EDITORIAL COMMENT

Wireless World

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COLOUR TELEVISION PITFALLS

There is a risk that the demonstrations of colour television given recently to Members of Parliament may have been too successful. Quality of the transmission was so good that it might well have provoked the light-hearted and over-optimistic decision that we need look no farther before adopting the British version of the American N.T.S.C. system for our national service.

According to a growing weight of informed opinion, that would be a premature and probably disastrous decision. Nobody denies that the N.T.S.C. system is ingenious and elegant or that the British adaptation of it preserves all the good points of the original. But American experience alone gives the warning signal for extreme caution. In almost every respect colour television in the United States has so far been a failure; the receivers have proved to be too expensive, to require too much maintenance and to be too difficult to adjust. There is no reason to believe that adoption here of the Anglo-N.T.S.C. system in its present form would have a significantly different outcome.

One of the shortcomings of the N.T.S.C. system is that it was planned basically for use with an inherently expensive and complex display device—the three-gun shadow-mask tube. What is still lacking is a cheap and simple display device, which surely must be necessary for an economically practicable colour service. Dr. E. L. C. White, writing in the February *Wireless World*, developed the argument for evolving a system not tied to the three-gun tube.

The question of compatibility inevitably arises. The general belief is that a colour service would be economically impossible in the near future unless it were receivable on existing black-and-white receivers. That is probably true; but, if there is any validity in what we have just said, it is equally true that, as no economically practicable system offers itself at present, there is no prospect whatever of starting a regular service during the next three or four years. If that be so, the question of compatibility becomes of lesser importance. In five years' time, say, the revenue from licence fees may be expected to have reached a figure large enough to support a parallel colour service without any need for compatibility.

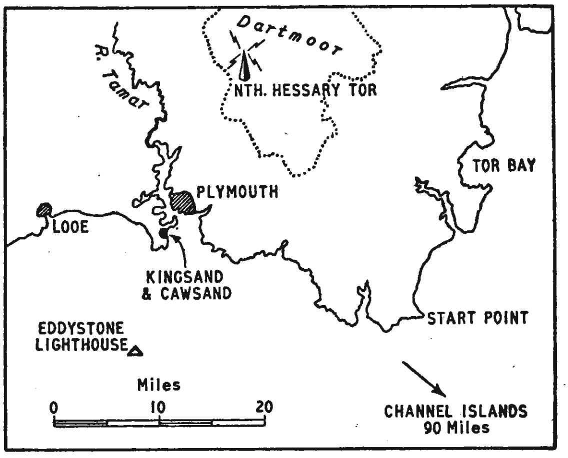
VALVES IN THE LIMELIGHT

Everyone knows—though usually in quite a vague way—that valves are sold in rather a peculiar manner. Sales to manufacturers of broadcast receivers and other equipment are at prices which are disproportionately low in relation to the retail price. The report of the Monopolies Commission, referred to on another page, shows the position to be a good deal more complicated than that. The valve is at the heart of our affairs, and probably nothing but good will come from bringing these matters into the limelight. It has been argued that the policy has been justified by results and that it has helped to keep the prices of all equipment at a low level: further, that the cost of maintaining stocks of replacement valves justifies their price. It is to be hoped that these matters will now be freely debated by all sections of the industry.

Television Interference Problem

BEAT EFFECT ON RECEPTION FROM NORTH HESSARY TOR

By *JAMES P. GRANT*, *Assoc.Brit.I.R.E.*



Map showing the district in which the interfering beat effect is experienced.

WHEN the North Hessary Tor television station came into operation in Channel 2 in December, 1954, reception from the temporary transmitter and 150-ft mast was reasonable in the Plymouth area. However, at Kingsand and Cawsand on the Cornish side of the River Tamar, close under a 450-ft hill which screens the two villages from the transmitter, reception was generally poor. Four-element aerials were necessary, and even then reception was marred by a constant pulsing effect. This took the form of a beat with a repetition frequency of around 40 a minute, giving fluctuating brightness and line pulling.

This effect was generally considered to be a symptom of the low power, low transmitting mast and high intervening hill. Viewing was possible and the inconvenience was endured for 14 months in the belief that the permanent station and high mast would cure the trouble. There was some dismay, therefore, in February, 1956, when the permanent transmitter came into service with the temporary 150-ft mast. The pulsing effect was certainly no better—if anything a little worse. Moreover, when in May, 1956, the main transmitter started to radiate from the high mast, the pulsation was so increased as to make viewing virtually impossible at times.

Rotating radar beacons have been eliminated by practical experiment, and tests indicate a reflection of the Hessary Tor transmission by some unknown object seawards which combines with the direct wave to form a fluctuating signal with a frequency of between 35 and 50 a minute. The reflection is not sufficiently well defined to show a definite ghost, but it has been estimated to be as much as 7% of the main 300-μV signal. The amplitude and speed of the beat vary from hour to hour, from day to day, and between daylight and darkness.

The effect is always present when Hessary Tor is transmitting, but is more severe on high power than during breakdowns and test periods on reduced power. It can be observed only on sites shielded from Hessary Tor by high ground open to the sea and within the limits of Start Point and Looe. It is fairly certain that the beat is present at all sites within this area, but is observable only when the shielding of the direct signal renders the reflection a significant part of the whole received signal. The maximum effect is at Cawsand at about the centre of the affected area, and the intensity of the beat reduces progressively towards the outer limits.

There is no recorded signal throughout the band when Hessary Tor is not transmitting. During severe beating there are ghosts, which successively reduce in intensity and appear to continue to the end of the line scan. Up to nine have been counted, more or less evenly spaced, and they appear to beat separately from the main signal and alternately change their polarity. During slight beating there is only one well-known local ghost.

During the summer a fairly consistent reduction in the beat was observed at dusk, so much so that a severe beat almost disappeared within an hour, only to return when it was quite dark.

Commercial directional receiving arrays have been tried in order to reduce the seaward pick-up, but to achieve this the main lobe must be turned towards the hills and multiple ghosting is exchanged for the beat. Horizontal aerials give only a slight reduction of the reflection. Although about the same distance from Hessary Tor, and having similar terrain, Tor Bay does not seem to suffer from the effect.

Since May, 1956, the Post Office and the B.B.C. have been investigating the problem without reaching any very definite conclusion. The B.B.C. are of the opinion that the beat is caused by a reflection from the surface of the sea. I cannot entirely accept this theory, as it does not account for all the peculiarities and anomalous propagation effects which have been observed during the past two years.

During the extensive observations of the beat in connection with the tide, weather, and atmospheric conditions, only one consistent factor has emerged, i.e., humidity. Reception conditions are good when the humidity is above 80%, and become sharply worse as the humidity drops below this figure. The only exception is when the humidity is 100% during severe sea mist and low cloud conditions, when receiving conditions may be either very good or very poor. (By good I mean practically no beating.)

It is my own theory that the reflection may be from the multiple, long, sloping-wire receiving aerials in the Channel Islands, with a path via the troposphere in each direction. Probably there is also a secondary reflection from the sea, as suggested by the B.B.C.

COMMENT.—*Having felt that the effect described above might be associated with weather conditions, "Wireless World" asked a meteorologist, A. H. Hooper, for his views. These are strictly personal opinions.*

THE experiences of Mr. Grant pose several problems and it is necessary to consider how the receipt of a second and delayed signal at the receiver can lead to variations in brightness. One visualizes either a second signal of constant delay but varying strength, or a second signal of varying delay and of strength which may or may not vary. The former condition leads in general to a fixed ghost picture of varying brightness which, with appropriate delay, may coincide with the main picture and so be indistinguishable. The last-mentioned condition gives a ghost picture drifting across the main picture and fluctuating alternately positive and negative in character as the carrier waves of the two signals alternately add and subtract.

When the reflecting object is stationary variations in signal strength can arise due to propagation changes acting on one of the two paths more than the other, or from rotation or eclipsing of the object in a cyclic manner. If, as it appears, the second signal arrives from a seaward direction then its path clearly passes close to the surface, whereas the direct path to Kingsand is well up in the air until the final stage of diffraction over the nearby hilltop. In such circumstances differential propagation effects appear very probable.

However, it is very difficult to visualize any such effect capable of yielding such rapid and continuous fluctuations as those observed. Examples of fluctuations in reflectivity of a fixed object are: (1) vibrations such as of the limbs of an aerial array—this would vary with wind speed, (2) rotation of radar scanning aerials, and (3) eclipsing of rocks out to sea by waves, although not generally at the rate observed in this instance. Moreover, the last effect would vary with state of tide and sea. It has been suggested that certain aerials on the Channel Islands are reflecting energy back toward the South Devon coastline. These islands, however, lie to the south-east and would also radiate energy towards the Tor Bay area (where beating is not experienced).

The one object lying out to sea and capable of re-radiating energy towards the coastline between Start Point and Looe is the Eddystone lighthouse. This is about 20 deg west of south from Hessary Tor and is within the direct line of sight, which passes right over Plymouth, out over the Sound and between the headlands of either side and then on to the lighthouse. Kingsand lies on the western side of Plymouth Sound, just off this line. Neither Hessary nor the lighthouse is directly visible to Mr. Grant, although the lighthouse would be visible from many coastal sites. The reflected signal could possibly vary with rotation of the lighthouse lantern assembly, but this occurs only after dusk. The distance from Hessary to Kingsand is about 27km direct and about 61½km via the lighthouse, giving a delay of about 1.15 lines. This may, in fact, be one of Mr. Grant's ghosts.

Turning now to the possibility of reflection from moving objects, it has been suggested that this could occur from extensive discontinuities in the atmosphere moving at a suitable steady rate and popularly referred to as meteorological fronts. Although the basic structure of meteorological fronts is in the opposite sense to that required, it happens that a proportion of such fronts are immediately preceded by a shallow layer of suitable structure and in such circumstances reflection becomes possible. With full allowance for marginal circumstances the number of fronts passing over Plymouth and possessing this suitable structure is quite few, with the result that the total possible duration of beating due to their presence is small. One would expect beating to occur occasionally for a few hours prior to the passage of each of such fronts, whereas Mr. Grant reports the effect as being semi-continuous.

Another moving source of reflections is to be found in sea waves and swell. The waves, however, will vary in height, length and direction and would only give optimum scatter for the Plymouth area when travelling to or from the S.S.W. Waves would appear —of equal significance—in Tor Bay, and when due to surface wind would often have substantially the same orientation as in the Plymouth area. As the line of propagation towards Tor Bay is perpendicular to that towards Plymouth one would expect any scatter effect to occur simultaneously at both places but of differing magnitude, with occasional extreme cases occurring on a given occasion in only one of the two areas. For the very long sea-wave lengths due to swell coming in from the Atlantic/Biscay area, it is to be expected that, although present off the Plymouth coastline, they would not penetrate into Tor Bay. Presumably it is necessary to demonstrate that reflections from a vast area of scatter sources can add to give an overall wave train of reasonable approximation to the original.

It has been suggested from three separate sets of circumstances that the beating effect increases with the strength of the main signal and depends upon sufficient amplitude of delayed signal. As already remarked, the ratio of the two signals is very likely to be modified by meteorological conditions. This agrees with the appearance of several ghosts when beating is strong. Thus a boosting of the delayed signal by anomalous conditions near the surface is accompanied by a boosting of the reflections from nearby objects which are normally too weak to be visible. This dependence upon refraction is supported, too, by the summer-time variations experienced about dusk when low-level changes due to the setting sun are occurring.

We are faced apparently with an effect involving movement of reflecting (or scattering) objects. The effect is continuous and is apparent over a considerable length of coast. It is claimed that the delayed signal arrives from the general direction of the sea. In such circumstances the one common feature is the surface of the sea itself. However, the effect does not occur along another coastline in largely similar circumstances. The discernible differences between the two sea areas are the presence both of a prominent reflecting object (a lighthouse) and of long-wavelength swell in one of them. Whether this is significant is hard to say, and one wonders whether similar circumstances exist elsewhere.

AWARDS TO AUTHORS

FORTY articles were submitted last year to the panel of judges for consideration for the Radio Industry Council's technical writing prizes. These are awarded annually with the object of encouraging the publication of clearly written expositions on British achievements in radio and electronics. One 25gn premium is given for each of the following:—

"Weather avoidance with airborne radar" by P. L. Stride (Ekco Electronics); *British Communications and Electronics,* April.

"Particle accelerators and their applications" by D. R. Chick (Research Labs., A.E.I.) and C. W. Miller (Research Dept., Metro-Vick); *British Communications and Electronics,* October and November.

"Klystron control system" by R. J. D. Reeves (E. K. Cole); *Wireless Engineer,* June, July and August.

"Two-channel stereophonic sound systems" by F. H. Brittain and D. M. Leakey (G.E.C. Research Labs.); *Wireless World,* May and July.

"Tridac—a research flight simulator" by J. J. Gait (R.A.E.) and J. C. Nutter (Elliott Bros.); *Electronic Engineering,* September and October.

WORLD OF WIRELESS

Organizational, Personal and Industrial Notes and News

Colour Television

FOR the benefit of members of Parliament special colour television programmes were recently transmitted by the B.B.C. using the N.T.S.C. system modified for 405 lines. The programmes included "live" studio material and film. Through the courtesy of Marconi's, *Wireless World* was able to see one of the transmissions at Chelmsford, where the field strength is only about 1 mV/m.

No receiver adjustments were needed during the half-hour's programme, and results were quite outstanding. In the "live" shots and in some of the film the colour rendering was admirable and greatly enhanced the entertainment value of the programme, compared with black-and-white reproductions. In spite of the fact that the effective video bandwidth is necessarily restricted by the presence of the colour sub-carrier, the apparent definition was so increased by the colour contrast that the final picture appeared appreciably sharper than a monochrome one.

The tests have certainly demonstrated that an entirely adequate colour picture can be obtained with 405 lines and that colour is very desirable. It now remains to develop an economically acceptable system.

Colour at TV Show

SO FAR colour television on the anglicized American standard has been seen in this country by a privileged few. The closed-circuit demonstrations to be given at the forthcoming Television Society Exhibition will therefore be the *pièce de résistance.* Demonstrations are being arranged jointly by Cintel, Bush and Murphy.

The show, in which some 25 exhibitors will be participating, will be held at the Royal Hotel, Woburn Place, London, W.C.1, on March 5th, 6th and 7th. The first day is for members only, but on the other days it will be open to ticket holders from 12.0 to 8.0. Tickets are obtainable free from the Society at 164, Shaftesbury Avenue, London, W.C.2. Applicants must send a stamped addressed envelope.

The exhibitors at the time of going to press are:—Avo, B.B.C., B.R.E.M.A., C. H. Banthorpe, Belling-Lee, Bush, Cossor, Cinema-Television, E.M.I., Edison Swan, Ever Ready, Fielden, G.E.C., Hallam, Sleigh & Cheston, Leyland Instruments, Livingston, Marconi's, Mullard, Murphy, Philco, S.T.C., T.C.M.C., Thorn, 20th Century and W. Vinten.

Physical Society Exhibition

AS IN the past the emphasis at the Physical Society's 41st Exhibition, to be held in the halls of the Royal Horticultural Society, London, S.W.1, from March 25th to 28th, is on new developments in scientific instruments and apparatus, and on possible applications. Tickets are obtainable by sending a stamped addressed envelope to the Society at 1, Lowther Gardens, Prince Consort Road, S.W.7.

The exhibition will be officially opened at 11.0 on March 25th by Professor P. M. S. Blackett, F.R.S., but admission is limited to members and the press until 2.0. It opens on the three following days at 10.0 and closes at 7.0, 9.0, 7.0 and 4.30 respectively. A lecture-demonstration on "The International Geophysical Year" will be given by Sir Harold Spencer Jones at 6.15 on the 25th and another on "Recent Trends in Acoustics" by Professor E. G. Richardson at the same time on the 27th.

The Exhibition handbook of some 300 pages is obtainable from the Society, price 7s 6d, including postage.

International Instrument Show

OVER 50 instrument manufacturers from eight countries are exhibiting at the third International Instrument Show being staged at Caxton Hall, London, S.W.1, from March 25th to 29th. The show opens at 12.0 on the first day and at 10.30 on other days, and closes at 6.30 except on the last day, when it closes at noon. Tickets are obtainable free on application to the organizers, B. & K. Laboratories, Ltd., 57, Union Street, London, S.E.1.

The exhibitors, listed nationally, include:—

Austria: Ludwig Seibold;
Denmark: Bruel & Kjaer, Disa Elektronik, Industrial Controls, Streuers Chemiske Laboratorium;
Holland: Peekel Laboratorium voor Electronica;
Sweden: Magnetic AB, Sivers Lab.;
Switzerland: Metrohm, Hans Muller Barbieri, Vibro-Meter;
U.K.: Advance Components, Avo, G. & E. Bradley, Cambridge Instrument, Cossor, Grayonics, Taylor;
U.S.A.: Advance Electronics Labs., Allen-Bradley, Associated Specialties, Audio Devices, Ampex, Brush, Crosby Labs., Demornay-Bonardi, Electrical Industries, Electro-Measurements, El-Tronics, Heath, Huggins Laboratories, Kay Electric, Krohn-Hite Instrument, Laboratory for Electronics, MB Manufacturing, Narda Corp., Nuclear-Chicago Corp., Panoramic Radio Products, Polarad Electronics Corp., Polytechnic Research & Development, Raytheon, Sperry, Sprague, Texas Instruments, Universal Atomics Corp., Varian Associates, Waterman Products;
Western Germany: Belzer-Werk, Deutsche Elektronik, Hackethal, Erich Herion, Heinrich Schneider, Wissenschaftlich-Technische-Werkstatten.

Balance of Trade

PROVISIONAL figures for radio equipment exported last year show an increase of some 20 per cent on the 1955 figure; £40,3M compared with £33M. As will be seen from the details below, the largest increase was in the direct export of capital goods—transmitters, communication equipment, navigational aids, etc. The striking increase in the export of sound-reproducing equipment continued, and it is worth recalling that the overseas sales in 1947 were less than half a million pounds.

