistors in series with one or more of the elements to meet the condition $r_1 r_2 = r_3' r_4'$.

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He also wishes to thank Mr. A. O. Carter, M.Eng., and Mr. H. A. Prime, M.Sc., for many helpful and and constructive criticisms made throughout the preparation of the articles.

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Appendix

An analysis is made below of the circuits shown in Figs. 23, 24 and 27.

The circuit of Fig. 23 may be redrawn for this purpose as in Fig. 35. Let the currents and voltages be as shown.

By Kirchhoff's Laws the following equations can be obtained:

From A to B to C to D:

$$V_i = I_r(R_2+R_3) + (I_r + I_a + I_L)R_1 \quad \text{.......... (1)}$$

From A to E to F to D:

$$V_i = R_1(I_r + I_a + I_L) + v + I_L R_L \quad \text{.......... (2)}$$

With *linear* valve characteristics,*

$$I_L R_L = I_a r_a - \mu V_g \quad \text{.......... (3)}$$

where r_a is the anode resistance of the valve, μ is its amplification factor and V_g is the grid voltage.

In this case

$$V_g = I_r R_2 - v \quad \text{.......... (4)}$$

From (3) and (4)

$$I_L R_L = I_a r_a - \mu(I_r R_2 - v) \quad \text{...... (5)}$$

From (1), (2) and (5) rearranging the terms:

$$I_a R_1 + I_r(R_1 + R_2 + R_3) + I_L R_1 = V_i \quad \text{.......... (6)}$$

$$I_a R_1 + I_r R_1 + I_L(R_1 + R_L) = V_i - v \quad \text{.......... (7)}$$

$$I_a r_a - I_r \mu R_2 - I_L R_L = -\mu v \quad \text{.......... (8)}$$

Subtracting (7) from (6):

$$I_r = \frac{v + I_L R_L}{R_2 + R_3} \quad \text{.......... (9)}$$

* The rigorous calculation of the performance of these circuits would be rather complicated, so to simplify the problem, it is assumed that valve characteristics are linear.

From (7) and (9):

$$I_a = \frac{[(V_i - v)(R_2+R_3) - I_L(R_1R_3 + R_1R_2 + R_LR_2 + R_LR_3 + R_1R_L) - R_1 v]}{R_1(R_2+R_3)} \quad \text{.......... (10)}$$

From (8), (9) and (10) and remembering that $I_L R_L = V_o$, the output voltage

$$V_o = \frac{V_i r_a(R_2+R_3) + v[\mu R_1 R_3 - r_a(R_1+R_2+R_3)]}{\dfrac{R_1 r_a(R_2+R_3)}{R_L} + [R_1(R_2+R_3+\mu R_2) + r_a(R_1+R_2+R_3)]} \quad \text{.......... (11)}$$

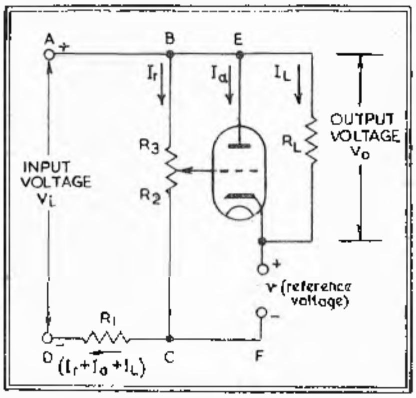


Fig. 35. Equivalent Circuit for Fig. 23.

First it is required to know the ratio of the percentage change of output voltage to the percentage change of input voltage, i.e., the quantity $\dfrac{dV_o}{V_o} \cdot \dfrac{V_i}{dV_i}$ or $\dfrac{dV_o}{dV_i} \cdot \dfrac{V_i}{V_o}$

Where dV_o is a small change of the voltage V_o and dV_i is a small change of the voltage V_i.

From (11)

From (11) dV_o/dV_i

$$= \frac{1}{1 + \dfrac{v}{V_i}\left[\dfrac{R_1(\mu R_3 - r_a)}{r_a(R_2+R_3)} - 1\right]} \quad \text{.. (12)}$$

Equation (12) can be used, therefore, to calculate the ratio of the percentage change of output voltage to the percentage change of input voltage. It should be noted that the larger the value of the reference voltage v the smaller is the quantity $\dfrac{dV_o}{V_o} \cdot \dfrac{V_i}{dV_i}$ i.e., the better the stabilisation. Also, if v is equal to zero then

$$\frac{dV_o}{V_o} = \frac{dV_i}{V_i}$$

Thus, stabilisation is impossible without a reference voltage. It can also be seen from Equation (12) that the larger the value of the mutual conductance of the valve g_m the better the stabilisation. Thus a valve with "steep" grid voltage-anode current characteristics is preferable.

Secondly, it is required to know the ratio of the percentage change of output voltage to the percentage change of the load resistance, i.e., the quantity $\dfrac{dV_o}{V_o} \cdot \dfrac{R_L}{dR_L}$ To find an expression for this quantity Equation (11) is differentiated with respect to R_L.

Write $V_o = \dfrac{k}{k_1/R_L + k_2}$

where

$$k = V_i r_a(R_2+R_3) + v[\mu R_1 R_3 - r_a(R_1+R_2+R_3)]$$

$$k_1 = R_1 r_a(R_2+R_3) \text{ and } k_2 = [R_1(R_2+R_3+\mu R_2) + r_a(R_1+R_2+R_3)]$$

Then

$$\frac{dV_o}{dR_L} = \frac{k(k_1/R_L^2)}{(k_1/R_L + k_2)^2}$$

$$\therefore \frac{dV_o}{dR_L} \cdot \frac{R_L}{V_o} = \frac{k_1}{R_L(k_1/R_L + k_2)}$$

Substituting for k_1 and k_2

$$\frac{dV_o}{dR_L} \cdot \frac{R_L}{V_o} = \frac{1}{1 + \dfrac{R_L}{r_a} + \dfrac{R_L}{R_1} + \dfrac{R_L}{R_2+R_3} + \dfrac{\mu R_2 R_L}{r_a(R_2+R_3)}} \quad \text{.......... (13)}$$

Thus, the ratio of the percentage change of V_o to the percentage change of R_L can be found. It should be noted that this expression is independent of the value of the reference voltage.

The circuit of Fig. 24 may be redrawn as in Fig. 36. Let the currents and voltages be as shown.

By Kirchhoff's Laws the following equations can be obtained:

From A to B to C to D to F:

$$V_i = R_1(I_L + I) + V_a + I_L R_L \quad \text{... (14)}$$

From B to E to D to C:

$$v = I(R_2+R_3) - I_L R_L \quad \text{...... (15)}$$

With *linear* valve characteristics as in the previous case:

$$V_a = (I_L + I)r_a - \mu V_g \quad \text{........ (16)}$$

and $V_g = v - IR_2$ .... (17)

From (14), (16) and (17):

$$I(R_1 + r_a + \mu R_2) + I_L(R_1 + R_L + r_a) = V_i + \mu v \quad \text{.......... (18)}$$

From (15) and (18):

$$I_L = \frac{V_i(R_2+R_3)+v(\mu R_3-R_1-r_a)}{(R_1+r_a)(R_2+R_3)+R_L(R_1+r_a+R_2+R_3+\mu R_2)}$$

Since $V_o = I_L R_L$

$$V_o = \frac{R_L[V_i(R_2+R_3)+v(\mu R_3-R_1-r_a)]}{(R_1+r_a)(R_2+R_3)+R_L(R_1+r_a+R_2+R_3+\mu R_2)} \quad \ldots\ldots\ldots\ldots\ldots (19)$$

In this case:

$$\frac{dV_o}{dV_i} = \frac{R_L(R_2+R_3)}{(R_1+r_a)(R_2+R_3)+R_L(R_1+r_a+R_2+R_3+\mu R_2)}$$

$$\therefore \frac{dV_o}{dV_i}\cdot\frac{V_i}{V_o} = \frac{1}{1+\dfrac{v}{V_i}\left(\dfrac{\mu R_3-R_1-r_a}{R_2+R_3}\right)} \quad \ldots\ldots\ldots\ldots (20)$$

This equation enables the ratio of the percentage change of V_o to the percentage change of V_i to be calculated. As in the previous case the larger the value of the reference voltage v the better the stabilisation. Also if v is equal to zero then

$$\frac{dV_o}{V_o} = \frac{dV_i}{V_i}$$

and stabilisation is impossible.