	1956 £M	1955 £M
Capital goods	16.6	13
Sound and television sets	3.8	4
Sound reproducing equipment	7.6	5.7
Components and test gear	8.8	7.5
Valves and c.r. tubes	3.5	2.8
	40.3	33

The industry's import-export trade gap has improved considerably, for whilst exports increased by £7M imports decreased by £2M (from 13.1 to 11.2).

Monopolies Report

THE Report of the Monopolies and Restrictive Practices Commission on the supply of valves and cathode-ray tubes* is described by the British Radio Valve Manufacturers' Association (B.V.A.) as an historical document, for it bears little relationship to present conditions in the industry as it covers the most prosperous four years (1951-54) in its history.

The commission found that B.V.A. members—who supply 93% of U.K. valves and tubes—so conducted their affairs as to restrict competition.

Since the opening of the investigation in 1954 the terms of reference of the commission have been changed, and it could, therefore, do no more than present a factual report without making any recommendations. It is left for the reader of the 194-page report to form his own opinion as to the effect of the activities of the B.V.A. and its members on the cost and supply of valves and tubes. The report throws a searchlight on the valve industry as a whole and makes interesting reading.

* H.M.S.O. 7s.

U.K. Display in New York

THE offer by the American Institute of Radio Engineers of space at its New York Convention and Show (March 18th-21st) for a collective U.K. display of radio and electronics equipment has been accepted. A number of firms or their U.S. agents are participating in the display in what will be known as the Great Britain Room. The venture is being supported by the R.E.C.M.F. and B.V.A. and among the manufacturers exhibiting are Belling & Lee, Egen, G.E.C., Marconi's, Muirhead, Mullard, S.T.C., and Solartron.

Wireless World will be seen on the stand of British Radio & Electronics, Ltd.

Communications into Electronics

ACCORDING to the annual report, activities of member-firms of the Radio Communication and Electronic Engineering Association are tending increasingly to swing from communications into electronics. During the year under survey an Electronic Data Processing Section has been formed to serve the many firms concerned with computers and allied equipment. An exhibition dealing with data processing is planned for the autumn of 1958.

Proposals were made last year for securing industrial representation in frequency planning. Further discussions with G.P.O. officials have clarified the industry's position.

A revised performance specification for marine radars has now been agreed by all concerned and is being accepted throughout the world. The industry to-day produces radars at the rate of five per day.

Receiver Sales

RETAIL sales of television receivers reached the record number of 1,484,000 last year. Figures issued by the British Radio Equipment Manufacturers' Association show that this was an increase of 11% on the 1955 figure of 1,335,000. The sales of sound receivers dropped by 6% to 982,000, and those of radio-gramophones by 21% to 212,000.

Hire-purchase or credit sales accounted for 50% of television sets sold, 32% of sound receivers, and 56% of radiograms.

April Shows

ARRANGEMENTS have now been made for the allocation of tickets for both the Components Show and the Audio Fair. Double tear-off tickets providing admission to both sections of the Components Show (April 8th-11th, Grosvenor House and Park Lane House, London, W.1) are obtainable free, by engineers and technicians in the "user" industries, research and the Services, from the organizers, Radio and Electronic Component Manufacturers' Federation, 21, Tothill Street, Westminster, S.W.1.

Tickets for the Audio Fair (April 12th-15th, Waldorf Hotel, London, W.C.2) are being distributed through exhibitors and audio dealers. Readers can obtain tickets from the editorial office of *Wireless World*. Applications, stating the day of visit, should be accompanied by a stamped addressed envelope.

Narrow-channel Mobile Radio

FURTHER details now available of the Toronto demonstrations (see page 57, February issue) of the Pye "Ranger" v.h.f. radio-telephone equipment reveal that these embraced both 15-kc/s and 30-kc/s channel spacing with both a.m. and f.m.

The 30-kc/s equipments were oven-controlled at the base stations but not in the mobiles, while the 15-kc/s versions employed crystal ovens for base and mobile transmitter and receiver oscillators and additional i.f. transformers in all receivers.

A comprehensive series of tests was conducted and the general conclusions reached were that 30-kc/s a.m. systems can be operated in the same areas quite satisfactorily. Intermodulation was the main limiting factor, but modulation limiters and filters in transmitters, and the latest reception techniques, go a long way towards eliminating its worst effects. The tests showed that 15-kc/s channel would be practicable with suitable geographical separation.

Direct interference with an a.m. system by an f.m. transmission in an adjacent 30-kc/s channel and at close range was not unduly troublesome, but more investigation seems desirable.

PERSONALITIES

F. S. Mockford, this year's chairman of the Radio Communication and Electronic Engineering Association, has been commercial manager of Marconi's since 1947. He joined the company in 1930, having previously been for ten years in charge of radio at Croydon airport, where he was responsible for much of the early planning and organization of the communication and direction-finding services.

H. G. Sturgeon has resigned from the board of Ultra Electric (Holdings), Ltd., and its subsidiary Ultra Electric, of which he had been chief engineer since 1946. He joined Ultra in 1944 and has been particularly concerned with the development of electronic equipment for the aircraft industry. He was appointed O.B.E. in last year's Birthday Honours.

Professor F. C. Williams, O.B.E., D.Sc., F.R.S., is to be the first recipient of the Benjamin Franklin Medal of the Royal Society of Arts, which is being awarded annually "to individuals who have attained early distinction, with promise of future achievement, in the promotion of arts, manufactures and commerce." Dr Williams, who is 45 and is professor of electrical engineering in Manchester University, receives it "for his contributions to electrical engineering." He joined the Bawdsey radar research station in 1939 and was employed throughout the war on the development of radar circuitry. In 1946 he resigned from Government service on being appointed to the Chair of electrical engineering at Manchester University, where he has been working on the development of electronic digital computers.

Dr. F. C. WILLIAMS

BRUCE WILKINSON

Bruce Wilkinson, formerly managing director of Electronic Tubes, Ltd., has joined the Plessey Company as divisional manager of the Swindon Components Division. After graduating as a Bachelor of Electrical and Mechanical Engineering from Sydney University in 1929, he joined the engineering department of Amalgamated Wireless (Australasia), Ltd. the following year. In 1946 he resigned from A.W.A., where for some time he was in control of the Research Laboratories, and came to England to take up an appointment as commercial manager of E.M.I. Factories. In 1949 he was appointed director and subsequently managing director of Electronic Tubes, an associated company of E.M.I.

OBITUARY

Marchese Luigi Solari, the last survivor of the original associates of Marconi, died in Rome on February 6th, aged 83. He first met Marconi in 1896, and was present when in July, 1897, Marconi gave the first official demonstration of ship-to-shore transmission over a distance of 18km—then thought to be considerable. In his book "Storia della Radio" he throws some interesting sidelights on early wireless experiments. In it he describes the Solari mercury detector used by Marconi during the transatlantic tests in 1901, during which Solari was at Poldhu.

Air Vice-Marshal O. G. Lywood, C.B., C.B.E., who became a director of Automatic Telephone & Electric Company on his retirement from the R.A.F. in 1946, died on February 3rd at the age of 62. Owing to ill-health he resigned from the board in 1955 but continued as chairman of A.T.E. (Bridgnorth), Ltd. For some time during the last war he was director of signals in the Air Ministry.

T. W. Price, A.C.G.I., A.M.I.E.E., who had been on the staff of Ediswan for 34 years, died on January 28th at the age of 54. He was intimately concerned with the development of cathode-ray tubes, and one of his major post-war contributions was his work on aluminizing. He was a member of the council of the Television Society.

IN BRIEF

In the December **licence figures** issued by the Post Office it is shown that the North West Region (which covers Westmorland, Cumberland, Lancashire and west Yorkshire) has joined the London and Midland Regions in having more television licences than "sound only" licences: London 1,405,884 (1,232,786), Midland 1,102,760 (947,627) and North West 938,402 (925,952). During December the number of television licences throughout the U.K. increased by 136,680 bringing the total to 6,570,097. The overall total of broadcast receiving licences at the end of the year was 14,434,127.

R.C.E.E.A. Council.—The member firms and, in parenthesis, their representatives forming the 1957-58 council of the Radio Communication and Electronic Engineering Association are: B.T-H. (V. M. Roberts), Cossor (F. J. Dellar), Decca Radar (C. H T. Johnson), E.M.I. (S. J. Preston), Ferranti (J. N. Toothill), G.E.C. (M. M. Macqueen), Kelvin & Hughes (C. G. White), Marconi's (F. S. Mockford), Metrovick (L. H. J. Phillips), Mullard (T. E. Goldup), Murphy (K. S. Davies), Plessey (P. D. Canning), Redifon (A. V.-M. E. B. Addison), and S.T.C. (R. McVie).

Schools TV.—Television receivers especially designed for use in schools are announced by two manufacturers. Ferguson have produced two sets, one a projection receiver giving a picture 24-in by 18-in, and the other with a 21-in tube for direct viewing. Cossor's two sets are both for direct viewing, one with a 24-in tube and the other a 21-in tube. Each has a built-in viewing hood to reduce ambient light.

In the note on **v.h.f. coverage** on page 54 of our last issue the Third Programme was listed as being radiated from Wenvoe on 92.1 Mc/s. Although this is eventually to be so, at present the West of England Home Service is radiated on this frequency.

"Output Transformerless Amplifiers."—In Fig. 4 of this article (February issue) the cathode of the lower output valve should be fed from a separate negative h.t. supply as in Fig. 7, and not from earth as shown. In Fig. 9 the cathodes of both the phase splitter and lower output valve should be fed from a separate negative h.t. supply.

National Gramophone Conference.—The bi-annual conference of the National Federation of Gramophone Societies will be held at High Leigh, Hoddesdon, Herts, from April 5th to 7th. Hugh Brittain, of G.E.C., and Percy Wilson, of *The Gramophone,* are among the speakers. Details are obtainable from the Hon. Conference Secretary, 106, Streatfield Road, Kenton, Harrow, Middlesex.

An exhibition of Airmec **electronic instruments** is being held at the Napier Hall, Vincent Street, London, S.W.1, from March 25th to 28th. Tickets are obtainable free on application to Airmec, Ltd., High Wycombe, Bucks.

A conference on **physics of the solid state** is being organized by Professor L. B. Bates, F.R.S., from April 8th to 10th in the Physics Department of the University of Nottingham. Details of the conference, in which contributors from universities and research establishments are participating, are obtainable from the Physical Society, 1, Lowther Gardens, Prince Consort Road, London, S.W.7. (Fee 10s.)

BUSINESS NOTES

A **Decca Navigator** chain of mobile stations is to be used in connection with the nuclear tests which will be held in the Central Pacific later this year.

A television camera, measuring under 3-in in diameter and 24-in long, has been produced by **Pye** for installation at Calder Hall. It is fitted on a mechanical grab which is lowered into the fuel channels of the graphite core to remove possible obstructions.

Ferranti Radio and Television Limited is the name adopted for the new company formed by E. K. Cole, Ltd. (as a wholly-owned subsidiary), to market Ferranti sound and television receivers. It was announced some time ago by Ferranti's that arrangements for the marketing of Ferranti receivers would in future be undertaken by E. K. Cole, Ltd. The head office of the company, which officially commences operation on April 1st, will be at 41/47, Old Street, London, E.C.1.

Emidicta recorders modified to permit a continuous repetition of the recorded message are being supplied by E.M.I. to the Post Office for the extension of the telephone weather service to seven provincial centres. The magnetic disc recording-replay instrument has been modified so that the reproducing head automatically returns along the tracking arm at the end of the recorded forecast.

For some time **Cossor** have had a television "know-how" agreement with Titan Television, Ltd., of Sydney, New South Wales, but they have now acquired a share in the equity of the company, which manufactures both Titan and Cossor receivers.

Closed-circuit television equipment is available on hire from **Audio and Video Rentals, Ltd.,** of 8, Devonshire Mews West, London, W.1 (Tel.: Welbeck 5137), who also rent audio equipment and film scanners. The company, of which Irvin C. Pannaman is managing director, uses Pye industrial television cameras modified for studio use. Prices for hire of a single camera unit, with monitor and sound equipment, range from £7 10s an hour to £75 per week.

Adhesive nameplates, dials, scales, etc., in brass, aluminium, steel or plastic are now provided for the trade by Millett, Levens (Engravers), Ltd., Stirling Corner, Barnet By-Pass, Borehamwood, Herts. (Tel: Elstree 2871.)

Carbion, a new kind of corrugated paper with considerable elasticity and exceptional crush resistance, is now being manufactured by Spicers, Ltd., 19, New Bridge Street, London, E.C.4. In the form of sleeves, it provides **protective packaging** for valves and the like.

The electronics division of Studio Irwin Technical, Ltd., 8, Breams Buildings, London, E.C.4, offers to industry a service for preparing **instruction manuals** and other technical literature.

HARD WORDS.—A writer in the current issue of Design *strongly criticizes "the current collection of formless packages which pass for cabinets," but of this Murphy A262 a.m./f.m. receiver he writes "flowing lines and a definite style give this set a character of its own." He complains of the cautious approach towards cabinet design in this "middle-aged industry" in which manufacturers "instead of continuing to look ahead are looking sideways at each other."*

Mercia Enterprises, Ltd., of 30, Silver Street, Coventry, have been appointed sole concessionaires in Great Britain for the A.E. low-voltage stabilizers manufactured by L'Accumulateur Etanche, S.A., of Brussels, Belgium (see *Wireless World*, February, 1956). Five types are available with current ratings of from 20 mA to 1 amp.

Additional production facilities for components (including transistors), electro-medical and sound equipment and fluorocarbons (PTFE and PCTFE), are provided by **Siemens-Ediswan's** acquisition of a factory at Brantwood Road, Tottenham, London, N.17.

A service department has now been opened at the London office of the **Champion Electric Corporation,** 8, Eccleston Street, S.W.1 (Tel.: Sloane 9838).

Winter Trading Co., Ltd., have opened a warehouse and trade counter at 118, Hampton Road, Ilford, Essex (Tel.: Ilford 6203).

OVERSEAS TRADE

First overseas installation of the new Marconi 16-mm **television film recorder** is for the Bavarian broadcasting authority, Bayerischer Rundfunk. Similar equipment has also been ordered for one of the Australian commercial television stations. The outstanding feature of the equipment is the fast pull-down film mechanism which ensures that each frame of film is moved into position during the blanking period between television frames—from 1.4 to 1.8 milliseconds. (See "Technical Notebook," page 137.)

Last April Automatic Telephone & Electric Co. and Marconi's W.T. Co. concluded an agreement for mutual co-operation in the telecommunications field. A.T. & E. have been awarded a contract for the supply and engineering of a complete v.h.f. frequency-modulated wide-band **radio-telephone link** in Portugal, and Marconi's are providing and installing the radio equipment, which is designed around three new travelling-wave tubes. The installation, which will span the river Tagus at Lisbon—a distance of about nine miles—will initially provide 60 telephone channels and ultimately 240.

RCA Great Britain, an associate company of the Radio Corporation of America, last year exported to the dollar markets $800,000 worth of British-made **audio equipment.** In addition capital equipment exports to the dollar markets were valued at $350,000.

Kelvin and Hughes are exhibiting at the **Leipzig International Fair** (March 3rd-14th) and among the equipment being shown will be a miniature supersonic flaw detector, high-speed pen recorders, electronic temperature controllers, and magnetic recording head.

Equipment for a further chain of four ground stations is to be supplied by Cossor as part of the plan to provide **Gee** coverage for the whole of **Western Europe** and Southern Scandinavia.

Transmitters, aerials and studio equipment for a new **broadcasting station** being built at Omdurman are being supplied by Marconi's. The station, which is to supplement the service provided by the Khartoum transmitter, is to be equipped with two 20-kW **h.f. transmitters.**

Representation in **Italy** of U.K. manufacturers of sound and television receivers is being sought by Filotecnica Salmoiraghi S.p.a., Via Raffaello Sanzio 5, Milan.

Viet-Nam.—Tenders for the supply of nine h.f. transmitters and 16 communications receivers covering the 2-32-Mc/s band, and sundry other radio and electrical equipment, are invited by **Co-Quan Mai-Dich** Ngoai-Vien, 29-bis **Phan-Dinh-Phung, Saigon.** The purchase is being financed by the International Co-operation Administration. Specifications can be obtained from the Viet-Namese Embassy, 12, Victoria Road, London, W.8, or the Export Services Branch, B.o.T., Lacon House, Theobalds Road, London, W.C.1.

Inexpensive High-Quality

CLASS A PUSH-PULL CIRCUIT WITH 5-WATT RATING

IN this article the design and construction of an amplifier rated to give 5 watts output is given. An inexpensive output transformer is employed, but an adequate stability margin has been provided for a wide range of output conditions.

The author holds that 5 watts is sufficient for high-quality reproduction in the average living room, and in a subsequent article will put forward evidence in support of this view.

The amplifier is suitable for use with the author's gramophone and microphone pre-amplifier described in *Wireless World* for January and February 1955 or with a simplified pre-amplifier to be described later.

THE aim has been, in the design of this amplifier, to keep the cost as low as possible consistent with achieving a performance not audibly inferior to that given by amplifiers of the most luxurious class.

By careful attention to circuit details, wide stability margins are maintained under all likely conditions of use, despite the simplicity of the output transformer, which was specially designed by the author for this amplifier.

The amplifier has an h.t. voltage of 300 V and, with the circuit as shown in Fig. 1, requires a sine-wave input of approximately 4 V r.m.s. for 5 watts output into a resistive load. It is, therefore, suitable for use with the pre-amplifier described in the January and February, 1955, issues of *Wireless World*, or simplified versions of that design[1]. A much simpler pre-amplifier, primarily intended for use with crystal pickups and radio tuner units only, and employing only one valve, will be described later.

By the addition of two electrolytic capacitors and two resistors to the Fig. 1 circuit, 5 watts output may be obtained for a sine-wave input of only 1.4 V r.m.s., the performance in other respects being substantially unaltered.

In the author's opinion, an amplifier rated at 5 watts, provided its performance is clean up to the full output, is quite adequate for domestic reproduction of the highest grade, assuming a loudspeaker of good efficiency—and it should be remembered that moving-coil loudspeaker efficiencies have tended to increase considerably as better magnet materials have been more widely adopted.

Output Stage.—The most expensive component in a high-quality amplifier is normally the output transformer, on which the outlay is sometimes over £5. The cost of an output transformer is dependent on many factors, but a very high ratio of shunt inductance to leakage inductance is always expensive because it necessarily involves dividing the windings into numerous interleaved sections.

In the present amplifier design, the output valves operate under pure class A conditions, and a clean high-frequency performance can consequently be obtained with quite a simple transformer, since there is no need for the leakage inductance between the two halves of the primary to be as low as is necessary under class AB or class B conditions.

[1] "Gramophone and Microphone Pre-Amplifier" by P. J. Baxandall, *Wireless World*, Jan. and Feb., 1955.

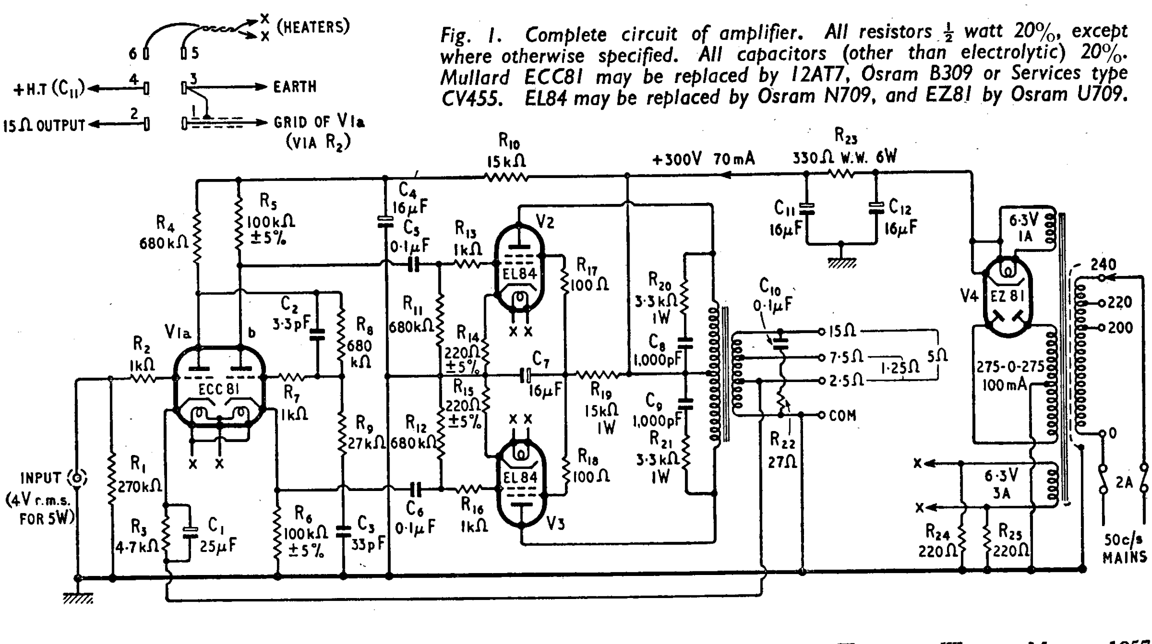


Fig. 1. Complete circuit of amplifier. All resistors ½ watt 20%, except where otherwise specified. All capacitors (other than electrolytic) 20%. Mullard ECC81 may be replaced by 12AT7, Osram B309 or Services type CV455. EL84 may be replaced by Osram N709, and EZ81 by Osram U709.

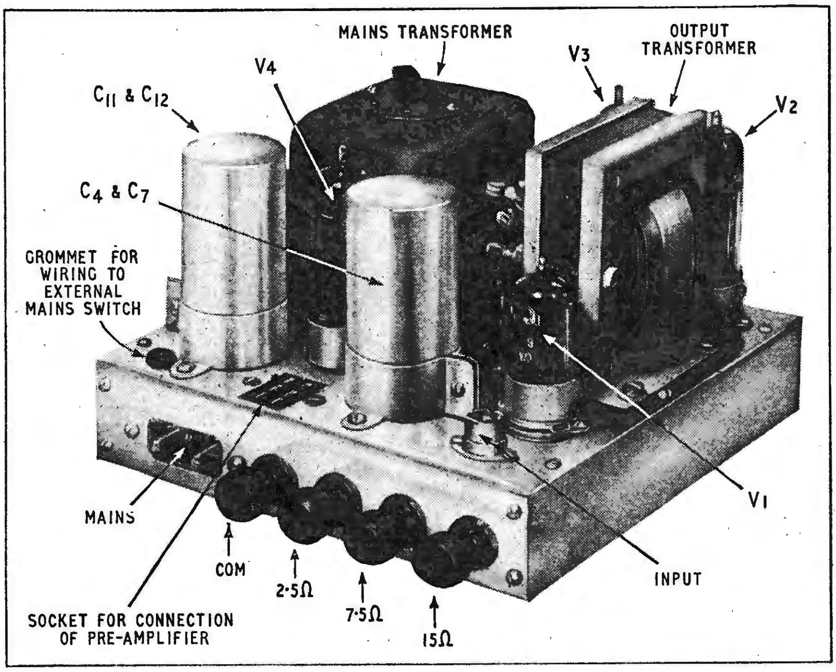
Amplifier

By P. J. BAXANDALL, B.Sc. (Eng.)

The transformer has, in fact, only two primary sections, with the secondary in one section between them.

A further advantage of class A operation is that the audible distortion is less, for a given unweighted total harmonic distortion, than in class AB or class B systems[2]. The efficiency is admittedly lower, but since 5 watts is considered to be sufficient for the purposes for which this amplifier is intended, the lower efficiency is regarded as of little importance.

The stated output rating of 5 watts is actually rather conservative, as will be seen from the measured results given later on; this is intentional, and makes it possible to predict with confidence that *all* amplifiers built to this design will be comfortably capable of giving an output of 5 watts, at adequately low distortion, throughout the frequency range 35 c/s to 10 kc/s, despite the effects of tolerances on components and valves.



General view of amplifier. The chassis in this prototype was made with 18 s.w.g. aluminium and measures 6¾in x 6¾in x 1⅜in.

The nominal d.c. operating conditions give a quiescent anode dissipation in each output valve of 9.5 watts, the maximum dissipation permitted by the makers being 12 watts. With this margin to spare, it is unlikely that the valve rating will be exceeded in any versions of the amplifier built, and a long average valve life should be obtained.

Negative feedback is taken from a tapping on the secondary winding, and not from a tertiary winding as was done in an earlier design by the author[3]. Whilst the use of a tertiary winding is still regarded as an excellent scheme, it unfortunately increases the cost of an output transformer more than might at first be expected for the following reasons:—

(a) The manufacturer has to pay a patent royalty on each transformer.

(b) It would appear to be desirable, when using a tertiary winding for feedback, to adopt a symmetrical winding arrangement with a central partition on the bobbin. With cheaper unsymmetrical winding arrangements, there will be some output at high frequencies from both the secondary and tertiary windings due to push-push even-harmonic distortion current fed to the primary, and it is unlikely that such distortion voltages will be induced equally effectively into secondary and tertiary windings. Consequently, at high frequencies the application of a large amount of negative feedback via the tertiary winding may not reduce the distortion, as measured at the secondary, by as large a factor as would otherwise be the case.

The increase in cost resulting from having to employ a bobbin with a central partition, compared with a simple winding arrangement in which all layers occupy the full winding width, is necessarily quite large, especially since, with the latter scheme, a very satisfactory transformer can be made commercially without side cheeks at all, i.e., using a paper interleaved and impregnated winding on a simple tubular former.

The author is indebted to R. F. Gilson, Ltd., and Partridge Transformers, Ltd., for much useful information relating to other less obvious factors affecting transformer cost. The original output transformer designed for this amplifier used a size of core which was later found to be not very readily available commercially. Moreover, a stack of twice the width of the middle limb was adopted in the interests of improving the ratio of shunt to leakage inductance—but it was pointed out that the use of such proportions would necessitate winding the transformer at lower than normal speed, resulting in a considerable increase in cost.

The final design uses a square stack of size 429 "waste-free" laminations made of ordinary silicon iron material, e.g., Stalloy. Waste-free laminations have proportions as shown in Fig. 2, which permit two "E" laminations and two "I" laminations to be stamped out of one rectangular sheet with no

[2] "The Influence of High-Order Products in Non-Linear Distortion" by D. E. L. Shorter, *Electronic Engineering*, April, 1950.
[3] "High-Quality Amplifier Design" by P. J. Baxandall, *Wireless World*, Jan. 1948.

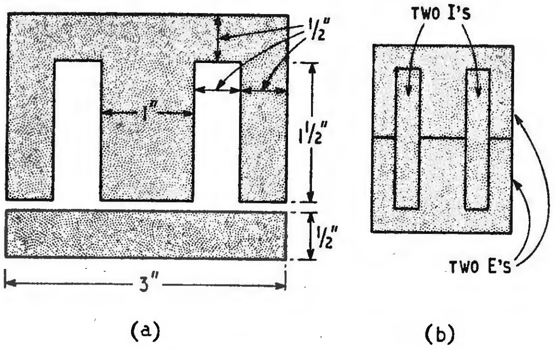


Fig. 2. (a) Dimensions of "waste-free" laminations used in the output transformer. (b) Showing how two "E's" and two "I's" are punched out of one sheet of material, leaving no waste. If grain-oriented material is used, the preferred magnetic direction runs vertically.

waste material left over, thus keeping down the cost. It will be seen from Fig. 2 that these laminations give a rather small winding depth in relation to the cross-section of the iron, compared with typical laminations of earlier design, but this is a help in giving a good ratio of shunt to leakage inductance with simple winding arrangements.

An incidental advantage of having the secondary in only one section, as in the present design, is that simple tappings may be provided for matching different load impedances, thus avoiding the inconvenience of series-parallel interconnection changes between secondary sections and perhaps the necessity for altering the values of components in the feedback network. Furthermore, if, for example, a 15-ohm tweeter is found to be too sensitive when used in conjunction with a particular 15-ohm bass speaker, the tweeter (and its associated cross-over components) may be connected instead across the 7.5-ohm or 5-ohm output terminals. Or, to give another example, a 3-ohm tweeter could be used in conjunction with a 15-ohm bass speaker by connecting it to the 5-ohm, 2.5-ohm or 1.25-ohm terminals, the choice depending again on the relative sensitivities and being made on the basis of aural judgment. In the author's opinion, a frequent cause of unpleasant reproduction is bad balance between the sensitivities of bass and treble speakers, particularly when the treble speaker is the more sensitive of the two; a difference in sensitivities of 6 dB is then enough to give quite strident reproduction, assuming a cross-over frequency in the region of 1 kc/s.

It will be seen from Fig. 1 that an unusual feature of the circuit is that no bypass capacitors are connected across the output valve bias resistors, which results in the application of a small amount of negative feedback to each output valve. Whilst this feedback undoubtedly improves the linearity of each valve, it is nevertheless found that the valve distortion, at a given output voltage, introduced by the complete output stage, in the absence of overall feedback, is not appreciably reduced by the local feedback. This result, perhaps surprising at first, is mainly due to the fact that each valve gives much more second-harmonic distortion than third; the local feedback gives a substantial reduction in second-harmonic distortion, and consequently in total distortion, *in each valve*, but, under the particular operating conditions used, happens to leave the third-harmonic distortion almost unaltered*. The second-harmonic distortion is, however, cancelled out in a balanced push-pull stage, so that the total distortion at the output, mainly third harmonic, is almost unaltered.

Thus, in the present design, the omission of the cathode bypass capacitors does not result in a useful reduction in output stage distortion (in the absence of overall feedback) when matched valves are used. The reasons for omitting the capacitors are, however, as follows:—

(a) Saving in cost and space.

(b) The reduction in forward gain makes it practicable to obtain very good stability margins when applying overall feedback directly from the 2.5-ohm tapping on the output transformer, thus avoiding the need for two resistors which would otherwise be required for giving a suitable value of feedback factor β. Furthermore, with the arrangement used, a sine-wave input of approximately 4 V r.m.s. is required for the full rated output of 5 watts, which is convenient in that it is the same as previously adopted by the author[1, 3].

(c) If the output valves have unequal mutual conductances, the local current feedback largely offsets the effects of this and the performance of the amplifier is affected less by the poor matching of valves than would otherwise be the case.

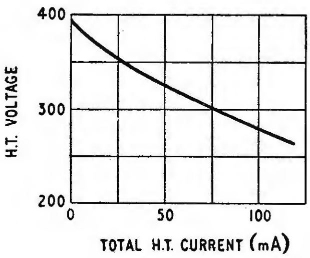


Fig. 3. Regulation curve for power supply shown in Fig. 1, measured at a mains voltage of 225 V on the 220-230 V tapping.

(d) The overload behaviour at high frequencies is made somewhat cleaner by the local current feedback, due to the reduction in push-push second-harmonic current fed to the output transformer primary.

It is appreciated, however, that some readers, not wishing to use pre-amplifiers based on the author's designs, may prefer a higher gain than that given by the Fig. 1 circuit. The necessary modifications are as follows:—

(a) Connect a 50-μF, 12-V electrolytic capacitor across each bias resistor in the output stage.

(b) Connect two resistors in series, of 180 ohms and 100 ohms, between the 2.5-ohm transformer tapping and earth, the 100-ohm resistor going to earth, and take the feedback from their junction.

The performance of the amplifier will not be significantly changed by this modification, except that

* It may be shown that, assuming a valve to introduce only second-harmonic distortion, i.e., to have a simple parabolic transfer characteristic, the application of negative feedback results in the introduction of higher-order harmonic distortion; all harmonics, however, ultimately become negligible if enough feedback is applied. Also, the effect on distortion of applying feedback separately to each valve in the manner adopted is not the same as that of applying the same amount of feedback over the complete output stage; the signal current flowing in each cathode resistor differing from the signal current component that flows through the complete transformer primary, since the former includes also the push-push second-harmonic current which is ineffective as far as the transformer is concerned.

an output of 5 watts will now be obtained for a sine-wave input of approximately 1.4 V r.m.s. instead of 4 V r.m.s.

Input Stage and Phase Splitter.—The first half of the double triode is a straightforward amplifying stage, d.c. coupled to the second half which operates as a phase splitter. With this arrangement, the only significant elements that give phase lead at low frequencies are the output transformer and the resistance-capacitance coupling between the phase splitter and the output valves; a large margin of stability can then easily be obtained by making the coupling time-constant sufficiently large, which can be done without exceeding a coupling capacitor value of 0.1 μF.

At high frequencies, the attenuation of loop gain is controlled by means of a resistance-capacitance network between the two halves of the double triode† and by further R-C networks across the primary and secondary of the output transformer. Whilst not all of these elements are absolutely essential, it should be emphasized that great care has been taken over this aspect of the design, to secure large stability margins under all likely conditions of load, and also on no load. It is confidently predicted that, if the circuit is built as specified, no troubles whatever will be experienced with instability, even with the most extreme combination of effects due to component tolerances.

The tendency to design and test amplifiers on the assumption of a pure resistance load of the correct value is to be deprecated; for a moving-coil loudspeaker has an impedance that rises considerably at high frequencies, and, when a long speaker lead is used, there will be appreciable shunt capacitance also. The safe procedure, for an amplifier for general use, is therefore to design for large stability margins not only on a 15-ohm resistive load but also in the extreme condition of capacitance load only. In the present design, speaker leads up to at least 100 yards long may be safely used, and no tendency to instability will result even if the speaker at the far end is temporarily disconnected for any reason.

The resistance-capacitance shunt across the secondary is a very effective dodge for increasing the stability margin on no load; when it is present, adding 0.01 μF across the output transformer secondary produces almost no effect on the no-load square wave response, and, in the prototype at least, even 0.05 μF does not produce oscillation. Without the R-C shunt, adding 0.01 μF on no load gives pronounced ringing, and 0.05 μF gives violent oscillation.

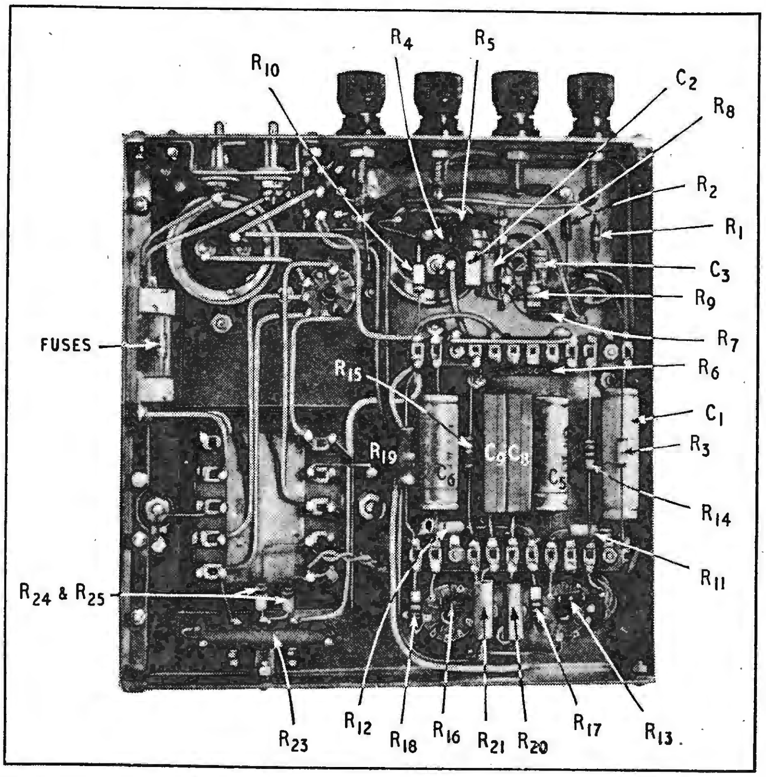
The Power Supply.—In the interests of economy, a capacitor-input rectifier circuit is used, with a smoothing resistor in place of the more usual choke. The regulation curve for the power supply is shown in Fig. 3. Because of the pure class A operation of the output valves, the total h.t. current taken by the amplifier varies by less than 2 per cent between zero and full rated output, so that there is very little fluctuation, with programme volume, of the h.t. voltage available for operating pre-amplifiers, peak programme meters, etc.