To calculate dV_o/dR_L Equation (19) is differentiated with respect to R_L.

Equation (19) can be written as:

$$V_o = \frac{R_L.K}{K_1 + R_L K_2}$$

where

$K = V_i(R_2+R_3)+v(\mu R_3-R_1-r_a)$

$K_1 = (R_1+r_a)(R_2+R_3)$

and

$K_2 = R_L(R_1+r_a+R_2+R_3+\mu R_2)$

Then

$$\frac{dV_o}{dR_L}\cdot\frac{R_L}{V_o} = \frac{K_1}{K_1+R_L K_2}$$

Substituting for K_1 and K_2

$$\frac{dV_o}{dR_L}\cdot\frac{R_L}{V_o} = \frac{1}{1+\dfrac{R_L(R_1+r_a+R_2+R_3+\mu R_2)}{(R_1+r_a)(R_2+R_3)}} \quad (21)$$

Thus, the ratio of the percentage change of V_o to the percentage change of R_L can be found and again it does not depend on the value of the reference voltage.

The circuit of Fig. 27 may be redrawn as in Fig. 37.

Let the currents and voltages be as shown.

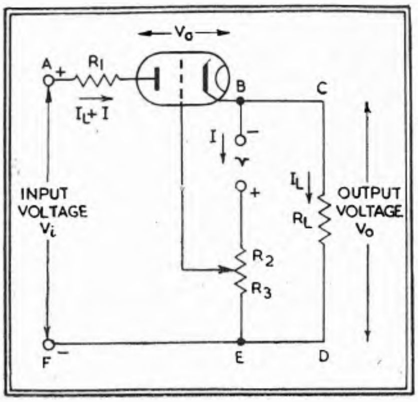


Fig. 34. Equivalent circuit for Fig. 24

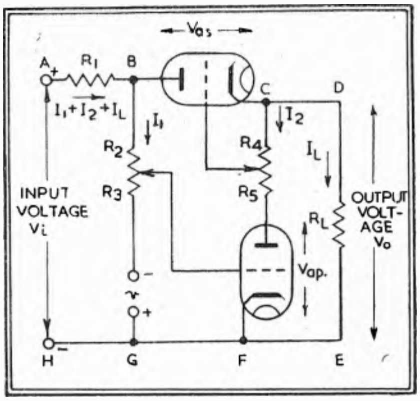


Fig. 37. Equivalent circuit for Fig. 27

By Kirchhoff's Laws the following equations can be obtained:

From A to B to G to H:

$$V_i = R_1(I_1+I_2+I_L)+(R_2+R_3)I_1 - v \quad \ldots\ldots\ldots\ldots\ldots (22)$$

From A to D to E to H:

$$V_i = R_1(I_1+I_2+I_L)+V_{as}+R_L I_L \quad \ldots\ldots\ldots\ldots\ldots (23)$$

From C to D to E to F:

$$V_{ap} = I_L R_L - (R_4+R_5)I_2 \quad \ldots\ldots\ldots (24)$$

With linear valve characteristics as in the previous cases:

$$V_{as} = (I_L+I_2)r_{as} - \mu_s(-R_4 I_2) \quad \ldots (25)$$

and $V_{ap} = I_2 r_{ap} - \mu_p(I_1 R_3 - v) \quad \ldots (26)$

where r_{as} = anode resistance of series valve

r_{ap} = anode resistance of parallel valve

μ_s = amplification factor of series valve

and μ_p = amplification factor of parallel valve

From (23) and (25) eliminating V_{as},

$$V_i = I_1 R_1 + I_2(R_1+r_{as}+\mu_s R_4)+I_L(R_1+R_L+r_{as}) \quad \ldots\ldots\ldots\ldots\ldots (27)$$

From (24) and (26) eliminating V_{ap},

$$\mu_p.v = I_1 R_3\mu_p - I_2(R_4+R_5+r_{ap}) + I_L R_L \quad (28)$$

Thus, from (22), (27) and (28) I_1 and I_2 can be eliminated and an expression for I_L obtained.

From (22) and (27) eliminating I_1,

$$I_2 = \frac{R_1(V_i+v) - V_i\Sigma R - I_L\{R_1^2 - (R_1+R_L+r_{as})\Sigma R\}}{\{R_1^2-(R_1+R_4\mu_s+r_{as})\Sigma R\}} \quad \ldots\ldots\ldots\ldots\ldots (29)$$

where $\Sigma R = R_1+R_2+R_3$

From (22) and (27) eliminating I_2:

$$I_1 = \frac{(V_i+v)(R_1+r_{as}+\mu_s R_4) - R_1 V_i + I_L R_1(R_L-\mu_s R_4)}{\Sigma R\{R_1+R_4\mu_s+r_{as}\} - R_1^2} \quad \ldots\ldots\ldots\ldots\ldots (30)$$

From (28), (29) and (30) eliminating I_1 and I_2:

$$I_L = \frac{Av - BV_i}{C} \quad \ldots\ldots\ldots\ldots\ldots\ldots (31)$$

where $A = \mu_p\{\Sigma R(R_1+r_{as}+\mu_s R_4)-R_1^2\} - R_3\mu_p(R_1+r_{as}+\mu_s R_4) - R_1(R_4+R_5+r_{ap})$

$B = R_3\mu_p(r_{as}+\mu_s R_4) - (R_2+R_3)(R_4+R_5+r_{ap})$

and $C = R_3\mu_p R_1(R_L-\mu_s R_4) - (R_4+R_5+r_{ap})\{R_1^2-\Sigma R(R_1+R_L+r_{as})\} + R_L(R_1+R_2+R_3)(R_1+r_{as}+\mu_s R_4) - R_L R_1^2$

$$\therefore V_o = I_L R_L = \frac{R_L(Av-BV_i)}{C} \quad \ldots (32)$$

In this case

$$\frac{dV_o}{dV_i} = -\frac{B.R_L}{C}$$

$$\therefore \frac{dV_o}{dV_i}\cdot\frac{V_i}{V_o} = -\frac{B.R_L}{C}\cdot\frac{V_i.C}{R_L(Av-BV_i)} = \frac{1}{1-\dfrac{Av}{BV_i}} \quad \ldots\ldots\ldots\ldots\ldots (33)$$

Thus again the reference voltage v is necessary for stabilisation and the larger its value the better is the stabilisation.

From (32) it can be seen that if B is zero, then the output voltage is independent of the input voltage V_i and only depends on the reference voltage.

If $B = 0$

$$R_3\mu_p(r_{as}+\mu_s R_4) = (R_2+R_3)(R_4+R_5+r_{ap})$$

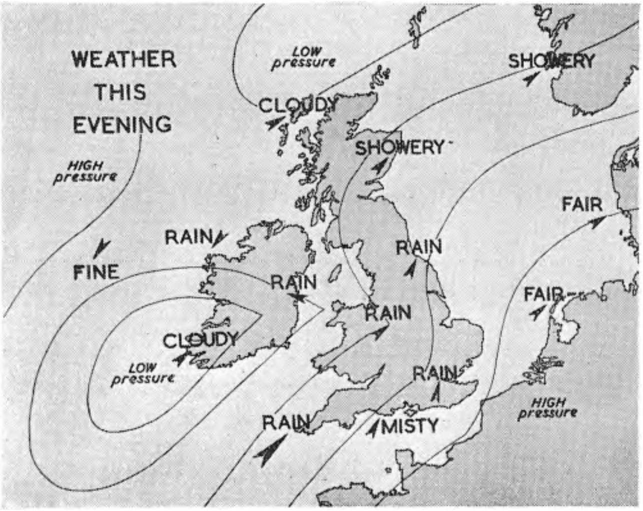
Thus with this condition, if the reference voltage remains perfectly constant, so does the output voltage.