With the rectifier valve and mains transformer specified (the prototype was supplied by Stern Radio, Ltd.), a total h.t. current up to 100 mA may be delivered without exceeding the rating of these components. Since the h.t. current taken by the amplifier itself is unlikely to exceed 80 mA, allowing for reasonable effects of component and valve tolerances, h.t. current up to about 20 mA may be safely supplied to external units. Readers wishing to supply more external h.t. load than this should modify the power supply design appropriately; just how this is done is unimportant, so long as the resultant h.t. voltage lies within the limits 280 V to 320 V and does not contain much more than 2 V r.m.s. of 100 c/s ripple.

Construction.—The layout adopted in the prototype is shown in the photographs. The amplifier and its power supply occupy, roughly speaking, separate halves of the chassis, so that substantially the same layout may be adopted by readers who wish to build them as separate units.

The layout is not critical, however, and there is

Layout of components on the underside of the chassis. R_{22} and C_{10} are mounted on top of the chassis between the transformers.



† The arrangement used is preferable, with a triode stage, to the simpler one of shunting a series combination of C and R directly across the anode load. With the latter, as the frequency is raised, the shunt becomes effective in reducing the gain only when its impedance has fallen to a value comparable with the a.c. resistance of the valve, which is very much lower than the value of the anode load resistor. At much lower frequencies than this, however, the resistance-capacitance shunt will severely limit the anode voltage swing that is available without overloading.

no reason why other layouts should not be used, provided that the following points are watched:—

(a) The components associated with the coupling network between the two halves of the double triode should be mounted close to the valve holder in order to reduce unwanted stray capacitances.

(b) The output stage anode leads should not be allowed to come too near to the wiring of previous parts of the circuit.

(c) The 330-ohm smoothing resistor should be so mounted that its heat will not harm other components.

(d) The transformers should be so positioned that the hum voltage induced into the output transformer by the stray magnetic field from the mains transformer does not give rise to an undesirably high hum output from the amplifier. In case of doubt, a simple experiment may be done before building the

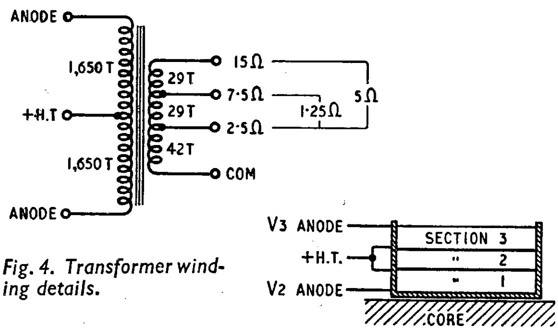


Fig. 4. Transformer winding details.

amplifier, as follows. Connect the primary of the mains transformer to the mains and the secondary of the output transformer to a loudspeaker. On moving the transformers about, it will be found that, even when they are very close together, there are certain positions in which the hum is almost zero. One such position is with the axis of the windings on the mains transformer passing through the centre of the output transformer at 90° to the axis of the windings on the latter. In the author's layout, the transformers are not quite arranged in this ideal way—to have adopted it would have required an increase in chassis size—but the hum, whilst just noticeable on first switching on, falls to a completely negligible level as soon as the amplifier warms up and feedback becomes effective in reducing the hum output.

It will be seen that in the prototype tag strips have been used instead of a group board. The type of tag strip employed, which has tags at ¼in spacing, has much to recommend it for home-constructed equipment; it is easily cut to length, tags may be removed where necessary for fixing screws, and two strips may be mounted at just the right distance apart to accommodate the particular components used in an elegant manner. The strip is readily available, e.g., from G. W. Smith & Co., 3, Lisle Street, London, W.C.2.

A 6-pin socket* is provided for making connections to pre-amplifiers, etc. The amplifier input lead in the corresponding cable should be separately screened, but none of the other leads in this cable need be screened. In the prototype, a Belling-Lee coaxial socket is also provided for the input, which may be found convenient in cases where the input source does not obtain its power supply from the present amplifier. A further provision is that one pin on the 6-pin socket is connected to the 15-ohm output terminal of the amplifier; this enables a simple peak programme meter, whose circuit will be given later, to be built into the pre-amplifier unit, if desired, but supplied with signals from the output transformer secondary.

Large screw terminals (Belling-Lee Cat. No. L. 1004/11) are used for the loudspeaker connections, and whilst these are more expensive than a socket strip, they are, in the author's opinion, much the most desirable form of connector for the purpose. Socket strips tend to lead, sooner or later, to the use of match-sticks!

Transformer Details.—A transformer suitable for this amplifier may be obtained from R. F. Gilson, Ltd., and is known as Type WO 893. A similar transformer may be obtained from Partridge Transformers, Ltd., and is known as their type P4076. For readers who prefer to wind their own transformer, the winding details are given below.

Core

1in stack of laminations (inter-Services size 429A) as Fig. 2, 0.014-in thick in ordinary silicon iron such as Stalloy (111A), Silcor II (29A) or Strantranis No. 1 (43A). The laminations may be interleaved alternately in the normal manner.

The frequency down to which the amplifier is capable of delivering its full rated output may be appreciably lowered by using "Unidi" or "Unisil" laminations. These are made of grain-oriented silicon iron, such as is used normally in C-type cores, and have superior magnetic properties in the rolling direction but not at right-angles to this direction. With "waste-free" laminations, however, as may be appreciated from Fig. 2, the laminations may readily be stamped so that, throughout the major part of the magnetic circuit, the flux is in the preferred direction in the material. Despite the technical advantage of this material, the author doubts whether its use in the present amplifier would confer any *audible* advantage whatever on any kind of musical programme. A transformer with "Unidi" laminations, otherwise similar to the normal model, can be supplied by R. F. Gilson, Ltd., and by Partridge Transformers, Ltd., who describe it as their type P4077.

Bobbin

To suit core, $\frac{1}{16}$in material.

Windings

Section (1). 1,650 turns of 38 s.w.g. enam., in nine or ten layers, with 0.002 or 0.003-in transformer paper between layers.

Cover with three layers of 0.005-in Empire cloth before winding section (2).

Section (2). In three layers, with 0.002 or 0.003-in paper between layers, as follows:—

1st layer—42 turns of 22 s.w.g. enam.
2nd layer—29 turns of 20 s.w.g. enam.
3rd layer—29 turns of 20 s.w.g. enam.

All connections between layers to be brought out as shown. (Fig. 4.)

Cover with three layers of 0.005-in Empire cloth before winding section (3).

Section (3). As section (1) and wound in same direction.

(*Continued on page* 113)

* The socket may be obtained from Painton & Co., Ltd., Kingsthorpe, Northampton, and has the catalogue number 500472. The corresponding cable entry plug has the number 500198.

Cover the outside of section (3) with Empire cloth for protection.

If the secondary is wound with the bobbin rotating in the same direction as for the primary sections, then the feedback will be negative, as required, when the outside of section (3) is connected to the anode of the output valve whose grid is fed from the cathode of the phase-splitter.

The home constructor is recommended to bring out the actual winding wire for connections to all sections. The alternative method of soldering flexible (stranded) lead-out wires to the primary winding, whilst reducing the danger of lead breakages after completing the winding, introduces lumps into the winding where the taped joints occur and hence makes uniform winding on a simple hand winding machine (e.g., hand-drill) considerably more difficult. It is not hard, given reasonably careful handling, to avoid breaking the 38 s.w.g. leads during construction of the transformer, but connection to the external circuit should be via a tag board or terminal board so arranged that the 38 s.w.g. leads to the back of the board cannot readily be damaged.

Tests

The following figures were obtained on a prototype from R. F. Gilson, Ltd.:

Total primary resistance	422 ohms
Total secondary resistance ..	0.45 ohm
Leakage inductance, measured at at 1,000 c/s across whole primary with whole secondary short-circuited	54 mH
Leakage inductance, measured at 1,000 c/s across one half of primary with the other half short-circuited	77 mH
Total primary inductance, measured at 50 c/s and 10 V r.m.s	60 H

(*To be continued*)

Automatically Tuned Direction Finder

Pilot-Operated Navigational Aid for Large Aircraft

RADIO direction finding plays, and will undoubtedly continue to play for some time, an essential role in air navigation over the principal air routes of the world. A new direction finder was recently announced by Marconi's; it takes the form of an automatically tuned DF set (ADF) designed especially to meet the requirements of modern high-speed passenger and transport aircraft. A miniaturized version for Service aircraft is also made.

The Type AD712, as the civilian version is called, was shown as a prototype at Farnborough last year and is now in production form. It is particularly suitable for pilot operation as it is necessary only to initiate the tuning by "clocking up" the frequency of the land station required on a small controller and the receiver makes all necessary tuning adjustments and displays the bearing, accurate to within ±2 degree, on a 0—to 360 degree bearing indicator.

This simplicity of operation is made possible by a unique tuning system involving the use of some 36 crystals. Setting up a frequency on the controller selects a particular combination of crystals, which, by the sum and/or difference of their frequencies, provides a reference frequency with which is compared a continuously tunable oscillator (the first mixer). The difference frequency is used to control a tuning motor driving a chain of dust-iron cores which form the tuning elements of the set.

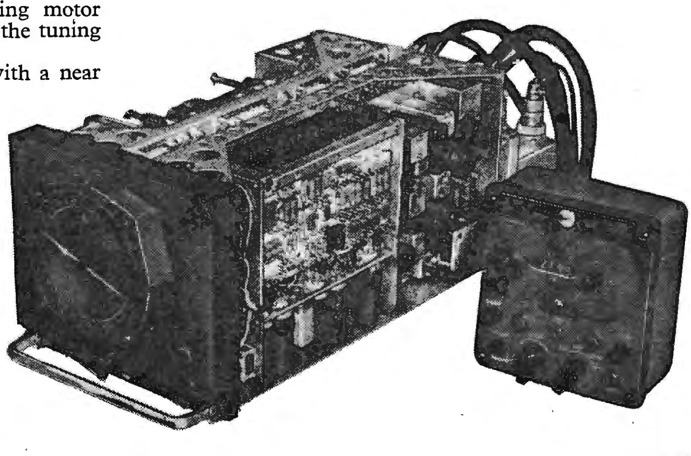
The receiver is a double superheterodyne with a near normal first i.f., but a rather low second one. The wavebands covered are 100 to 415 kc/s and 490 to 1,799.5 kc/s and selection of a frequency within these limits can be effected in steps of 0.5 kc/s. Two bandwidths are provided; ±700 c/s and ±1.5 kc/s, measured between −6 dB points.

For ADF operation signals are fed to the receiver from a pair of dust-iron cored crossed loops housed in a thin fibre-glass moulding of suitable contour and aerodynamic form for mounting on the outside of the aircraft skin.

Signals from the crossed loops are fed to a quadrantal error correction unit, thence to a goniometer and after suitable "processing" the resultant signal is mixed with the output from an omni-directional "sense" aerial and passed to the i.f. and detector stages. The modulation is used to drive the goniometer search coil to the null-signal position. The goniometer motor drives also the pointer of the DF indicator on the front of the receiver and a selsyn-type system repeats the bearing on a remote indicator in the pilot's cockpit.

A low-power audio output provides aural reception with headphones, or over the aircraft's intercom, as required. Ground beacons, radio ranges and Consol are receivable and the set can be used, within its frequency ranges, as a communications receiver.

For a ±2 degree overall DF accuracy the field strength required at the aerials is 25 μV/m; and for communications 5 μV/m with 30% modulation of the signal give a signal/noise ratio of 6 dB. Power requirements are, 140 VA at 115V, 400 c/s and 1 A at 28 V d.c.



Marconi Type AD712 ADF set removed from its case. The remote controller is shown on the right.

The Short-Circuited Turn

DETERMINING THE CONDITIONS UNDER WHICH IT MAY BE HARMFUL, USEFUL OR JUST HARMLESS

By THOMAS RODDAM

IF a quick skimming through the standard books is any guide, nobody seems to have bothered very much about the short-circuited turn, although it leads a life which at first glance is comparable to that of Jekyll and Hyde. The faulty low-frequency coil does not prevent us using a brass slug to tune our high-frequency coils. Why is there this split behaviour? Where does the division between the useful and the useless lie?

The obvious thing to do is to draw the actual circuit of a coil with a short-circuited turn and calculate its impedance. If the result can be expressed in simple terms we should be able to build up a behaviour picture: if the result is just a long mathematical expression we shall have to work out enough special cases to provide the foundation for a general pattern. Fortunately, it turns out that, if you make the right approach, the result can be expressed in terms which are already familiar in quite a different context. And then we see that this is just what we might have expected.

The basic circuit is shown in Fig. 1(a). The wanted circuit is an inductance L_1 having resistance R_1. This is itself a simplification, because shunt losses are neglected, and at high frequencies the series resistance will not be constant. However, it is better to understand a simplified system than to fail to understand the phenomena at all. The short-circuited turn, which may be more than a single turn, of course, is taken to be the separate winding L_2, imperfectly coupled to L_1, and this is considered to have what we may call a self-resistance of R_2.

The transformer L_1L_2 can be replaced by its equivalent circuit to give the network of Fig. 1(b). This is one of the equivalents given some time ago in *Wireless World*[1]. Moving over to the other side of the ideal transformer we get the form shown in Fig. 1(c). Now we are ready to write down the impedance of our coil with its short-circuited turn.

The parallel combination of k^2L_1 and $k^2n^2R_2$ has an impedance Z of

$$1\Big/\left(\frac{1}{j\omega k^2L_1}+\frac{1}{k^2n^2R_2}\right) = \frac{j\omega L_1k^4n^2R_2}{j\omega L_1k^2+k^2n^2R_2}$$

so that the total impedance is

$$R_1+j\omega L_1(1-k^2)+j\omega L_1k^4n^2R_2/(j\omega L_1k^2+k^2n^2R_2)$$

$$=R_1+j\omega L_1(1-k^2)+j\omega L_1k^4n^2R_2(k^2n^2R_2-j\omega L_1k^2)/(\omega^2L_1^2k^4+k^4n^4R_2^2)$$

$$=R_1+\omega^2L_1^2k^6n^2R_2/(\omega^2L_1^2k^4+k^4n^4R_2^2)$$
$$+j\omega L_1(1-k^2)+j\omega L_1k^6n^4R_2^2/(\omega^2L_1^2k^4+k^4n^4R_2^2)$$

[1] "Some Electrical Theorems," by W. Tusting, November 1954.

After some multiplying and rearranging we come to the form:

$$Z=R_1\,\frac{1+\dfrac{\omega^2L_1^2}{n^4R_2^2}\left(1+\dfrac{n^2k^2R_2}{R_1}\right)}{1+\dfrac{\omega^2L_1^2}{n^4R_2^2}}+j\omega L_1\,\frac{1+\dfrac{\omega^2L_1^2}{n^4R_2^2}\,(1-k^2)}{1+\dfrac{\omega^2L_1^2}{n^4R_2^2}}$$

Still, you may think, pretty intractable. But now let us substitute $f^2=\omega^2L_1^2/n^4R_2^2$ and $r=n^2k^2R_2/R_1$ and we have

$$Z=R_1\frac{1+(1+r)f^2}{1+f^2}\qquad+jwL_1\,\frac{1+(1-k^2)f^2}{1+f^2}$$

In this expression "f" is proportional to frequency. If f is zero, the impedance reduces to $R_1+j\omega L_1$, just as we should expect, because the transformer action to the short-circuited turn is ineffective. If f is very large indeed, the impedance is $Z=R_1+n^2k^2R_2+j\omega L_1(1-k^2)$. Looking back to Fig 1(c)

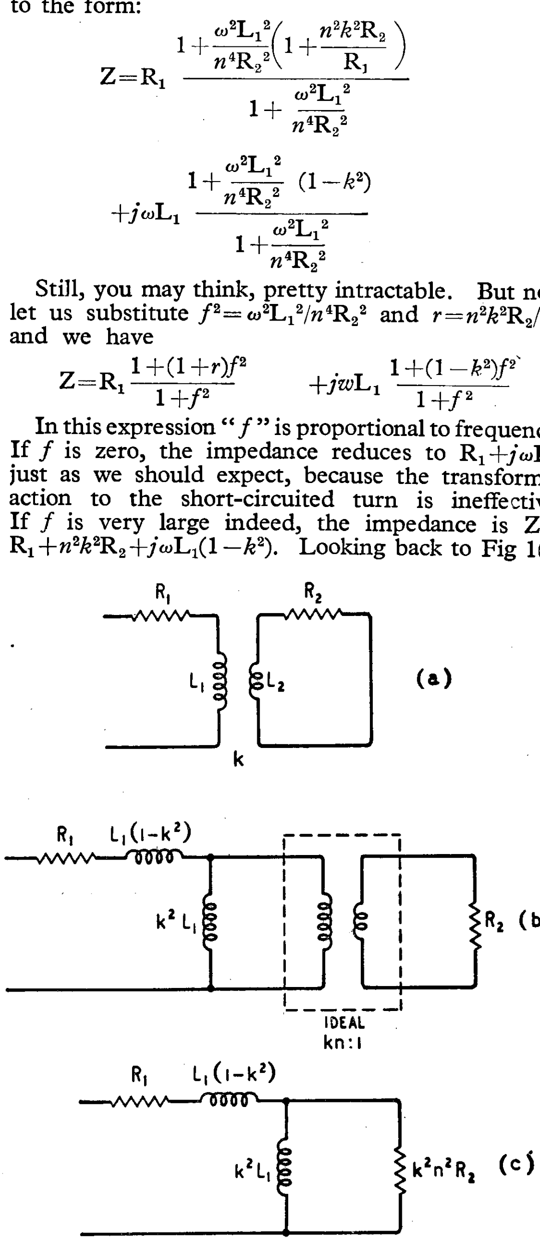


Fig. 1. (a) The short-circuited winding L_2 has a "self-resistance" of R_2. It can be transformed via (b) to the simple network (c).

this again is just what we should expect, because $j\omega L_2$ is so large compared with $n^2k^2R_2$ that we can neglect it. Can we easily find out what happens in between?