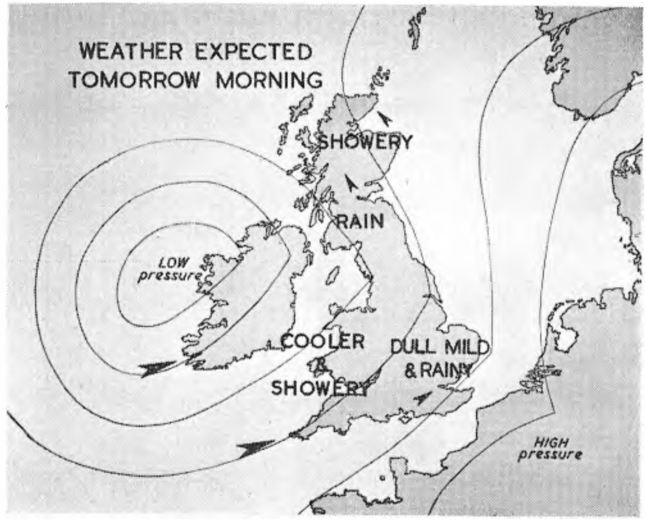
From (32):

$$\frac{dV_o}{dR_L}\cdot\frac{R_L}{V_o} = \frac{C - R_L\{R_3\mu_p R_1 + \Sigma R(R_1+r_{as}+\mu_s R_4 - R_4 - R_5 - r_{ap}) - R_1^2\}}{C} \quad \ldots\ldots\ldots\ldots\ldots (34)$$

Thus, the ratio of the percentage change of V_o to the percentage change of R_L can be found.

B.B.C. Television "Stills"





HOME BUILT RECEIVERS FOR RADIOLYMPIA

We are pleased to announce that the "Home Built Televisor," designed by Messrs. W. I. Flack and N. H. Bentley, has now been adapted by W. I. Flack for reception of the Sutton Coldfield transmissions. The design is essentially the same as the original receiver for the Alexandra Palace transmissions and the modifications apply only to the sound and vision receiver portions.

Full constructional details are being prepared in a booklet, similar to the existing "Home Built Televisor," which will be published in time for Radiolympia.

The Sutton Coldfield Televisor booklet, the price of which will be 4/6, will include a full list of approved components, all the necessary wiring diagrams, and a simplified wiring diagram.

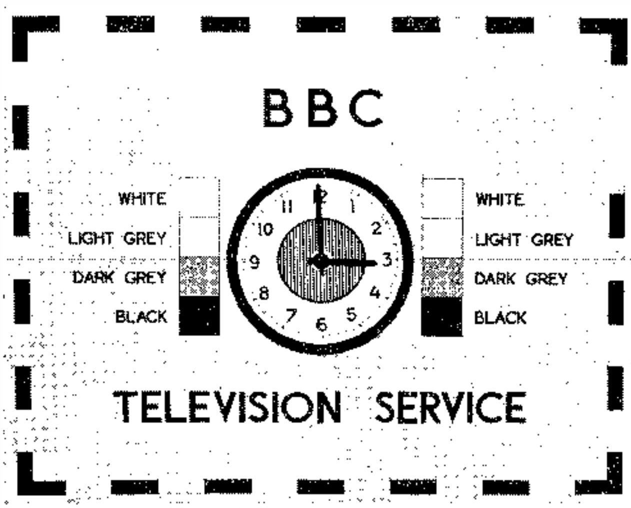
We are also pleased to announce that a High Fidelity Frequency-Modulated Receiver has been designed for us by Dr. K. R. Sturley. This receiver will be suitable for reception of the B.B.C.'s F.M. transmissions to take place from Wrotham this autumn (see *Electronic Engineering*, p. 248, July, 1949). A booklet giving full constructional details of this interesting receiver will be published, and further particulars will be given in the September issue of "*Electronic Engineering*."

It is proposed to publish a design for a "*De Luxe*" Model of the "Home Built Televisor" to give still further improved television reception, together with gramophone reproduction and high quality all-wave reception.

The Sutton Coldfield and Alexandra Palace Home Built Televisors, the Frequency-Modulated Receiver, and the "*De Luxe*" Edition of the Home Built Televisor will all be displayed on Stand 155 at the forthcoming Radiolympia.

Weather forecasts for television viewers will be inaugurated on July 29th, 1949. They will be prepared by the B.B.C., in collaboration with the Meteorological Office, and the spoken forecast will be illustrated by two charts specially designed for the television screen. One will show prevailing conditions, and the other those forecast for the following day. Samples of the charts to be used are shown at the top of this page.

The B.B.C. also announces the alteration of the tuning signal radiated for five minutes before each programme. As will be seen from the illustration of the new signal below, the changes comprise the addition of a clock face in the centre and lettering to indicate the correct shade of the contrast gradations.



CORRESPONDENCE

Variable Frequency R.C. Oscillators

I have read carefully through the letters from Mr. Parton and Mr. Roorda, checked the analysis performed by the latter and re-calculated the attenuation ratios and frequency coefficients for 3, 4, 5 and 6-stage R.C. networks as given in Mr. Parton's letter.

In my list of attenuation ratios there are two correct results and two with relatively small errors, caused by making rough approximations.

As regards my table of frequent coefficients, the figures are in error by a factor of two, although the original network analysis which I made, and which is repeated in an abbreviated form below, leads to precisely the same general results as those obtained by Mr. Roorda, using an entirely different theoretical approach.

Regarding the more practical points raised by Mr. Parton, the 25-17,000 c/s. oscillator shown in Fig. 4 uses a 5-step R.C. network, the nominal maximum variable capacitance being 500 pF. The frequency-coverage figures shown are practical, measured values. The resistors used are of 10 per cent tolerance and were not specially selected.

Differences between the observed and the theoretical frequency coverages are due primarily to the phase shift occasioned by the grid stopper resistance and the input capacitances of the cathode follower and first amplifier valves. At the low-frequency end of the range, coupling capacitors and associated grid resistors cause additional phase displacement and reduction of frequency.

I am indebted to both correspondents for pointing out the errors in my paper and appreciate very much the amount of work they have done in order to correct them. At the same time, I am anxious to re-assure readers of the practical soundness of design of the oscillators described, notwithstanding my mistakes in the exposition of the theory.

Analysis of Generalised Ladder Network

(See "*Electric Circuits and Wave Filters.*" A. T. Starr, p. 73, 1934 edition.)

In the figure below, let

a = series impedance element

$b = \frac{1}{y}$ = shunt impedance element

y = shunt admittance element

By inspection, the input impedance is seen to be:

$$Z_{in} = a + \frac{1}{y+}\ \frac{1}{a+}\ \frac{1}{y+}\ \frac{1}{a+} \text{ etc.}$$

The successive even convergents to this continued fraction are:

$$C_2 = a + b; \quad C_4 = \frac{a^2 + 3ab + b^2}{a + 2b}$$

$$C_6 = \frac{a^3 + 5a^2b + 6ab^2 + b^3}{a^2 + 4ab + 2b^2}$$

$$C_8 = \frac{a^4 + 7a^3b + 15a^2b^2 + 10ab^3 + b^4}{a^3 + 6a^2b + 9ab^2 + 3b^3}$$

$$C_{10} = \left\{a^5 + 9a^4b + 28a^3b^2 + 35a^2b^3 + 15ab^4 + b^5\right\} \div \left\{a^4 + 8a^3b + 20a^2b^2 + 17ab^3 + 4b^4\right\}$$

$$C_{12} = \left\{a^6 + 11a^5b + 45a^4b^2 + 84a^3b^3 + 70a^2b^4 + 21ab^5 + b^6\right\} \div \left\{a^5 + 10a^4b + 35a^3b^2 + 51a^2b^3 + 39ab^4 + 5b^5\right\}$$

The odd convergents are of no interest here.

The above expressions represent the input impedances of increasingly complex networks.

The transfer impedances and attenuation ratios for each are given by the successive numerators of the even convergents, divided respectively by b^{n-1} and b^n.

Writing down the complex attenuation ratios and, for the R.C. network, setting $a = R$, $b = 1/j\omega C$ and writing $\alpha = \omega CR$, we have, on separating the real and imaginary parts:

A_3 = attenuation ratio for 3-stage circuit

$$= 1 - 5\alpha^2 + j\alpha(6 - \alpha^2)$$

For 180° shift, the coefficient of j is zero and $\alpha^2 = 6$.