The resistance and reactance terms each have the form

$$M=(1+a^2f^2)/(1+f^2)$$

If we can deal with this, we can deal with each of the components of Z. Let us take logarithms:

$$\log M=\log (1+a^2f^2)-\log (1+f^2)$$

You may already have recognized the form of the expression: you may recognize the form $\log (1+f^2)$. Just in case you have not connected it up, consider the circuit of Fig. 2. For this circuit

$$\left(\frac{V_1}{V_2}\right)^2=1+\omega^2C^2R^2$$

and if we put $\omega^2C^2R^2=F^2$

the frequency response is $10 \log (1+F^2)$ decibels.

This is a very familiar shape indeed. In some articles on feedback problems in *Wireless World*[2], I described how straight-line approximations could be used to sketch out characteristics of this form. You can find a summary of this in Langford-Smith, "Radio Designer's Handbook" (p. 363). In very simple terms, we assume that if F is less than unity we neglect it: if F is greater than unity, take $(1+F^2) \approx F^2$ so $\log (1+F^2) \approx 2 \log F$. This is a straight line on graph paper using a logarithmic scale for frequency. A rather better sketch is obtained by noting that at $F=1$, $10 \log (1+F^2) \approx 3$ which gives a point at the corner to enable it to be rounded off.

With this connection established, the form of M becomes familiar too. It is a "step" characteristic, the shape we introduce in our feedback amplifiers to manœuvre past a point of inadequate stability. In its simplest approximation form it consists of two horizontal sections, $M=1$ and $M=a^2$, joined by a sloping line. The corners are at $f=1$ and $f=1/a$. All we need to do, then, is to draw this pattern, remembering to use logarithmic scales. It isn't, of course, necessary to hunt out log-log graph paper for this. I prefer to use centimetre squares, scaled in octaves. This is much cheaper, and it gets over the difficulty that only too often one has a supply of one maker's log paper one year, and another maker's the next. Centimetres are always the same size.

Now let us turn back to Z. The corners of the resistance characteristic are at $f=1/\sqrt{(1+r)}$ and $f=1$, and the corners of the reactance at $f=1/\sqrt{(1-k^2)}$ and $f=1$. For the sake of an example, let us take

$r=3$

and $(1-k^2)=0.25$, i.e., $k^2=0.75$, $k=0.865$.

The step heights are: for R, 4

for L_1, 4

and the corner frequencies: for

R, $f=1$ and $f=\frac{1}{2}$

L, $f=1$ and $f=2$.

Fig. 3 shows the simplified shapes which are obtained.

We are now in a position to look more generally

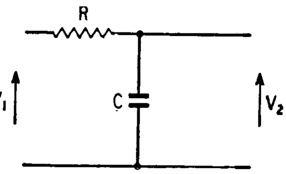


Fig. 2. For this network $V_1/V_2 = 1+j\omega CR$, so $|V_1/V_2|^2=1+\omega^2C^2R^2$.

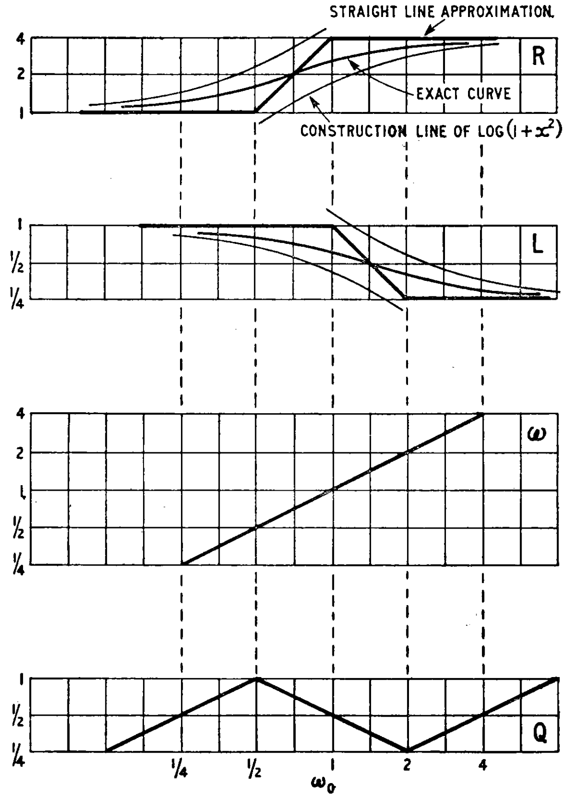


Fig. 3. Typical shapes obtained using the straight-line approximation method for the conditions discussed in the text.

at what happens. The key frequency is obviously given by $f=1$. Looking back we see that

$$f=\omega L_1/n^2R_2$$

so that the key frequency ω_0 is given by

$$\omega_0=n^2R_2/L_1$$

Below this frequency the resistance has already been increasing, while the inductance has stayed unchanged: above this frequency the inductance is falling, but the resistance has already reached its limit.

The next important frequency to consider is given by $f^2=1/(1+r)$ so that it is just

$$\omega_2=\omega_0/\sqrt{(1+r)}.$$

This tells us where R starts to rise.

The third important frequency is where $f^2=1/(1-k^2)$ when L reaches its final value. It is, of course, $\omega_2=\omega_0/\sqrt{(1-k^2)}$.

Before going on to explore these details, let us just add to Fig. 3 a line showing frequency as a function of frequency—a straight line, as you might expect, and then a simplified graph for $Q=\omega L/R$ which on a log-log scale gives us $\log Q=\log \omega+\log L-\log R$.

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[2] "Stabilizing Feedback Amplifiers," March 1951.

To draw this we simply add and subtract, as indicated, the lines already drawn. We see that Q increases up to ω_1, with $Q \propto \omega$, then decreases with frequency between ω_1 and ω_2 with $Q \propto 1/\omega$ and finally, above ω_2 increases with frequency again. This Q-factor is not, in general, the true Q of the coil, because it takes account only of the copper loss, and even this is assumed to be constant. The effect of the short-circuited turn is, however, clearly shown. In general terms it reduces the limiting Q by a factor of $(1-k^2)/(1+r)$.

Some Numerical Examples

Now, perhaps, we might go on to discuss some of the implications of our results. If we have a true short-circuited turn, by which I mean that L_2 is actually part of L_1, $nR_2=R_1$ because the area of the conductor is the same for the two windings (or parts of the winding). Consequently

$$r=n^2k^2R_2/R_1=nk^2.$$

In a low-frequency coil, k^2 will be near enough to unity not to be worth keeping in the picture, so that $r \approx n$. The key frequency is n^2R_2/L_1 or nR_1/L_1.

Let us try some numbers: a coil for a low-frequency filter might well have an inductance of 100 mH, with 1,000 turns and a resistance of 10 ohms. At 1,600 c/s, this coil would have a Q of 100. It is, in fact, a good coil. Now let us assume we have a short-circuited turn. The resistance will start to rise at a frequency

$$\omega_1=\omega_0/(1+n)^{\frac{1}{2}} \quad (\text{since } r=n)$$

$$=nR_1/L(1+n)^{\frac{1}{2}}$$

$$\approx n^{\frac{1}{2}}R_1/L \text{ (since } n \text{ is large enough for } 1+n \approx n).$$

Thus $\omega_1=n^{\frac{1}{2}}10/0.1=100n^{\frac{1}{2}}$.

The maximum value which n can take is 1,000, when a single turn is shorted. Then $\omega_1=3{,}000$, roughly, and the frequency is 500 c/s. If a block of 10 turns is short-circuited, $\omega_1=1{,}000$, and the frequency is about 160 c/s. The values of ω_0 lead to frequencies of 16,000 c/s and 1,600 c/s. As we have seen, it is only above the key frequency ω_0 that the inductance starts to fall. A test at 1,000 c/s, then, would show the correct inductance but very high losses. As we have already seen, the resistive term tends towards $(1+r)$ times its normal value, so that on the basis of the straight line approximation the resistance will be 10,000 or 1,000 ohms for the two values of n at ω_0.

Now let us look at the brass tuning slug. In a high-frequency coil we might make $k^2=\frac{1}{2}$, and since the slug is very much thicker than the wire of the coil, nR_2 will be much less than R_1. To get some figures, let us consider a 10-turn coil, and a slug made up of 10 turns in parallel. Then $R_2=R_1/100$ and $r=\frac{1}{2}\times 100\times\frac{1}{100}=0.5$. The resistance of this coil will be increased by 50%, while the inductance is brought down to one-half its original value. To adjust the coil we withdraw the slug, and as we make k smaller, L will rise and R will fall. If we only need a 10% reduction in L we can take $k^2=0.1$ so that R only rises by 10%. That certainly is not too expensive.

These two examples confirm the result which we might have derived from our expression for the impedance: in most practical situations the first parameter to examine is r. If r is small, nothing much will happen to the loss of the coil. If k is very small, nothing will happen to the inductance either, but a small value of k does not necessarily mean a small value of r. It helps, though, as you would expect, because if the short-circuit isn't coupled to the coil it can't do much harm. Keeping R_2 low keeps r small, so that a silver-plated slug will be slightly better than a brass one. But for a small adjustment, k will look after this, and as we saw, you may only be losing 10%. It is interesting to notice that if we had altered our 10 parallel turn slug to a two-" turn " slug, each turn made up of 5 standard turns, although n^2 would have fallen to 25, R_2 would have risen to $R_1/25$ and r would not have been affected.

Having checked for good or bad by examining r, a test for the active frequency region begins with the determination of ω_0. This tells you whether your application is likely to find the shorted-turn disturbing the inductance or the resistance.

In all the discussion above we have used the straight line approximation. Of course, the whole analysis is based on an approximation, but for the benefit of those who want to see how much the smooth-curve solution deviates from the straight-line form, I have added the smooth curve to Fig. 3. The basic smooth curve can be found as in Fig. 7.55D of " Radio Designer's Handbook." and a general survey is given on pages 363–365. All that need be done is to add the smooth standard curves instead of the approximation. The straight line approximation is at its worst near the corners of the characteristic, so that Fig. 3 makes it look just about as bad as it can be. With a little practice it becomes fairly easy to sketch in the rounding and to produce a freehand curve quite close enough to the correct one. Fig. 7.55F of the above shows how this sort of technique comes out in practice.

Screening Problems

Can we make use of all this work for any other purpose? Life is not all slugs and defectives. One fairly obvious application is to the problem of screening coils. The screen is just a short-circuited turn, and the problem resolves itself into the determination of k and R_2. The only simple expression I have been able to find is given by Terman (" Radio Engineer's Handbook," 1st Edition, p. 71, equation 87). He gives an approximate expression for the coefficient of coupling between two coaxial concentric coils as $k=a^2l/A^2x$, where a and A are the radii of the inner and outer coil, and $2l$ and $2x$ are their respective lengths. If we assume the screen to be twice the length of the coil itself and the screen radius to be twice the radius of the coil, this gives us $k=\frac{1}{8}$. From what we have already seen, the limiting inductance is $L_1(1-k^2)$ so that we lose rather under 2% of our inductance. If we also assume that the screen is the same kind of conductor as the wiring we get back to the expression $r=nk^2$.

For a 10-turn coil, then, $r=0.156$. In this particular case the inductance drops 1.56% but the resistance goes up by 15.6%.

Unfortunately these figures are in violent disagreement with those given in Section 10.1 vii of Langford-Smith. The RCA curves for k^2 rather suggest a misprint in Terman, because there would be fair agreement if Terman's expression were actually for k^2. This leads us to the conclusion that the effect of the screen is to drop the inductance about

12% and increase resistance to more than double its initial value.

It is rather a pity that there is this disagreement. However, the RCA curves for k^2 can always be used, and the expression for r enables us to get some idea of what will happen to the losses. We can also get some idea of the frequency range over which L will be varying. This is important, because we often find it convenient to test a coil at one frequency and use it at another. A screened coil may have a different inductance when the frequency is changed. When measuring the self-capacitance, too, we assume that the inductance itself is constant. With a screened coil this is not necessarily so.

One feature of our results not yet discussed is that there is a worst value for the quantity n^2R_2. If n is fixed, this means that there is a worst value for R_2: if nR_2 is fixed, the case of a short-circuit on a uniform winding, there is a worst value of n. To examine this effect we may proceed to differentiate the expression for Z: I haven't done this, because it seems to be one of the easiest ways to cover a lot of paper without arriving at any results. Let us try a rather more roundabout approach, confining our attention for the moment to the resistance. In fact, it is only the resistance which behaves in this way, but the proof of that I shall leave to the reader.

We have

$$R = R_1 \frac{1 + (1 + r)f^2}{1+f^2} = R_1\left(1 + \frac{rf^2}{1+f^2}\right)$$

The only term which varies is the factor $rf^2/(1+f^2)$. This is a maximum if $(1+f^2)/rf^2$ is a minimum. So now we need only think about

$$\frac{1}{rf^2} + \frac{1}{r}$$

and this is

$$\frac{R_1}{n^2k^2R_2} \cdot \frac{n4R_2^2}{\omega^2L_1^2} + \frac{R_1}{n^2k^2R_2} = \frac{R_1}{k^2}\left[\frac{n^2R_2}{\omega^2L_1^2} + \frac{1}{n^2R_2}\right]$$

$$= \frac{R_1}{k^2\omega L_1}\left[\frac{n^2R_2}{\omega L_1} + \frac{\omega L_1}{n^2R_2}\right]$$

It is fairly well known, and fairly easy to prove, that a quantity $(a+1/a)$ has a minimum value when $a=1$. A quick numerical check will show how very plausible this is. Therefore if

$$\frac{n^2R_2}{\omega L_1} = 1$$

the resistive term is a maximum. Since

$$\frac{1}{rf^2} + \frac{1}{r} = \frac{2R_1}{k^2\omega L_1}$$

at this point, the circuit resistance will be

$$R = R_1(1 + k^2\omega L_1/2R_1).$$

If you like bringing in Q, you can write $\omega L_1/R_1 = Q$ giving $R = R_1(1+k^2Q/2)$ and the peak occurs when

$$\frac{n^2R_2}{R_1} = Q$$

An application of this part of the analysis can be found in "Recent Developments in Long-Distance Telephony," A.C. Timmis, *J.I.E.E.*, Vol. 78, p. 601, June 1936.

In an appendix we find Fig. 4 (based on Fig. 15, *loc. cit.* p. 615). This shows how the resistance term in the basic characteristics of telephone cable varies with the thickness of the copper tape used for screening. The screen acts as a short-circuited turn coupled to the long narrow loop formed by the pair of conductors. Roughly speaking, R_2 will be inversely proportional to the thickness of the screen. As we expect, there is a worst value of R_2 for any particular frequency. As the frequency is increased, this maximum occurs at higher values of R_2, or lower thicknesses. And the figure shows, too, that the incremental resistance at the maximum is roughly proportional to the frequency of the maximum. All in accordance with theory.

Other Applications

Although only a very rough picture can be obtained, the theory of the short-circuited turn does give some idea of why you need to use thinner laminations in an iron-cored coil if you want to get a good Q at higher frequencies. Each lamination, is, in section, a small shorted-turn. The thinner the lamination the higher the value of ω_0, the key frequency. Different material resistivities alter ω_0 too: the results are only of value in providing a general concept, because the current distribution across the lamination alters with frequency, and R_2 is by no means constant.

As any reader who has progressed this far will have seen, the short-circuited turn is worth a detailed study. The theory has wider application than would appear at first sight; it shows us that there are some mathematical operations which come in useful for all sorts of purposes and it leads to an agreeably tidy solution. There is, of course, no great new discovery involved. All this article has attempted is a tidying up operation: it has certainly tidied up my own ideas on this pleasantly ordinary problem.

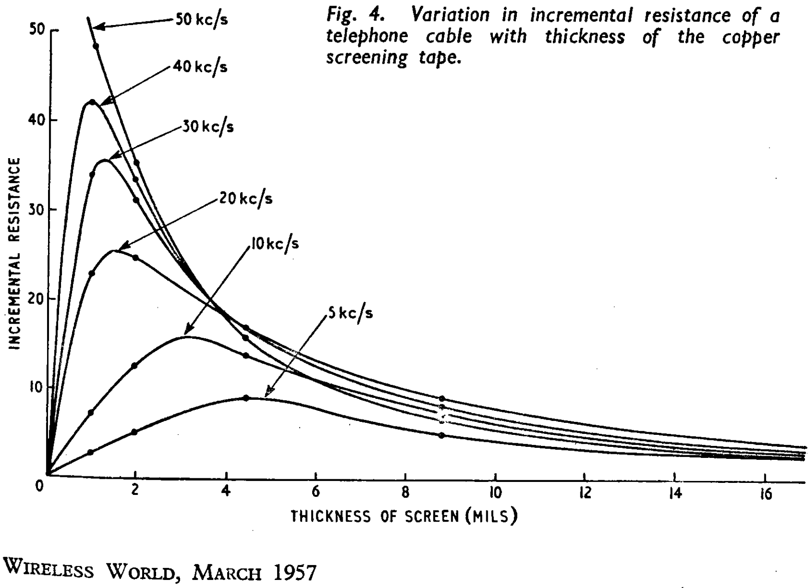


Fig. 4. Variation in incremental resistance of a telephone cable with thickness of the copper screening tape.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents

Colour Television

WHILE the B.B.C. were transmitting some NTSC-type colour television for the benefit of M.P.s a few weeks ago I happened to look in at the monochrome version, and I must say I was not at all impressed by the compatibility. The pictures had an unaccustomed soft look, which might have been due to sub-carrier interference (visible on my set), or to some fault of gamma correction, or to the loss of luminance detail by gamma correction described by Dr. White in your February issue. It would be interesting to hear an explanation from the B.B.C.—and also if they were using a "notch" filter to reduce sub-carrier interference, or some other method.