The attenuation is thus $A_3 = -29$ and the frequency is given by $\omega^2C^2R^2 = 6$.

$$\text{Hence } f = \frac{\sqrt{6}}{2\pi CR} = \frac{0.3898}{CR}$$

The complex attenuation ratios for 4, 5 and 6-stage networks are given by:

$$A_4 = \alpha^4 - 15\alpha^2 + 1 + j\alpha(10 - 7\alpha^2);$$

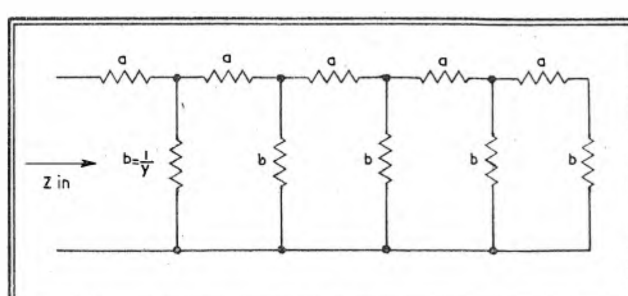
$$A_5 = 9\alpha^4 - 35\alpha^2 + 1 + j\alpha(15 - 28\alpha^2 + \alpha^4);$$

$$A_6 = -\alpha^6 + 45\alpha^4 - 70\alpha^2 + 1 + j\alpha(21 - 84\alpha^2 + 11\alpha^4).$$

Evaluating the attenuation ratios and frequency coefficients from these equations, the following figures have been tabulated for comparison with those given in the above letters:

Steps	Attenuation Ratio	Frequency Coefficient
3	—29	0.3898
4	—18.387	0.1902
5	—15.427	0.1176
6	—14.116	0.0810

It will be seen that, even when the utmost care is taken over these computations, there are still small discrepancies between the figures derived by Mr. Parton, Mr. Roorda and myself. The variations arise because there are small quantities involved which are the differences between relatively large quantities, a condition which makes for large percentage errors in the results.



General ladder network

(Referred to in letter from F. Butler.)

It may be of interest to point out that the product of the frequency coefficients for an *R-C* ladder and for its inverse *C-R* network is a constant. This fact is not generally known, although it is evident from the table given by Mr. Parton, in which the product in question is approximately 0.02535. The precise value of the constant should be $1/4\pi^2$, *i.e.*, 0.02533.

F. Butler.

Wave Analyser Performance

Dear Sir,—In your May issue, Mr. N. F. Barber discusses methods of overcoming the inherent limitations of Wave Analysers and other types of Panoramic Display. His approach may be summed up thus: The factor *K* (relating sweep rate and filter width) is increased, and the resulting distortion allowed for by applying correction factors.

For normal purposes, *K* is taken as < 0.5,[1] at which value the distortion is negligible, and correction is unnecessary. An increase to $K = 1$ involves a small amount of distortion which might be considered negligible for many purposes. Further increases in *K* introduce a highly complex "ring" distortion, and correction becomes essential.

Taking one case quoted by Mr. Barber, if $K = 4$, the effective bandwidth is doubled. If, however, the *actual* bandwidth were doubled, *K* would be reduced to unity. No corrections would be necessary, and the sweep could be the same. There seems no point, therefore, in raising *K* to 4.

Mr. Barber shows that the optimum value of *K*, giving the minimum effective filter width, is in the region of 8. The minimum effective bandwidth so obtained is, however, only 20 per cent less than that obtained with $K = 1$. The advantage gained is thus small, even in the optimum condition.

The analysis also fails to consider the minimum useful frequency to which the sweep can extend. Reference is, in fact, made to a sweep from 0 to 10 Kc/s. in 100 seconds. The sweep rate would be 100 c/s/s. for a linear sweep, and it is doubtful if the range below 200-300 c/s will be of much value.

The difficulty here may be resolved by use of a log. law sweep.[1,2] This also enables the sweep time to be reduced, especially if arrangements can be made to alter the filter width to maintain constant *K*. A good example of an instrument using this principle is the American "Sonic Analyser" (Panoramic Radio Corpn.) which scans from 40 c/s to 20 Kc/s in one second. The *K* value is greater than unity, but the filter is designed so that the ring distortion is kept to a minimum.

G. L. Hamburger has proposed the use of a hyperbolic law sweep. (Discussion on Ref.[1]) This is based on analysing filters of constant Q.

These methods of improving the sweep time involve no tedious corrections to the readings, and have proved suitable for most practical requirements.

Yours faithfully,

D. W. Thomasson.

References.

1 "The Principles and Practice of Panoramic Display." D. W. Thomasson. *J.Brit.I.R.E.* VIII, 4,171, p. 154.

2 "An Automatic Response Curve Tracer." G. L. Hamburger. *Ibid*

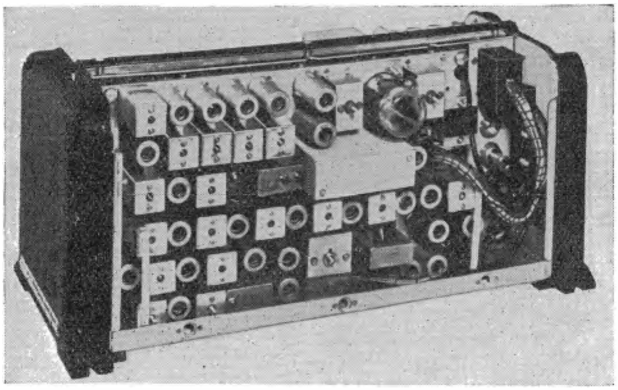
Mr. Barber replies:

Mr. D. W. Thomasson ignores the distortion which occurs at a value K = 1. *From the response curves given in Fig. 1 of my article or from the curve of Fig. 4, it will be seen that at* K = 1 *the bandwidth is effectively 30 per cent greater than its normal value. There is also an appreciable lag in the peak response. The argument therefore, stands as follows: a filter working at* K = 4 *with unit nominal pass band has an effective pass band of 2 units. At the same rate of change a filter with a nominal pass band of 2 units would be working at* K = 1, *and have an effective pass band of 2.6 units, 30 per cent greater as my curve of Fig. 5 indicates. The distortion moreover is still appreciable, the lag of the peak response being 0.35 of the effective bandwidth or 0.9 units. This is not much less than the lag of the peak response of the narrower filter which is 0.6 of its effective bandwidth, or 1.2 units. It is misleading therefore, to suppose that because there is no obvious "ringing" at* K = 1 *the distortion is quite negligible compared with that at* K = 8 *where the "ringing" becomes obvious. If Mr. Thomasson finds in practice that he need make no correction in frequency and amplitude at* K = 1, *I think this is because he has arranged his scanning system to maintain a constant rate of sweep so that* K *is constant and the frequency error is uniform throughout the scale and may be set right by a small shift of the frequency scale. Similar techniques applied to a system using* K = 8 *would provide an automatic correction with 30 per cent better resolution in the same time.*

My aim in the recent article was to show that "ringing" is not a mysterious phenomenon involving unknown errors and that one may as well take any advantages it offers. A simple rule is as follows: if a spectrum is to be explored at a rate of x *c/s. per second the best resolution obtainable is* $\sqrt{x}$ *c/s. effective bandwidth and is achieved by using a filter with a nominal bandwidth of about 0.36* $\sqrt{x}$ *c/s. though any value between* $\frac{1}{4}\sqrt{x}$ *and* $\frac{1}{2}\sqrt{x}$ *is almost as good.*

My findings do not at all detract from the value of the interesting articles by himself and by Mr. G. L. Hamburger that Mr. Thomasson has cited. I have in fact provided an answer to Mr. Hamburger's complaint that "the law of frequency sweep versus time for a display comprising several octaves cannot be stated unless the actual response curve is known, and we have made up our minds as to what distortion we can tolerate." The distortion at K = 1 *is appreciable and if one is to work at* K = ½ *where the distortion is small it means a considerable waste of time. By working at a uniform value* K = 8 *either with a linear scale and constant bandwidth, or with a hyperbolic time scale and constant* Q *the power and frequency corrections are uniform throughout the analysis and are provided automatically by a shift of the scales. The analysis at* K = 8 *is obtained in about one-third the time of a similar analysis made at* K = ½.

A point I did not make in the recent article is that there is appreciably less breakthrough of unwanted frequencies at high K *values than at low ones. It is interesting too that for some purposes the form of the "ringing" at very high* K *values of 25 or 100 has special advantages. I may be able to make these points in a later article.*



Electronic

A monthly record of British elec-
accessories, compiled from information

G.E.C. Fixed-Mobile F.M.

THE transmitter-receiver pictured above is used in the mobile stations of the new G.E.C. multi-station F.M. system. In a typical arrangement there are three fixed stations, a master and two links (or satellites), using a total of two or four frequencies, depending on whether land-lines are available from the links to the master.