I would certainly mark the effort as "8+" or "well tried," but for me, at any rate, compatibility has got to be perfect. Such pictures would not be at all acceptable as a regular thing—although I must say I enjoyed the show rather better than the normal B.B.C. programmes! (Perhaps it was necessary to "sell" compatible colour to the hon. Members.)

London, S.E.22. K. R. McALISTER.

WHILST I am in no position to discuss the attitude of our General Post Office in relation to the possible transmission standard for colour television signals, R. F. Colvile may like to know that a similar state of affairs to that prevailing here exists in the United States and throughout a large area of Europe.

The American approach is rather interesting as it is a guide to the mysteries surrounding the preoccupation with a 405-line colour TV standard in this country. In short, the ATT and Bell networks convert the NTSC full-specification signal to a "Narrow Band NTSC Signal," the relative details are that the colour sub-carrier is shifted to 2.66 Mc/s approximately. Apart from scanning rates, therefore, the total occupied spectrum (3 Mc/s) closely resembles that currently used in the B.B.C. tests.

Speaking personally, I feel that it will be quite a long time before the Television Advisory Committee reaches a final decision, and even then they will be influenced by the viewpoint of the major manufacturers and the over-all economic situation.

Winston Electronics, Ltd., Shepperton, Middx. G. LEVINE.

EXISTING systems of colour television are governed by two constraints: (a) the receiving apparatus is assumed to use a three-component method of reconstructing the coloured picture and (b) the transmission is required to be compatible.

If it were not for these constraints, the obvious method of transmitting a colour picture which would still be usable on monochrome receivers would be to transmit luminance, hue and saturation, the first according to the existing monochrome standards. But hue and saturation are not convenient variables for the reconstruction process. So far as I know the only variable-hue device is an adaptation of the Kerr cell, which implies a projection receiver, and there is no direct variable-saturation device.

In a linear system the luminance, hue and saturation signals could be translated in the receiver into red, blue and green intensities, but this is excluded if gamma correction is applied at the transmitter to anything more than the simple luminance signal. It could be removed from the latter by an inverse gamma correction at the receiver before setting about the construction of three colour components. In these days when crystal diodes are quite cheap, is it really impracticable to require the manufacturer of the receiver to incorporate in it the non-linear circuit which is needed to compensate the gamma of the picture tube? One could then transmit true luminance and colour signals.

A realistic assessment of the importance of absolute compatibility depends on a forecast of transmission schedules. Will all transmitters go over to colour for the whole of their transmissions as soon as a colour system is established, or will there be at least an intermediate stage in which some programmes will still be transmitted in monochrome? Will the cost of colour receivers remain so far above the cost of monochrome receivers that there will still be a market for the latter, and will programme production costs be much higher in colour than in monochrome?

Only in the light of answers to these questions can one decide whether the whole future of colour television should be prejudiced for the sake of absolute compatibility.

Birmingham. D. A. BELL.

Scale Distortion Again

WHILST I fully agree with the arguments put forward by your reviewer, M. G. L., in his reply to Stanley May (p. 30, your January issue) I think he did less than justice to Vox Productions in his review of their record DL130, "This is High Fidelity."

The main part of the booklet issued with the record was a photo-copy of the American version. But a number of comments that seemed to be required to adapt the text to British practice was made in a foreword which the British company asked me to write. In that foreword the point was specially made that most British acoustic engineers did not concur in the American advocacy of a "compensated gain control" based on the Fletcher-Munson curves.

It has always seemed to me that far too much importance has been attached to these curves (which after all are only an empirical expression of the average of a number of observations made during a particular series of experiments); and, indeed, that they have been applied as authoritative evidence in circumstances which are outside their terms of reference. They purport to show the intensities of pure tones of equal loudness at different frequencies, the loudness being based on the average of the judgments of the persons who were concerned in the experiments. But it does not by any means follow that if a piece of music is reproduced at a volume level greater or less than the original (whatever that may mean!) the frequency response should follow the contour of a Fletcher-Munson curve. Logically, there is no necessary relationship between the two. An entirely different set of experiments would be necessary to determine (even if it could be determined with any precision) what are the rules that should be applied to reproduction at different volume levels in order that the result may sound natural.

The beginnings of such a research were started by G. A. Briggs and his associates at his Festival Hall demonstrations. They showed conclusively that the intensity level which reaches our ears in a concert hall is much smaller than we had previously assumed, and indeed that it is possible to achieve the same level in one's home without the music sounding over-loud, even to the ladies. But they told us nothing at all about the desirable frequency response for reproduction in the home, whether at that intensity or at higher or lower intensities.

Assumptions which are extrapolations of observations in particular experiments are very risky in the field of hearing. Who, for example, could have supposed on *a priori* grounds that when a complex sonorous vibration from a loudspeaker is presented to the ear it will be resolved, not into a set of constituent tones, but into a series of groups of tones, one group representing a violin, another group a piano, another an oboe and so on? Why doesn't the ear do something analogous and sort out what one might term (for shortness) the stereophonic components in the vibration?

I suggest that until we have specific *ad hoc* evidence in this matter of loudness *v.* frequency response we had better reserve judgment and simply adjust our controls to please our womenfolk.

Technical Editor, "The Gramophone." PERCY WILSON.

Information Theory and Broadcasting

SO the human mind is to be turned into a "black box" of calculable capacity for insertion into a communication chain! That thought (editorial comment, your January issue) rather shocks me. Anyway, I doubt if you have succeeded in showing how Information Theory can be applied directly towards improving broadcast programmes. All the same, I agree that the programme people might benefit from studying the underlying philosophy.

Take the information content of television pictures. V. J. Cooper, after pointing out (your April 1956 issue) that the vision bandwidth is 100 times greater than that of the accompanying sound, went on to assert we get very poor value for the extra Mc/s. Your editorial set me trying to verify Mr. Cooper's assertion. After spending quite a lot of time in watching typical programmes, my conclusion was that he did not exaggerate. Indeed, there were occasions when the *semantic* information content of the picture seemed to be a negative quantity! The sound transmission alone sometimes evoked in my mind a visual image that turned out to be more satisfying, pleasing or appropriate than the picture seen on the screen when I reopened my eyes. And I am not supposed to be a highly imaginative type.

Reading, Berks. C. J. STRATTON

THE editorial of your January issue advances strong arguments which show that the B.B.C. should make a complete reappraisal of the regional broadcasting system.

I had hoped that when the v.h.f. network spread it would carry a cosmopolitan programme of the most general interest, leaving the medium waves for the Regions, but, alas that was not to be. I fear that the eagerly awaited v.h.f. station at Rowridge will carry the West Region service instead of the far more apposite London programmes.

Romsey, Hants. B. JAMES.

Television Interference

IN your February issue "Diallist" refers to, and expresses some surprise at, a few cases reported from the Leeds area of interference from the Holme Moss v.h.f. sound transmissions with television reception from the same station.

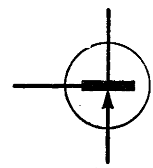
This is most likely second-channel interference on television receivers having non-standard i.fs. in the 20-Mc/s region with, of course, their local oscillators "high." There are still quite a few of these receivers in use, and the second-channel rejection of some is unfortunately not all that could be desired. The trouble can usually be overcome by the use of a simple stub rejector consisting of a section of coaxial feeder cut to the appropriate length and connected at the aerial input to the receiver. The alternative of fitting some sort of second-channel rejection circuit inside the receiver or changing the i.f. is not always convenient, but may be necessary in some cases.

Second-channel interference has also been experienced by viewers in the Norwich area since the v.h.f. sound station sharing the same site as the Norwich television station was brought into operation in December. Here the trouble affected television receivers having i.fs of 19.5 Mc/s (sound) and 16.0 Mc/s (vision), which when tuned to Channel 3 for reception of the Norwich station 56.7 Mc/s (vision) and 53.25 Mc/s (sound) are prone to second-channel interference on vision from the v.h.f. Light Programme transmitter on 89.7 Mc/s and on sound, but to a lesser degree, from the v.h.f. Third Programme transmitter on 91.9 Mc/s. The B.B.C. has given advice on the problem, and thanks to the energetic efforts of the radio trade and of local Post Office engineers the complaints that have been received are being dealt with effectively. None of this trouble is, of course, being experienced on television receivers with i.fs of 38.15 Mc/s sound and 34.65 Mc/s vision, which have now been adopted as standard by the radio industry.

Engineering Information Department, B.B.C. L. W. TURNER.

Transistor Symbols

I FIND I have been guilty of unconscious plagiarism in submitting the transistor symbol shown in your last issue. Something very similar appeared earlier in the December, 1956, issue of the *Journal of Scientific Instruments* (see sketch) in a paper by Bane and Barber. My apologies are nevertheless tinged with satisfaction at getting this support from such an august body as The Institute of Physics (which publishes the *Journal*) and from the authors, who are N.P.L. people.



London, S.E.5. JAMES FRANKLIN.

Etymological Inexactitude

"CATHODE RAY" rebukes me in his letter (Feb. issue) for treating the word "data" as singular. In so doing I was, strictly speaking, as fully guilty of an etymological inexactitude as he himself is in his letter when he uses the word "panchrome" instead of the puristically proper word "pantochrome." No doubt he is consistent and takes his offspring—or, more correctly, little Fluorescences—to the "panmime" which pedantic people still call a pantomime.

But, seriously, although we are obviously both trying to follow modern usage, I have by far the stronger case. Nowadays the word "datum" has a special positional meaning as in the sentence "sea level is the datum for measuring mountain height." In English, it is no longer the singular of "data." The word "data" has virtually become a singular noun in its own right in the same way as the word "agenda," to which, Sir, you so rightly call attention. Whoever heard the Chairman of a committee say "Gentlemen, the agenda *are* rather long to-day"; and if there be only one item on it, does he call it an agendum?

"FREE GRID."

Peak or R.M.S.?

I HAVE always been under the impression that there was a convention that all audio and r.f. voltages which would normally be measured by a valve voltmeter were expressed as peak values, and I have for a number of years used a valve voltmeter which starts with a diode probe.

I notice lately, however, that there is a tendency for other forms to become popular. For instance, the instrument shown on page 611, December issue, measures the mean or average value, although it may be calibrated to read r.m.s. or peak on some definite waveform. There is another one advertised on p. 144 (Dec.) which may be similar.

Many makers of recording tape and recorders do not state whether the figures they quote for erase, bias and signal voltages are peak or not, and I think I have seen one tape advertisement where r.m.s. figures are quoted.

This all seems to be adding up to some confusion.

Bideford, Devon. THOMAS G. WARD.

Guarantees

I AGREE with your February editorial that guarantees are usually unsatisfactory.

Our firm's guarantee reads "Departures from the specification during the first 12 months of proper use will be corrected free of charge." This at least has the merit of brevity, and our customers evidently like it.

Servomex Controls, Ltd. R. C. STEEL.
Jarvis Brook, Sussex.

Radar Displays

I REGRET to take issue with anything which Dr. Eastwood has to say on the subject of radar displays. I believe that the substance of his comments in his letter in your issue for December is perfectly correct until it makes the claim that the first perfected comprehensive fixed-coil display system used in this country was developed and produced by Marconi's Wireless Telegraph Company in association with the R.R.E.

There is perhaps little credit in any case in being first in the field, but for the record I should like to point out that the Liverpool harbour radar, designed and developed by A. C. Cossor Limited for Sperry Limited, incorporates a fixed-coil display which has proved satisfactory in operation since it was officially commissioned at an opening ceremony on July 3rd, 1948. The first M.T.I. radar in operation at London Airport, also designed by A. C. Cossor Limited, which was installed there in July, 1953, incorporated a fixed-coil display and interscan provision for a C.R.D.F. presentation.

A. C. Cossor Ltd., K. E. HARRIS.
London, N.5.

COMMERCIAL LITERATURE

Signal Sources, including noise and pulse generators, take pride of place with some 90 pages in the 1957 catalogue of measuring instruments from Marconi Instruments of St. Albans, Herts. There are also instruments for measuring voltage, power, frequency, f.m. deviation, distortion, field strength, Q and standing waves. An industrial section includes X-ray apparatus, moisture meters and pH meters. The catalogue is lavishly illustrated with photographs and functional diagrams.

Non-Soldered Connections by means of "taper receptacles" or small tubular units of silver-plated brass into which tapered pins are inserted. These and many other types of terminals (for soldering) and accessories are listed and illustrated in a catalogue from Harwin Engineers, Nibthwaite Road, Harrow, Middlesex.

Tape Amplifiers, for recording and reproduction, designed for various well-known makes of tape decks and also for double-channel stereophony. Four models, as well as two other amplifiers for sound reproduction, are described (with specifications) in an illustrated catalogue from Shirley Laboratories, Worthing, Sussex. Overseas distributors are Sound Diffusion (London), Duracraft Works, Portslade, Sussex.

Electronic Reading Machine for recognizing printed characters at 120 per second and recording the information on punched cards, or tape, or magnetic tape, for computer input. This is one of the new projects under development outlined in a review of progress by the Solartron Electronic Group for 1956. Available from the company at Thames Ditton, Surrey.

Interlocking Storage Trays for small components, suitable for factory assembly benches. A new "midget" range, moulded in phenolic material, is illustrated in a leaflet from Precision Components (Barnet), 13, Byng Road, Barnet, Herts.

Polythene Sheets in gauges between 0.01in and 0.125in. Physical properties and applications of "IRIDON-1000" are described in literature from the Iridon Division of Commercial Plastics, 1, Avery Row, Grosvenor Street, London, W.1.

Coated Soldering Bits with thin layer of an iron alloy over the copper to protect it against oxidation. Claimed to last 10 times longer than conventional bits. Various sizes and shapes, for screwing or plugging into irons, with notes on use and care, are given on a leaflet from the Hexacon Electric Company, 276, W. Clay Avenue, Roselle Park, N.J., U.S.A.

Barium Titanate Pickup cartridges claimed to be impervious to distortion from humidity and temperature changes. Change of styli (normally sapphires) by turnover method. Weight: 5 grammes. Frequency response curve and other performance data given in a leaflet from Technical Ceramics, Wood Burcote Way, Towcester, Northants.

A.M./F.M. Signal Generator covering 7.5Mc/s to 230Mc/s. Internal frequency modulation: 1,000c/s with fixed deviation of $\pm$60kc/s, or mains frequency with variable deviation of 0 to $\pm$150kc/s. External modulation: between 20c/s and 20kc/s for deviation up to $\pm$150kc/s. Amplitude modulation: 10% or 30% at 1,000c/s. Crystal calibration at 5-Mc/s intervals. Specification on a leaflet from Advance Components, Roebuck Road, Hainault, Ilford, Essex.

Pencil-Type Soldering Irons. A range of six Oryx models for low voltages between 6V and 50V, lengths 6-7in and bit sizes $\frac{1}{16}$ to $\frac{3}{16}$in, are described in a leaflet from Antex, 3, Tower Hill, London, E.C.3. Mains step-down transformers are also available.

Subminiature Electrolytic capacitors, suitable for transistor circuits and hearing-aids. Five new types (CE58) with capacitances from 0.25 μF to 6 μF and working voltages of 25 V to 1.5 V, measuring only $\frac{5}{8}$in long $\times$ $\frac{1}{8}$in diam., listed in Technical Bulletin No. 51 from The Telegraph Condenser Company, North Acton, London, W.3. Also a miniature range, $1\frac{1}{16}$in $\times$ $\frac{3}{8}$in and 2-100 μF in Bulletin No. 52.

Crystal Set using a germanium diode. Leaflet from the British Distributing Company, 591, Green Lanes, Harringay, London, N.8.

Moving-Coil Pickup, with diamond stylus for microgroove and sapphire stylus for standard records. Response: 20 c/s-16 kc/s constant velocity on microgroove. Compliance: better than 6×10^{-6} cm/dyne. Stylus pressure: 5 grammes. Leaflet on model GMC5 from The Garrard Engineering and Manufacturing Company, Swindon, Wilts.

Miniature "3000" Relay, with twin silver contacts, buffered springs, and coil consumption in the region of 0.075-0.2 watts, depending on contact arrangements required. Coil resistance, any value up to 5,000 Ω. Overall size, $1\frac{1}{2}$in $\times$ $1\frac{3}{16}$in $\times$ $\frac{1}{2}$in. Made by PAR of Nottingham and distributed by D. Robinson and Co., 58, Oaks Avenue, Worcester Park, Surrey.

Valve Retainers of various types. A manual listing a large number of CV valve types and their commercial equivalents with appropriate data on retainers and top-cap connectors. From Electrothermal Engineering, 270 Neville Road, London, E.7.

Simplified Relay, for a.c. up to 440 V and d.c. up to 110 V, departs from the normal "pile" method of mounting the contact blades and has them brought out directly on to insulating panels. This makes it possible to remove any set of contacts without disturbing the others. Leaflet from Electrical Remote Control Co., East Industrial Estate, Harlow New Town, Essex.