Due to the extra path length of the signal going via a link transmitter to a mobile station, the direct transmission from the master station has to be delayed by 5μS per mile so as not to arrive in anti-phase at equal signal strength areas, where serious distortion would otherwise occur.

G.E.C., Ltd.,
Magnet House, Kingsway, London, W.C.2.

L.F. Oscillator

(Photo below)

THE Edison Swan Electric Co., Ltd., have introduced a new low frequency oscillator designed for testing, calibration, and set-up of biological amplifiers, recorders, strain and vibration recorders, and low frequency wave analysers.

It has a resistance/capacity circuit of special design with automatic amplitude control to ensure constant output and good waveform at frequencies from 1.1 to 5,000 c/s. The circuit is remarkably free from trouble associated with change of valve characteristics, ensuring that accuracy is dependent upon only the frequency selective network components.

An incremental frequency switch is included specifically for the measurement of Q in frequency selective circuits of filters or wave analysers.

Edison Swan Electric Co.,
155 Charing Cross Road, London, W.C.2.

E.T.A. I.F. Transformers

TWO types of permeability trimmed I.F. transformers have been produced by Electro Technical Assemblies, the IT11 (with grid lead on top) which is critically coupled, and the IT12, which is overcoupled for feeding a standard diode circuit. Silvered mica fixed capacitors are used, and the whole assembly is impregnated to ensure stability of characteristics. The trimming screws are brought out at the side of the screening can so that alignment can be carried out above the chassis.

The transformers are 1⅛ inches in diameter by 2½ inches tall, and have fixing lugs at 1½ inch centres, so that they conveniently mount over an international octal size chassis hole. Frequency range is 450-480 Kc/s, and a Q of 110, with can in place, is claimed.

Electro Technical Assemblies,
West Hill, St. Leonards-on-Sea, Sussex.

The Alpha Leakproof Battery

(Sketch on right)

THE Alpha Leakproof Cell (British Patent No. 531237), remains absolutely as new during its shelf life; it will not leak, withstands rough handling and wide temperature variations and has a greatly increased store life, say the manufacturers.

These advantages are obtained by the use of specially selected materials and a doubly insulated and doubly sealed steel container which completely encases the cell, so that it cannot leak. Alpha Accessories, Ltd., will replace not only the battery, but also any torch which may be damaged as a result of such a cell proving to suffer from defects common to ordinary batteries.

Alpha Accessories, Ltd.,
Hayes, Middlesex.

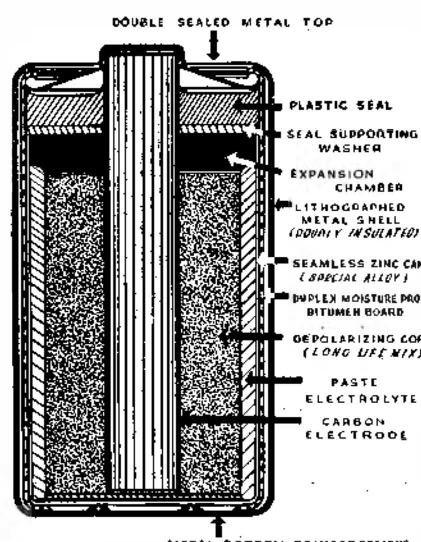
Shaded Pole Motor

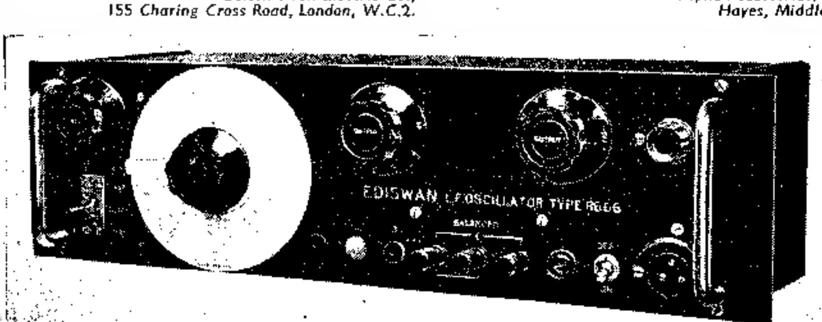
BIRMINGHAM Sound Reproducers', Ltd., models S.R.1 and S.R.2 shaded pole motors have been designed to give silent and trouble-free running in such applications as gramophone motors, wire and tape recorder drives, fan and timing mechanism motors. They will stand heavy overloads, and for intermittent ratings are capable of giving up to twice the rated power. The rotor bearings are the self-aligning graphite bronze oil-less type.

Specification

	Type S.R.2	Type S.R.1
Watts (light) ...	17	21
R.P.M. (light) ...	2,750	2,750
Starting torque (ozs.)	1.7	2.3
Full load torque (ozs.)	2.0	3.0
Full load r.p.m. ...	2,000	2,000
Weight (lb.) ...	1.7	2.31
Shaft diameter (inches) ...	0.1875	0.1875

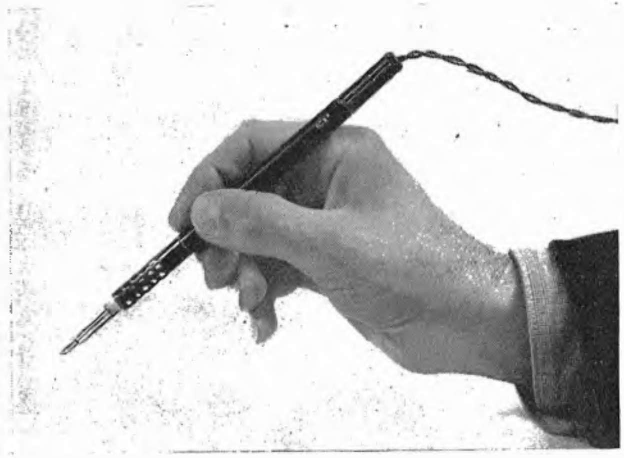
Birmingham Sound Reproducers, Ltd.,
Claremont Works, Old Hill, Staffs.





Equipment

tronic apparatus, components and supplied by the manufacturers.



Spearette B7G Valve Extractor
(Illustrated on left)

A NEW B7G miniature valve extractor is being manufactured by the Spear Engineering Co., Ltd. The device shown in the photo is pushed over the valve it is required to withdraw, and this is held firmly by a rubber compression ring inside the cylinder. When the valve is free, it is pushed out of the extractor in the same direction, *i.e.*, top first. A further model for B8B or B8G valves will become available shortly.

Spear Engineering Co.,
Titan Works, Warlingham, Surrey.

The Ekco Solder Pencil
(Illustrated above)

THE Ekco Solder Pencil, a miniature soldering iron of special value in the making of miniature and sub-miniature electronic equipment, has recently been placed on the market. Neat in design, light in weight, it can be comfortably handled all day without overheating, and its power consumption is low either from battery or with transformer on mains operation. A welcome feature is the heating of the bit to soldering temperature, from cold, in fifty seconds.

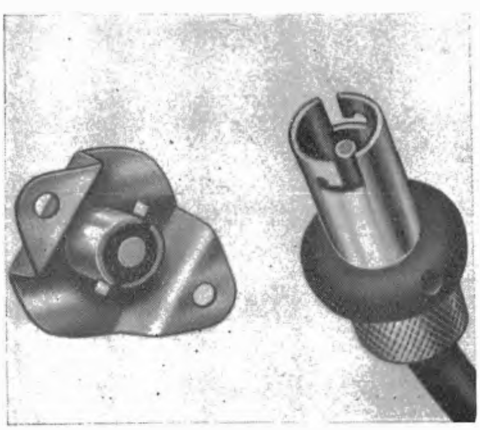
E. K. Cole, Ltd.,
Southend-on-Sea, Essex.

Co-axial Connector
(Photo below)

A SPRING-LOADED bayonet type co-axial plug and socket have been produced by Aerialite, Ltd. They are interchangeable with standard British and American car radio connectors, and will take co-axial cable sizes $\frac{1}{8}$ inch to $\frac{5}{16}$ inch outside diameter. No soldering operation is required to fit the plug.

The socket is fitted to the instrument or set by nuts and bolts or rivets. All parts are nickel-plated brass, except the contacts, which are silver plated.

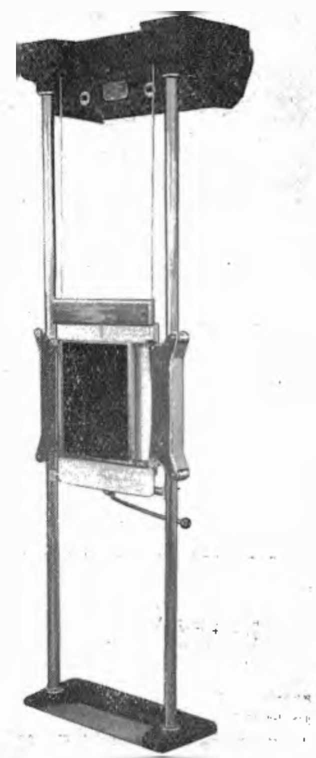
Aerialite, Ltd.,
Castle Works, Stalybridge, Cheshire.



Hills Automatic X-ray Exposure Control
(Illustrated on right)

THIS unit has been developed in collaboration with Dr. T. Hills, of Guy's Hospital, and is intended for precision mass-radiography, particularly chest work, using full-sized radiographic equipment, as opposed to miniature techniques. A photo-cell circuit monitors the intensity of X-radiation falling upon the photographic film contained in a cassette, and the exposure time is adjusted automatically to provide a constant exposure of the photographic medium, and thus gives a uniform density and graduation to all negatives. The control is fully automatic, affording a very considerable speeding of routine diagnostic radiography, as trial exposures and adjustments are eliminated, and a group of patients can be radiographed in quick succession. Furthermore, a series of radiographs obtained over a period of time on one subject are all of standard densities, thus facilitating the recognition and study of small tissue changes over a considerable time interval. A further valuable feature is that variations in the output of the X-ray tube caused by mains input fluctuations, etc., are also compensated for instantaneously by the control circuits. It is recommended to obtain the full benefit of the automatic control, that the darkroom processing be rigidly standardised upon a time and temperature basis.

Alltools, Ltd.,
2 Transport Avenue, Great West Road,
Brentford, Middlesex.



BOOK

Records and Research in Engineering and Industrial Science

A Guide to the Sources, Processing and Storekeeping of Technical Knowledge—with a Chapter on Translating. By J. Edwin Holmstrom. Second revised and enlarged edition. XII, + 366 pp. Chapman & Hall, Ltd., London, 1947. Price 21s. net.

THE large interest in the organisation of the scientific and technical information service found its expression by the formation, on the part of the Government, of a "Panel on Technical Information Services of the Committee on Industrial Productivity" in December 1947 and by the convening of the "Royal Society Scientific Information Conference" held in June/July 1948. The author of the book under review is a member of that Government panel and not only contributed three papers to the conference but acted also as editor of its section III dealing with "Indexing and other Library Services."

The book which appears now in its second edition was first published in 1940 when it was greeted as a comprehensive and admirable guide to sources of information and its great value to business men, scientists, engineers, teachers, consultants, abstractors, translators, indexers and librarians was rightly stressed by the scientific and technical press. As the first edition appeared early during the war many of those interested in the subject may not have had an opportunity to get acquainted with its contents and, therefore, a brief review of the second edition will not be out of place.

A characteristic feature of the book is a chart representing the whole field of "documentation" which serves for collecting and distributing scientific knowledge from hypotheses found by speculation to the application of a final product by the ultimate consumer. These charts are printed on the two end papers and some of the chapters, especially the second, are devoted to their detailed explanation.

The introductory chapter shows by the help of a well-chosen example how knowledge is pooled from different sources. But it also stresses that "every question scientifically answered gives rise to others" and that "the goal of perfection is continually being approached but never reached." Examples are given of the attainment of scientific knowledge by controlled experiment, controlled sampling and controlled guesswork and how the results of such research are collated by individuals and by organised bodies.

The following chapters, besides explaining the charts, show the successive phases in scientific work whereby new knowledge is obtained, recorded, distributed, stored, selected and applied to practical ends. The planning of research projects usually takes its start from measuring the properties of the materials to be used so that a solid foundation is obtained for the design whether it be for a large work of civil engineering or a manufacturing process. The importance of accurate gauging for mass production is stressed.

Then the various kinds of tests are analysed. They may be of an analytical nature or may be carried out in a simulated or an actual performance. Statistical methods play their part in the examination of the results. The tests may be destructive or non-destructive. In some cases indirect test methods may be used. Examples are given for all these kinds of tests. A broad acquaintance with fundamentals is essential as knowledge in one branch of science may be necessary for progress in an entirely different branch.

Standardisation on an internal, national or international level may lead to a considerable saving of costs by copying what has been found to work best. But it must not be done prematurely and provision for future revision must be made.

The linkage between the physical and the human is formed by the production management. Those responsible for it must not be specialists but should have a wide scope of interest and a variety of skill on one side and be leaders of men on the other side. Manufacturing processes may be rationalised, e.g., on the basis of motion and time studies. A sound method of cost accounting must fulfil among other tasks that of an equitable allocation of overhead costs.

A somewhat brief section deals with inspection. The routine testing of boilers, engines, electrical plant, etc. ("the conscience of the concern") is in fact not only very important for the safety of the user but frequently furnishes valuable contributions to improvements in design and manufacturing processes.

The author then deals with inventions, patents and planning. In deciding whether an invention merits to be carried into effect some kind of "com-

REVIEWS

mercial research" is indispensable. The procedure in acquiring patents is briefly dealt with and some controversial questions as regards patent politics are mentioned.

In assessing the knowledge value of the results achieved practical experience is of paramount importance.

Chapter III is the longest and enumerates and characterises the experimental organisations in Great Britain, suitable for providing "Primary data by experiments, tests and analyses." Some interesting figures are given relating to the expenditure of the various institutions, to the ratio between university students and population in different countries and between the number of advanced students to the total number of students. The research fellowships endowed by industrial firms are mentioned and the specialised fields on which research is carried out at different universities are listed. Then the activities of the Government research stations under the administration of the Department of Scientific and Industrial Research, e.g., the National Physical Laboratory, are described in detail. The trade research associations, the research institutions of the defence services and other government departments and those of industrial concerns like I.C.I., G.E. Co., Ltd., and others, are discussed. Finally those dealing with production and personnel are dealt with and the part played by psychotechnics is mentioned.

The next chapter deals with British collative organisations under which heading the unspecialised and specialised learned societies, the standardising institutions, the development organisations, the classification societies and the like are described.

Chapter V, which in the first edition was combined with the preceding one, describes the respective international and foreign organisations. The author is correct in stating that an amplification of this chapter might be desirable. What is said about Russia and Germany is of necessity somewhat sketchy. But especially in France much research work is done and documentation is on a high level at least in some branches of engineering, to which facts reference might be made in a later edition.

The two following chapters are in the author's opinion the most important of the book as the collection of data from technical literature (Chapter VI) and the methods by which facts and ideas may be sorted and integrated (Chapter VII) are relatively neglected branches of scientific work.

To bring the numerous original publications in periodicals, specific reports, books, works of reference, patent specifications, catalogues, etc., to the knowledge of those interested abstracting services are indispensable which tell the worker which are the most promising references and save him from wasting time. A very useful list of such abstract series is given together with a key indicating their character. The work of A.S.L.I.B. and similar bibliographical associations and some of the more important libraries are described. The important fact that nearly 22 millions of books inclusive of those of the Science Museum Library are obtainable through the National Central Library from any of the numerous local libraries is presumably very little known.

Some useful hints are given on note taking and a dozen of different suggestions are made on the use of publications, in which connexion Bacon's saying is quoted "To spend too much time in study is sloth."

Cataloguing, analytical indexing and index filing are explained in Chapter VII and it is shown how the requirements and methods differ for indexing a central library, a special library or information bureau and index filing by an individual who uses his personally selected material for aiding the development of his own ideas. Special classification systems are described, e.g., that of the Science Library, the Universal Decimal Classification, the Kaiser system with its "concrete" and "process" terms, the advisable methods for organising an efficient information service within an organisation. After describing his own system of index filing, the author shows how such a system is well adapted for the integrating of ideas to form new knowledge. A few remarks are made about patent classification and on various methods of automatic sorting of indexing cards.