Grid-Dip Oscillator

NOVEL APPLICATION FOR A

CATHODE-RAY TUNING INDICATOR

By H. B. DENT

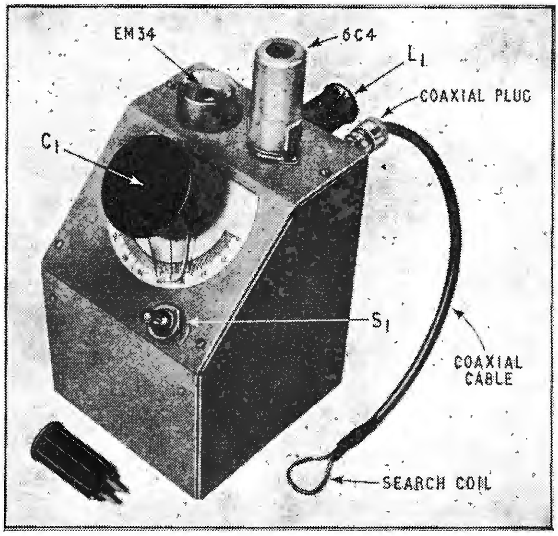
THE grid-dip oscillator can be likened to an absorption wavemeter used in reverse, for instead of absorbing energy in the process of measurement it has energy extracted from it. The absorption principle is used with oscillating circuits and the grid-dip method with quiescent circuits, the two being complementary in test gear.

Basically, a grid-dip oscillator (GDO for short) consists of a tunable r.f. oscillator with a very sensitive current measuring meter in its grid circuit. Two typical arrangements are shown in Fig. 1. Fig. 1 (a) will be recognized as one of the Colpitts family, while (b) obviously belongs to the Hartley group.

The instrument derives its name from the manner of operation. When the coil L is coupled to the inductive element of a non-oscillating circuit a "dip" in grid current occurs whenever the two circuits come into resonance.

No circuit changes are needed to either Fig. 1 (a) or Fig. 1 (b) to convert them into absorption wavemeters: all that need be done is to lower the anode voltage until the valve ceases to oscillate. There is some regeneration when the value is just short of the oscillating point, but this will improve rather than impair the performance as an absorption wavemeter.

When used as a grid-dip oscillator the changes in grid current are often quite small, especially when v.h.f. circuits or awkwardly placed h.f. circuits are

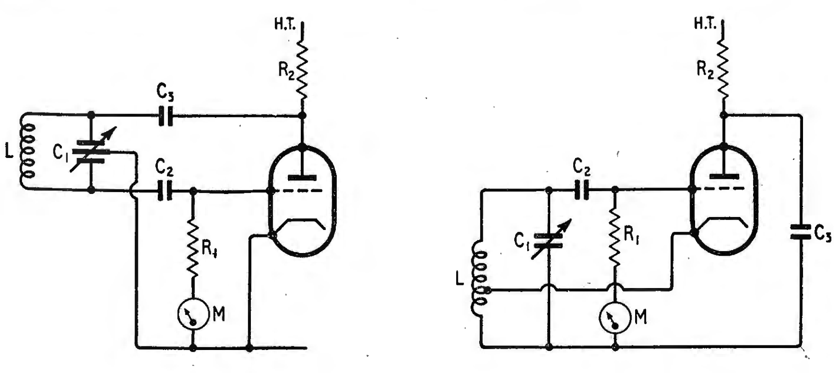


Form of construction adopted for the GDO described in the text. The power supply occupies the base part and the oscillator the top part.

involved which preclude coupling the GDO tight enough. Consequently very sensitive current meters are required in the grid circuit. Despite the manifold usefulness of this type of test set it is not always in such constant demand as to justify tying up an expensive microammeter for this one purpose. Plug-in meters can, of course, be employed but the writer has always disliked the idea of having to search round for a lot of loose items before a test set can be used.

What seemed to offer a solution to the problem appeared in the September issue of the New Zealand journal *Break-in*. It was a description of a grid-dip oscillator built round an EM80 cathode-ray tuning indicator. The really unique feature of this design is that the "triode" part of the EM80 is used as the r.f. oscillator, while the "magic eye" functions as the indicator of resonance. The circuit is shown in Fig. 2 and, with a suitable set of coils, is said to cover a frequency range of 80 kc/s to 200 Mc/s.

A "breadboard" version of Fig. 2 was assembled using an EM34 in place of an EM80 as the former was, but the latter was not, available and the EM34 was said in the original article to be a likely substitute. A few minor changes in the circuit were made; for example, the two "anodes" of the EM34 were strapped together and joined to a single anode resistor, also the "frills" S_1, S_2, R_2 and R_4 were omitted. These are included in the original design to enable the unit to be used either as a GDO or as an absorption wavemeter.



(a) (b)

Fig. 1. Two typical circuits used for grid-dip oscillators; (a) is a Colpitts and (b) a form of Hartley sometimes called an "electron-coupled" oscillator.

Despite the temporary layout being rather unsuitable for v.h.f. operation it was possible to obtain oscillation up to about 120 Mc/s. The lower frequencies were not explored, but it is reasonable to assume there will not be much difficulty in this region. The temporary layout served to confirm the practicability of the scheme and the "eye" winked most satisfyingly whenever an external circuit was coupled to the coil (L) and tuned through the resonant frequency of the oscillator, or *vice versa*. The only drawback (if it can be regarded as such) was that the EM34 required an h.t. supply of the order of 200 V for the "valve" to oscillate, and this seems also to be the requirement of the EM80 as the h.t. line was 250 V. Even with 200 V h.t. the anode resistor of the EM34 had to be dropped well below 100 kΩ to achieve oscillation in the v.h.f. bands. The general sensitivity appeared to be comparable to that of an orthodox GDO circuit using a sensitive grid-current meter.

As it was desired to limit the h.t. to 120 V or so the tuning indicator idea was embodied in a GDO built round a 6C4 triode oscillator, as shown in Fig. 3. In this case the tuning indicator, an EM34, is operated by the rectified d.c. voltage which in all "grid-leak" oscillators appears as a negative bias on the grid of the valve and coexists with the grid current, so that indirectly the tuning indicator responds to "dips" in grid current. Thus there is no need to find another name for the unit. As the quiescent voltage on the grid of the EM34 is negative the indicator segments normally tend to close and open whenever a "dip" in grid current occurs in the oscillator.

Using 120 V h.t., and the circuit values in Fig. 3, the 5-V segment of the EM34 can be made to close fully with a suitable cathode tapping on L_1. The h.t. consumption is very light, being about 2.5 mA at 120 V. Of this the 6C4 takes 2 mA and the EM34 0.5 mA. Of course, the EM34 is not as brilliant as when operated at the normal 250 V but it is adequate for all normal purposes. The h.t. and l.t. are supplied by a small double-wound transformer T_1 (home made) giving 130 V and 6.3V at 0.4 A, an RMO

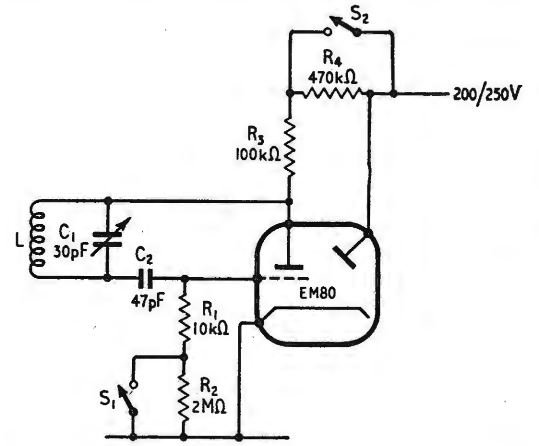
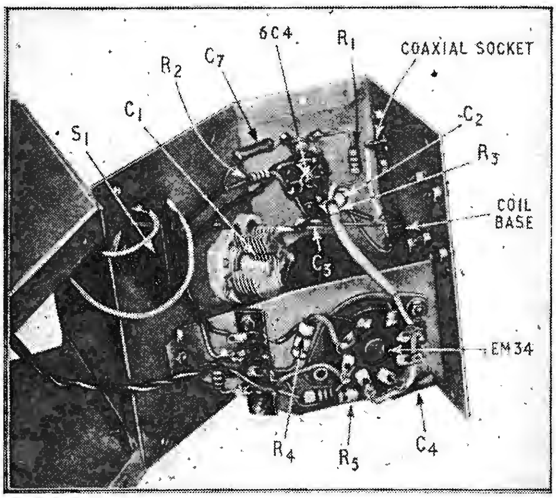


Fig. 2. Circuit of a grid-dip oscillator built around a single cathode-ray tuning indicator (described in September 1956 Break-in).



The oscillator is laid out to enable all connecting leads to be kept short. The tuning indicator is seen in the background.

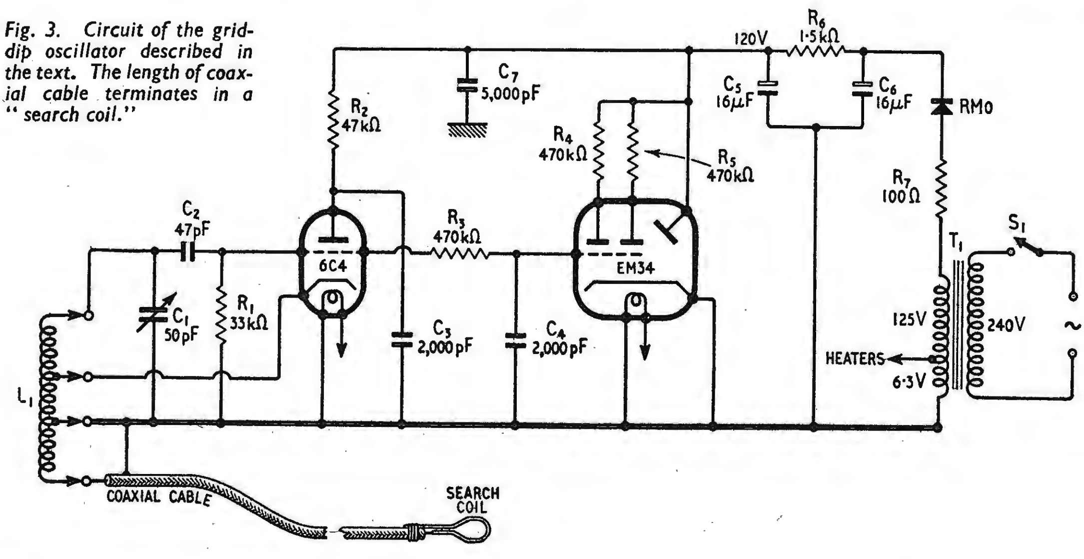


Fig. 3. Circuit of the grid-dip oscillator described in the text. The length of coaxial cable terminates in a "search coil."

"Centercel" rectifier, and the smoothing network shown. Incidentally C_5 and C_6 are 150-V working electrolytics.

The length of coaxial cable terminating in a loop shown in Fig. 3 is included to enable this GDO to be used in conjunction with v.h.f. equipments where it is often difficult to obtain a tight enough coupling to produce a measurable "dip" in grid current. The cable terminates in a coaxial plug and the "coupling coil" part of L_1 is taken to a coaxial socket on the back of the unit.

The "search coil" idea is not without its snags but the only troublesome one is that the cable has a self-resonance determined by its construction and length. If the resonant frequency falls in the tuning range of the oscillator absorption occurs and the indicator "winks," just as it will when coupled to any other tuned circuit. However, with a 10in length of "Standard Aeraxial" cable the resonant frequency fell just above 120 Mc/s, which is the highest frequency covered by the experimental unit. No originality is claimed for the "search-coil" idea as the writer has a recollection of seeing it used somewhere before, but neither the place nor the details can be recalled.

Two L_1 coils have been made so far; one covers 52.5 to 120 Mc/s and the other 24 to 53.5 Mc/s. The higher-range coil consists of 5½ turns of No. 18 s.w.g. tinned copper wire ⅜in diameter and spaced to occupy ¾in. Tappings are made to it two turns from either end and the coil is slipped down *inside* an Eddystone Type 763 miniature coil former. Connections are made to the pins as shown in Fig. 4. The second coil is connected in the same way but consists of 8½ turns of No. 26 s.w.g. enamelled copper wire wound on the outside of an Eddystone Type 765 former, which is ribbed and threaded 21 t.p.i. The tappings are taken in this case 2½ turns from one end for the earth tap and 4½ turns from the other (grid) end for the cathode tap.

Calibration is always a problem unless a signal generator or wavemeter is available. However, with the help of a v.h.f. receiver and the shortwave bands of a receiver, and also a lot of patience, acceptable calibration curves can be produced. Great accuracy is not needed in a GDO and for the same reason there is little to be gained by fitting a slow-motion tuning dial. A fairly wide frequency coverage is desirable with any one coil and at the higher frequencies a 2-to-1 frequency range is satisfactory. This is easily achieved with a tuning capacitor of 0 to 50 pF. Nevertheless stray capacitance must be kept at a minimum.

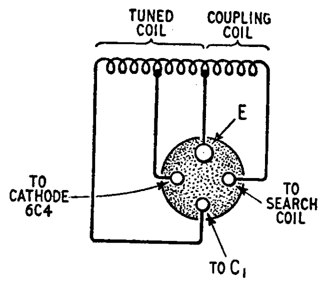
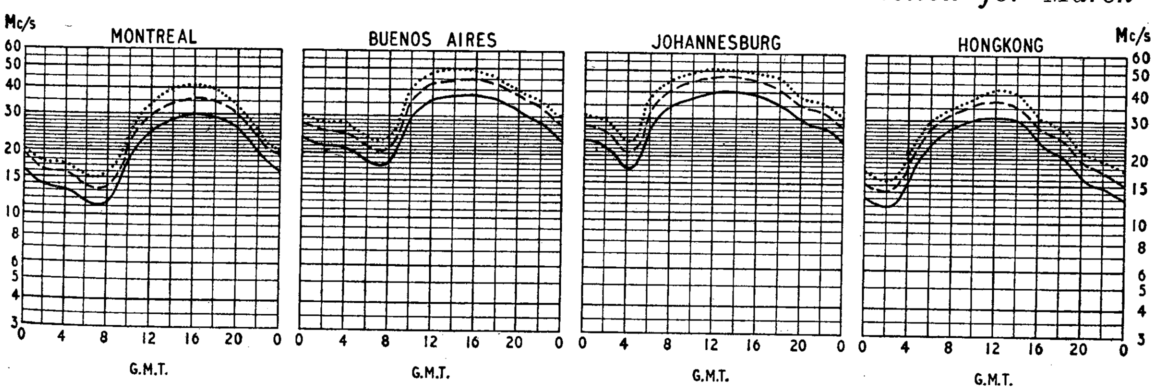


Fig. 4. Connections of the coil L_1 in Fig. 3 to the base pins of the Eddystone former.

The form of construction is unimportant and the GDO can be self-contained with the h.t. unit included and mounted on a handle so that the coil, which must be outside the case, can be poked into the insides of equipments. Another form is to have the power supply separate, and still another is the form shown in the illustrations. The latter has no particular merit except that it enables the leads to the three vital components, the valve, the coil holder and the tuning capacitor to be kept short. The power unit is in the base part. The arrangement shown leaves a little to be desired as the earthy return path of the capacitor is a little longer than is desirable for v.h.f. purposes. It would be better to use a Colpitts circuit if v.h.f. were the only requirement; the reason this circuit was not used in the present case is that a split-stator capacitor of suitable capacitance could not be found. One of 100 + 100 pF and reasonably small physically was required. This is the main reason why no attempt has been made to reach a higher frequency than 120 Mc/s.

SHORT-WAVE CONDITIONS

Prediction for March



THE full curves given here indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during March.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.

•••••••••• FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

———— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

Limiters and Discriminators for F.M. Receivers

By G. G. JOHNSTONE, B.Sc.*

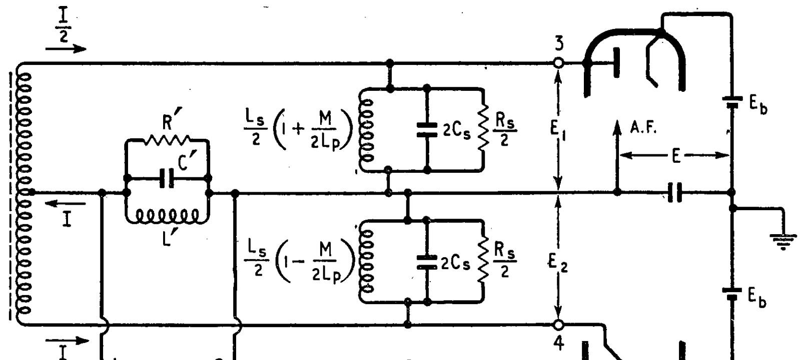
3—The Ratio Detector; Analysis of the "Idealized" Circuit

THE circuit of the conventional ratio detector circuit is essentially similar to that of a Foster-Seeley discriminator, and is shown in simplified form in Fig. 1. It differs from the Foster-Seeley circuit in that one of the diodes is reversed in sense, and in addition a capacitor of the order of 4–20 microfarads is connected in parallel with the load resistors R_L. Because of this capacitor, the voltage across the load resistors cannot change rapidly, and for the purpose of analysis, the two halves of the load circuit can be replaced by two batteries of appropriate voltage. This substitution is justified provided that the rate of variation of the carrier envelope is small compared with the time-constant of the load circuit. We shall return to this qualification later.

In part 1 of this series, an equivalent diagram for the phase-difference transformer shown in Fig. 1 was derived; this equivalent circuit is shown in Fig. 2. The analysis can be considerably simplified by assuming what we propose to show, namely, that the two tuned circuits connected between terminals 2, 3 and 2, 4 fed with equal currents provide a detector inherently insensitive to amplitude modulation. Thus we can ignore the tuned circuit connected between terminals 1, 2 initially, because its effect is to amplitude-modulate the current fed to the centre-tap of the "ideal" transformer T. The latter transformer ensures that the current divides equally between the branches connected to its ends.