Chapter VIII under the title "the expression and transmission of facts and ideas" deals with graphic representations, mathematics, speaking, writing, dictating, typewriting and duplicating, photographic reproduction and—as the latest development—with the microfilm service. Also a few paragraphs are added on printers and publishers. In giving good advice, the author rightly stresses the desirability of terse, precise and purposeful expression in speaking and writing and gives some examples of good and bad style.

The book ends with two brief chapters on foreign languages and their translation and on the technician as

BOOK REVIEWS *(continued)*

a person. The author gives some helpful hints on the learning of languages, on the procedure in translating and on technical dictionaries. The existence of the "A.S.L.I.B. Register of Specialist Translators," mentioned in a preceding chapter, merits certainly to be more widely known.

Questions of education and training, conditions of work and salaries are briefly dealt with and a list is given of firms providing trainee schemes for engineering graduates.

The book is well printed and author and publisher can be congratulated on having produced such a readable book with such a vast amount of useful information. It can be strongly recommended not only to all those interested in the wide field of documentation but also to every engineer and scientific worker engaged with original or literary research.

R. NEUMANN.

The Instrument Manual

548 pages + cxiii. (United Trade Press Ltd., 24, Bride Lane, Fleet Street, London, E.C.4), 70s.

ANTICIPATING the first query, the editor of this book has defined his subject as "devices to facilitate observation, make measurements, record data and manually or automatically control processes." Apart from the handbook issued by the Physical Society of Scientific Instruments shown at their annual exhibition, there has been no British directory of these instruments. The book under review sets out to provide such a guide to the industry and is intended for those who have applications for measurement or control apparatus rather than those concerned in its design. The Instruments described range from a simple micrometer to an electron microscope, and in addition there is a long chapter in which Automatic Controls from a diaphragm valve to a complete industrial air conditioning plant are described. The book is divided into twenty-one sections and most of these are concerned with the measurement or control of a particular function or characteristic such as temperature, pressure, humidity, specific gravity, time, *p*H and fluid flow. One of the most interesting of these chapters is entitled "Instruments for the determination of Compositional Quality," and this discusses emission spectroscopy, absorption spectrophotometry X-ray diffraction, electron diffraction, mass spectrometry, radiography and gas analysis including infra-red absorption and recording calorimetry. In covering such a wide field the treatment can of course only be very general, but compensating for this, an important feature of the book is the bibliography of recent work, a list of relevant B.S.I. specifications and a Buyer's Guide at the end of each section.

Bearing in mind that a book of this type, to be useful, must provide reference information to the specialists in their own fields, some of the sections are rather sketchy. The chapter on *p*H measurement, for instance, gives a good account of the elementary principles of the subject, but misses a good opportunity to bring industrial chemists, and others interested, up to date with the equipment available. It would have been useful to have recorded the formulæ and tables of E.M.F.s that are required to calculate out the *p*H values or alternatively to include something about the functioning and versatility of the new direct reading *p*H meters. The chapter on Optical Instruments could have left out some pictures of microscopes and mentioned a few of the many other optical instruments (such as the profile projector) that have important industrial applications.

The majority of instruments and control gear described are mechanisms and although electronic devices are not ignored, the authors are evidently more acquainted with precision light engineering than with electrical engineering. The vacuum mercury tube switch is a useful instrument component, and the chapter on Automatic Control makes great use of it, but the diagram on page 410 needs at least one more line to make the circuit feasible, and quite a lot more to make it useful. The electronic engineer will find very few circuit diagrams in the book and be disappointed in the subjects chosen for the section entitled "Review of Progress in Electronic Devices." It is felt that some mention of the electric servo mechanisms and the applications of magnetic amplifiers would be more in keeping with the aims of the book than the descriptions of the magnetron, klystron and communication techniques. The reference to "Stratovision" seems to be particularly out of place when so much development in instrument practice could be recorded In the first edition of such a collection of information there are bound to be some typographical errors; two or three of these were noticed among the Temperature Conversion factors on page 224.

The book is well illustrated with hundreds of diagrams showing the elementary principles of the various instruments described, and the text has been written in simple descriptive language assuming little technical knowledge on the part of the reader. A directory of British Industrial and Scientific Instruments could fill several volumes of this size and it is therefore easy to think of items that have been left out, but the considerable effort represented by this book has resulted in a useful start to a Standard directory.

W. R. CONWAY

The Radio Amateur Handbook

26th edition. 605 pages. (The Rumford Press, New Hampshire, U.S.A.), $2.

THE Radio Amateurs Handbook, an annual publication by the American Radio Relay League, is well known to British amateurs among whom it has acquired a well deserved reputation as a standard manual and reference book. It covers every aspect of amateur activity and its treatment of radio communication theory is directed towards speedy application rather than abstract discussion.

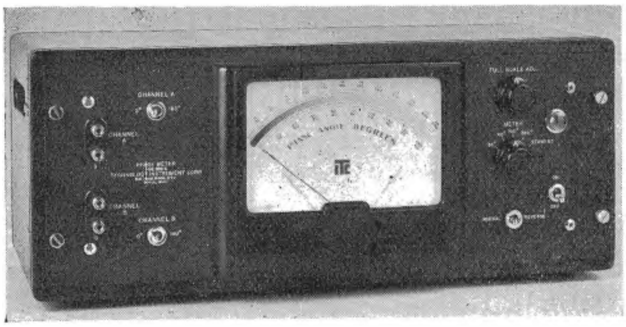
In traditional style the first four chapters are devoted to the history of amateur radio, electrical theory, including valves, and the principles of high frequency communication. The next 20 chapters, as in previous editions provide designs for modern transmitters, receivers, and aerial systems, together with constructional details of useful apparatus which will assist in their assembly and maintain and test their performance. The final chapter of 51 pages provides that valuable feature, which is always associated with this publication, of the tabulated operating conditions of many hundreds of transmitting and receiving valves.

In the 1949 edition the section on power supplies now includes some useful curves on capacitance input filters and to the chapter on antenna and transmission lines has been added graphs of director, antenna, and reflector lengths for three element beams. The last chapter too, on vacuum-tube data, has been extended and now covers subminiature and cavity magnetrons. Alterations have been made in presentation, in index and text, but the modifications are small when viewed against a background of 605 pages. The reviewer consequently would strongly recommend the purchase of this 26th edition to any amateur not already in possession of the 25th.

K. R. STURLEY

Made in America

Being a selection of American electronic equipment and products, with notes compiled from the manufacturers' data,



The Type 320-A Phase Meter

(See above)

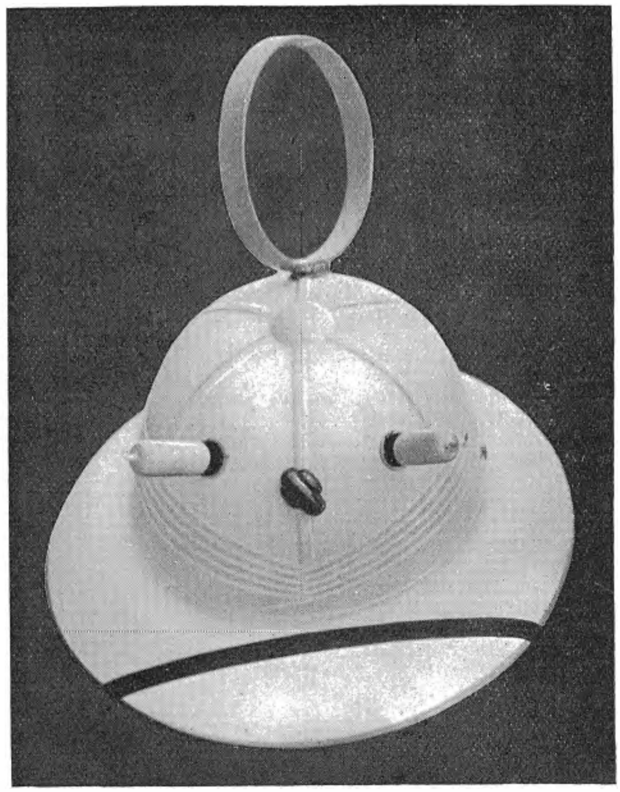
THE type 320 phase meter is a completely electronic instrument for the direct measurement of the phase difference between two voltages.

Direct readings of phase angle without ambiguity are indicated on a large meter which has four full-scale ranges of 360°, 180°, 90° and 36°. In addition, 180° phase reversing switches for each channel are provided The instrument is designed for operation at audio and supersonic frequencies and, with some sacrifice of accuracy, may be used at sub-audio frequencies. Its operation is essentially independent of applied voltage, wave shape and frequency, and no adjustments, balances or corrections are involved.

The operation of the phase meter is based on pulse methods. The two signals being compared are converted into two trains of short pulses which are located at the zero-axis crossings of the respective signals. The time displacement between the two pulse trains is indicative of the unknown phase angle. The pulse trains are fed into a "flip-flop" circuit which measures the ratio of the time displacement to the pulse-repetition period. For a given phase difference, this ratio is independent of frequency, and the meter is therefore direct-reading at all frequencies within the operating range.

Copies of a descriptive folder giving full details of the phase meter are obtainable from:—

Technology Instrument Corp.,
Waltham,
Massachusetts.

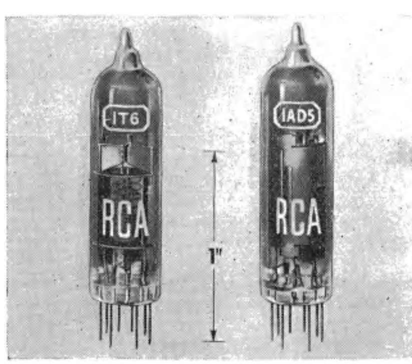


RCA Subminiature Valves

(Photo below)

R.C.A. has just offered to equipment designers a series of "subminiature" valves consisting of four types—a power pentode 1AC5, a sharp-cutoff pentode 1AD5, a pentagrid converter 1E8, and a diode-pentode 1T6. The 1AD5 and the 1T6 are illustrated.

These four types provide a complete range for the design of compact, light-weight, portable receivers operating in the standard A.M. broadcast band and having low A-battery drain



—only 0.040 ampere per valve.

Constructed with a glass-button 8-pin base sealed to the glass bulb, these subminiature valves have a seated length of $1\frac{1}{2}$ in. and a diameter only slightly greater than $\frac{3}{8}$ in.

Tubes Dept., RCA
Harrison, New Jersey.

The Radio Hat

(Illustrated above)

AN ingenious portable local-station receiver has been designed by the American Merri-Lei Corporation in the shape of a tropical helmet, with the electronic components usually associated with futuristic head-gear mounted prominently on top.

The two valves—coated with a tough plastic for protection purposes—are a 1S5 connected as a modified ultraudion (regenerative) detector and a 3V4 pentode output feeding the single earphone. Power is supplied by an 8 oz. battery pack which is carried in the pocket; a $22\frac{1}{2}$ volt H.T. battery and two $1\frac{1}{2}$ volt flashlight type cells, which should give twenty hours service on intermittent use.

The weight of the Radio Hat is twelve ounces, and it sells in America for less than $8.

American Merri-Lei Corporation
Brooklyn, New York.

NOTES FROM THE INDUSTRY

New Director of the National Physical Laboratory

The Lord President of the Council has appointed Professor E. C. Bullard, M.A., Ph.D., F.R.S., Professor of Physics in the University of Toronto, to be Director of the National Physical Laboratory. It is expected that Professor Bullard will take up the appointment in January, 1950.

Professor Bullard will succeed Sir Charles Darwin, K.B.E., M.C., Sc.D., F.R.S.

British Standards Institution

To deal with further expansion the British Standards Institution has just acquired new premises at 24-30 Gillingham Street, near Victoria Station, and its Sales and Distribution Department will shortly be transferred to that address. It was not possible to obtain suitable accommodation in Victoria Street.

The main offices, council room, library and five committee rooms will remain at Victoria Street, and two additional committee rooms will be provided at the Gillingham Street premises. It is hoped that the rearrangement will be completed by autumn.

B.S.I. 1949 Yearbook

The Yearbook of the British Standards Institution, which has just been published, gives a subject index and a synopsis of each of the 1,500 British Standards now current. These standards have been prepared by representative committees of 55 different industries.

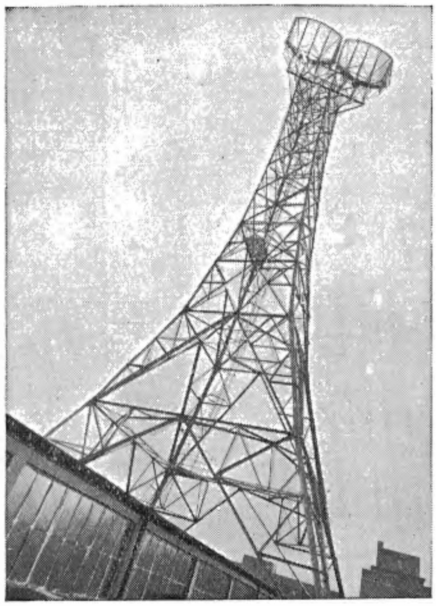
The Yearbook also includes lists of members of the General Council, the Divisional Councils and the Industry Committee of the Institution as well as other useful information about its work. Price 5s. post free, it can be obtained from the Sales and Distribution Department, British Standards Institution, 24 Victoria Street, London, S.W.1.

New Department at Mullard

Mullard Electronic Products, Ltd., are in the process of forming a new department at their works at Aboyne Road, Tooting, S.W.17, for handling vibration equipment for diagnosis and measurement purposes.

The new department will be mainly technical in character and will give advice to prospective users on the most efficient methods of using this technique.

The marketing of vibration apparatus which includes by agreement specialised equipment developed by de Havilland Propellers, Ltd., will also be conducted through this department.



Television Link Terminal

The 100 ft. tower shown in the photograph has been erected by Pirelli-General on the roof of Telephone House, Birmingham, to receive television signals beamed from London by the G.E.C. radio link. The top of the tower is 200 ft. above street level, and the structure weighs 12 tons. The paraboloids, each 14 ft. in diameter, can be electrically heated in winter to prevent icing.

Marconi VHF Installed at A.A. Headquarters

A 60 ft. aluminium tower erected on the roof of Fanum House, New Coventry Street, headquarters of the Automobile Association, carries the dipole aerial of the Marconi VHF radiotelephone system by which the A.A. controls its night breakdown service in the London area. The additional height provided by the tower will increase the operational range of the VHF equipment, and so extend the radius of communication between Fanum House and the breakdown vans. This will allow the Automobile Association's breakdown vans to extend their radius.

Both the fixed and mobile equipments are crystal controlled and are of 10 watts power output. They are as simple to operate as an ordinary telephone and provide constant communication between the vehicles and their headquarters, and enable the vans to be directed immediately to the help of A.A. members in trouble.

Midlands Television Aerial System on Test

The sound and vision aerial system for the Sutton Coldfield station of the B.B.C. television service, which has been manufactured by Marconi's Wireless Telegraph Co., Ltd., to B.B.C. specification, is now undergoing tests at the Marconi company's works at Chelmsford.

This aerial system consists of eight dipoles which are fed by both the vision and sound transmitters through a combining unit. By this method a single aerial system can be used without mutual interference between the two transmitters. Under test the aerial system has been loaded with 35 KW vision and 12 KW sound power.

An integral part of each of the dipoles is a system of channelling designed to carry away rain and, in order to test this system, the aerial array has been fully loaded with sound and vision power and a Fire Service hose used to play water over the whole structure for a long period. It has thus been subjected to a downpour, far in excess of anything it is ever likely to encounter after erection, with complete success.

At Sutton Coldfield this aerial system will be mounted at the top of a 750 ft. mast. (*See frontispiece.*)

Kelvin and Hughes, Ltd.

The manufacturing activities of Kelvin Bottomley and Baird, Ltd., and Henry Hughes and Son, Ltd., are being transferred to their joint holding company, Kelvin and Hughes, Ltd., in whose name the factories at Hillington (Glasgow), Basingstoke and Barkingside will now operate.

All future invoices should be addressed to Kelvin and Hughes, Ltd., and sent in duplicate to the factory to which the goods are delivered; statements should be sent direct to the Central Accounts Department, New North Road, Barkingside, Essex.

Change of Address

Steatite and Porcelain Products announce that as from July 4, they are transferring their London office to Victoria Station House, 191 Victoria Street, S.W.1 (Telephone No.: Victoria 7715).

The London office is established primarily for technical service in the London and Home Countries area, and no alteration is intended in their present organisation other than the change of location of that office. Correspondence should therefore still be addressed to their head office and works at Stourport-on-Severn, which deals with all inquiries, quotations and delivery queries.