We shall first consider two loss-free tuned circuits fed with equal currents with perfect diode detectors, i.e. rectification efficiency is 100 per cent. We shall use the circuit values appropriate to the phase-difference transformer, but the results are equally applicable to an arrangement of two tuned circuits, connected as shown in the equivalent circuit to be analysed (Fig. 3).

"Idealized" Ratio Detector.—Consider first the current flowing in the two diodes. Each diode conducts when the applied voltage reaches its peak value and a short pulse of current flows. It is a property of such a pulse that the d.c. component I_{dc} is equal to half the peak value of the fundamental frequency a.c. component I_{ac} in the equivalent frequency spectrum. These currents can be shown



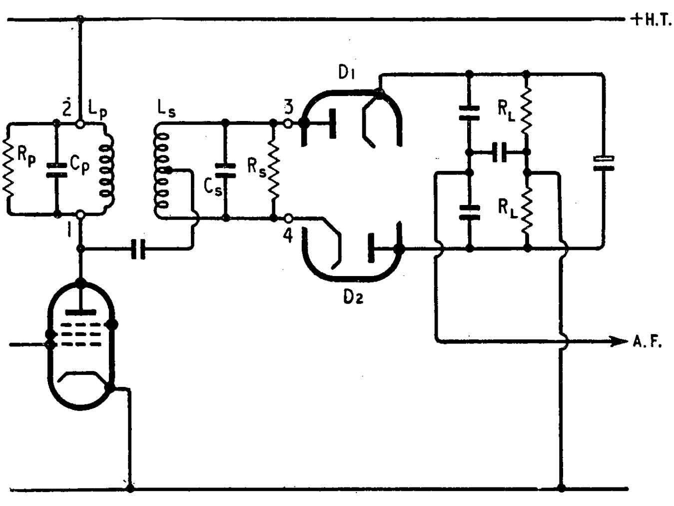
$R' \parallel \frac{R_s}{4} = R_p$

$L' \parallel \frac{L_s}{4} = L_p$

$C' + 4C_s = C_p$

Above: Fig. 2. Equivalent circuit of Fig. 1.

Below: Fig. 1. Simplified circuit diagram of ratio detector.



as loop currents flowing in the paths indicated in Fig. 4. There are currents at harmonic frequencies also, but we shall assume that the loop impedances are very low at these harmonic frequencies, and hence the voltages arising from these components can be ignored. There is only one path for the direct current in both diodes, and hence these currents must be equal. It then follows that the fundamental frequency a.c. components must also be equal in magnitude, although not necessarily in phase.

* B.B.C. Engineering Training Department.

The voltages across the tuned circuits are E_1 and E_2 respectively, and the fundamental frequency a.c. component in each diode is in phase with its applied voltage; this is again a property of the components of a short pulse of current. The tuned circuits are loss-free and the currents I_1 and I_2 fed to them are in quadrature with the applied voltages. Thus we may write $(I/2)^2 = I_{ac}^2 + I_1^2$ and $(I/2)^2 = I_{ac}^2 + I_2^2$ where I/2 is the input current to each half of the circuit. From these equations it follows that the magnitude of I_1 is equal to the magnitude of I_2. Thus a basic property of this circuit is that equal currents are fed to the two tuned circuits.

The magnitudes of the voltages E_1 and E_2 will be written as $|E_1|$ and $|E_2|$ and the magnitudes of the currents I_1 and I_2 as $|I_1|$ and $|I_2|$. If the magnitudes of the impedances of the tuned circuits are $|Z_1|$ and $|Z_2|$, then $|E_1| = |I_1| \cdot |Z_1|$ and $|E_2| = |I_2| \cdot |Z_2|$

We have assumed the diode rectification efficiency to be 100 per cent and hence $|E_1| = E_b + E$ and $|E_2| = E_b - E$, where E is the a.f. output voltage. We can thus write

$$E_b + E = |I_1| \cdot |Z_1|$$
$$E_b - E = |I_1| \cdot |Z_2|$$

Adding and substracting these expressions gives

$$2E_b = |I_1| (|Z_1| + |Z_2|)$$
$$2E = |I_1| (|Z_1| - |Z_2|)$$

and dividing gives

$$E = E_b \frac{|Z_1| - |Z_2|}{|Z_1| + |Z_2|}$$

This expression shows that the signal-frequency output voltage is independent of the input current I, i.e. that the circuit is not responsive to amplitude modulation.

To derive the relationship between the output voltage and signal frequency, it is convenient to replace the terms Z_1 and Z_2 by their corresponding admittances Y_1 and Y_2. Writing 1/Y for Z yields

$$E = E_b \frac{|Y_2| - |Y_1|}{|Y_1| + |Y_2|}$$

But

$$Y_1 = 2j\omega C_s + 2/j\omega L_s(1 + M/2L_p)$$

$$Y_2 = 2j\omega C_s + 2/j\omega L_s(1 - M/2L_p)$$

These expressions can be simplified by using Δf_1, and Δf_2 defined as

$$\Delta f_1 = f - f_1$$
$$\Delta f_2 = f - f_2$$

where f_1 and f_2 are the resonance frequencies of the two tuned circuits and f is the signal frequency.

In the neighbourhood of f_1 and f_2,

$$Y_1 = 4jC_s\Delta\omega_1 \quad \text{where} \quad \Delta\omega_1 = 2\pi\Delta f_1$$
$$Y_2 = 4jC_s\Delta\omega_2 \qquad \Delta\omega_2 = 2\pi\Delta f_2$$

These expressions can be given in terms of the half bandwidth $\Delta F = (f_1 - f_2)/2 = \Delta\Omega/2\pi$, and the separation $\Delta f = \Delta\omega/2\pi$ of the signal frequency from the centre frequency $f_o = (f_1 + f_2)/2$.

Then

$$\Delta f = \Delta f_1 - \Delta F = \Delta f_2 + \Delta F$$

Thus

$$Y_1 = 4jC_s(\Delta\omega + \Delta\Omega)$$

$$Y_2 = 4jC_s(\Delta\omega - \Delta\Omega)$$

The values of $|Y_1|$ and $|Y_2|$ are plotted in Fig. 5, together with $|Y_1| + |Y_2|$. The resultant characteristic of $E_b(|Y_2| - |Y_1|)/(|Y_1| + |Y_2|)$ is plotted in Fig. 6. This shows that the idealized ratio detector has perfect linearity over the range between the resonance frequencies of the circuits, the output in this range being given by $E = -E_b\Delta f/\Delta F$. In practice, of course it is not possible to realize loss-free tuned circuits and diodes with 100 per cent efficiency. An approach to this condition might be made by applying regeneration to the tuned circuit, but this has not been done to the author's knowledge.

The a.m. rejection properties of a ratio detector must be considered in two parts (a) the degree of

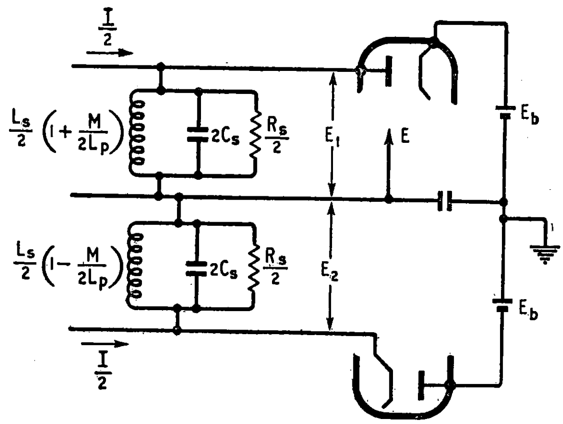


Fig. 3. Simplified circuit for initial analysis.

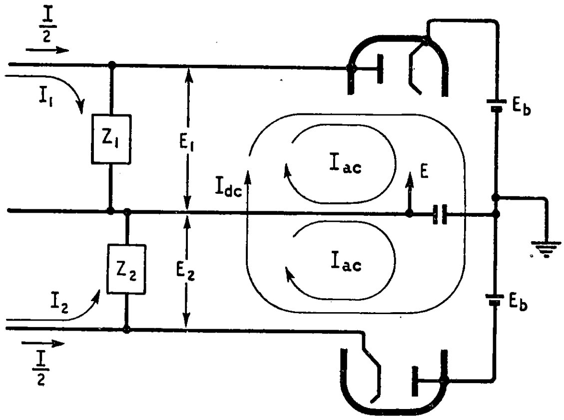


Fig. 4. Showing current paths.

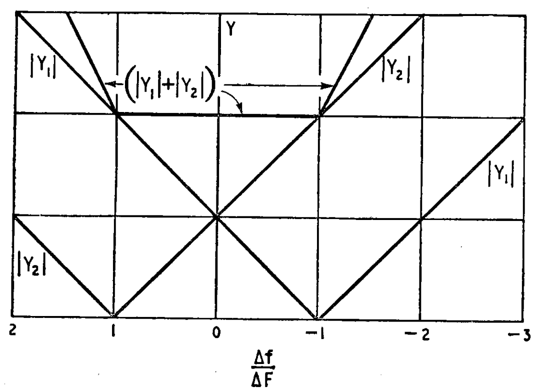


Fig. 5. $|Y_1|$, $|Y_2|$, and $(|Y_1| + |Y_2|)$ plotted against $\Delta f/\Delta F$.

a.m. rejection, and (b) the working range of signal amplitude over which this rejection is maintained. In the idealized ratio detector considered above, the output was shown to be independent of I, the r.f. input current; thus the detector has no response to a.m. However, it was implicit in the analysis that the input current input was sufficient to maintain current in the diodes at all times, i.e. that the peak voltage across each tuned circuit never fell below that of the battery. The condition where the diodes are cut-off can only occur when the amplitude of the input signal is decreasing, i.e. there is "downward" amplitude modulation. There is no corresponding limit if the signal amplitude increases.

The maximum degree of "downward" amplitude modulation that the detector can handle can be calculated readily. As stated above, the limit occurs when the current through the diodes falls to zero; under these conditions, all the input current (I/2) flows into the tuned circuit. Near the centre frequency, the impedance of each tuned circuit is approximately equal in magnitude to $1/4C_s\Delta\Omega$, and the voltage across each tuned circuit is equal in magnitude to E_b. The resultant current is of magnitude $E_b 4C_s\Delta\Omega$. The fundamental frequency a.c. component in the diodes is $2E_b/R_L$ (i.e. twice the d.c. component). These two components are in quadrature and hence

$$(I/2)^2 = E_b^2(16\,C_s^2\Delta\Omega^2 + 4/R^2_L)$$

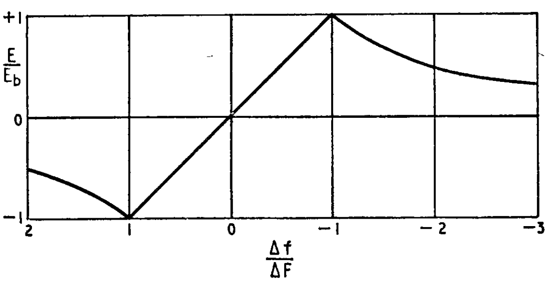


Fig. 6. Audio output plotted against frequency for "idealized" ratio detector.

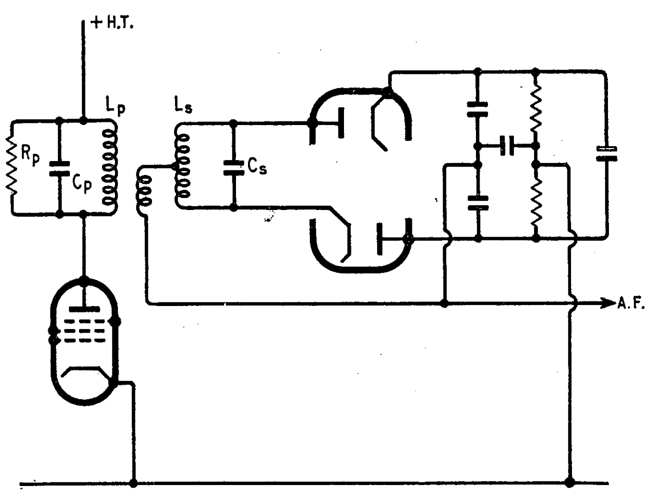


Fig. 7. Ratio detector with tertiary winding closely coupled to primary winding.

When the diode current is cut-off, the input current I′ is given by

$$(I'/2) = E_b(4C_s\Delta\Omega)$$

Thus the maximum amplitude modulation depth that the detector can handle is given by

$$m_{max} = 1 - I'/I$$

$$= 1 - \sqrt{\frac{16\,C_s^2\Delta\Omega^2}{16\,C_s^2\Delta\Omega^2 + 4/R_L^2}}$$

$$= 1 - \sqrt{\frac{4\,R_L^2C_s^2\Delta\Omega^2}{1 + 4R_L^2C_s^2\Delta\Omega^2}}$$

This can be simplified by rearranging the terms, and introducing Q_w, the working Q-value of the tuned circuits, i.e. the Q-value measured under quiescent conditions with the diode circuit damping present. The damping due to the presence of the diode load resistor is equivalent to a resistance of $R_L/2$ in parallel with each circuit, and thus the working Q-value may be defined as

$$Q_w = \frac{R_L}{2}\cdot\frac{1}{(L_s\omega_o/2)} = R_L\omega_oC_s$$

Then

$$m_{max} = 1 - \sqrt{\frac{(2Q_w\Delta F/f_o)^2}{1 + (2\,Q_w\Delta F/f_o)^2}}$$

If m is large, the expression simplifies to

$$m_{max} = 1 - 2\,Q_w(\Delta F/f_o)$$

From the expressions derived above, the conditions that the detector should have good "downward" a.m. rejection properties are apparent. These are that Q_w and ΔF should be small, and f_o should be large. In general the half-bandwidth ΔF cannot be decreased indefinitely, or distortion results. Similarly f_o is fixed by other considerations. Hence Q_w is the only independent variable. If, for example, $\Delta F = 75$ kc/s, and $f_o = 10.7$ Mc/s and the detector is required to handle a.m. to a modulation depth of 0.9, then

$$0.9 = 1 - 2Q_w(75/10700)$$

$$Q_w = 7.2 \text{ approximately.}$$

In terms of circuit values, this requires that the load resistor be 1,150 ohms approximately, if the tuning capacitance of the phase-difference transformer is 50 pF.

The above calculations show clearly that the conditions for good "downward" modulation handling capabilities require a narrow bandwidth; thus if a wide-band detector is required, it must be preceded by a limiter stage, since its inherent ability to deal with a.m. is seriously impaired by its wide bandwidth. This situation cannot be remedied by reducing Q_w, since in a practical circuit there is a limit to this imposed by considerations of diode efficiency.

To complete the investigation of the "idealized" ratio detector we will deduce the sensitivity of the circuit. It was shown above that the a.f. output voltage is proportional to E_b and, other parameters being fixed, it is desirable that E_b should be as large as possible. The usual way of achieving this object is to employ a tertiary winding closely coupled to the primary circuit as shown in Fig. 7. This steps up the input current and reduces the impedance level. The use of a tapped primary circuit

(*continued on page 127*)

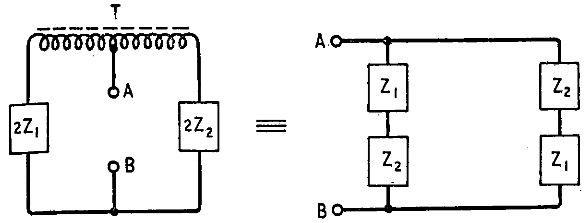


Fig. 8. Equivalent circuit to determine impedance measured between terminals A and B.

was discussed in part 2 of this article, where it was shown that the primary circuit proper must be replaced before the analysis is commenced by another tuned circuit, whose parameters are given below. The fraction a represents the fraction of the primary circuit voltage tapped off by the tertiary winding. $L_p' = a^2L_p$; $C_p' = C_p/a^2$; $R_p' = a^2R_p$; $I' = I/a$; $M' = aM$.

To determine the value of I we must calculate the input impedance presented at the centre tap of the transformer T in the equivalent diagram of Fig. 2. This can best be done by utilizing one of the intermediate stages in the derivation of the equivalent circuit, which was given in part 1; this is shown in Fig. 8. At the centre frequency, the input impedance R_{in} is purely resistive and can be shown to be

$$R_{in} = (R_L/4)/\{1 + (2Q_w \Delta F/f_o)^2\}$$

We shall assume that the signal is close to the centre frequency. This is the resonance frequency of the circuit connected between terminals 1 and 2 and hence the reactive component of its impedance can be ignored. Since $R_s/4$ is infinite, the equivalent circuit reduces to that of Fig. 9.

The proportion of the input current I_{in} fed to the centre-tap of the transformer T is thus given by

$$I = \frac{I_{in}}{a} \cdot \frac{a^2R_p}{R_{in} + a^2R_p} = I_{in} \frac{aR_p}{R_{in} + a^2R_p}$$

This reaches a maximum value when

$$a^2 = \frac{R_{in}}{R_p} = \frac{1}{R_p} \frac{R_L}{4\{1+(2Q_w \Delta F/f_o)^2\}}$$

At this value of a

$$I = I_{in}/2a$$

If we assume that $(2Q_w \Delta F/f_o)$ is small, as required for good "downward" a.m. handling capacity, the expression for a simplifies to

$$a^2 = R_L/4R_P$$

We have shown earlier that the output voltage $E = -E_b \Delta f/\Delta F$. The value of E_b can be determined simply when the value of a is chosen for power matching as described above, when $I = I_{in}/2a$. The power delivered to the centre-tap of the transformer T is $P = \frac{1}{2}(I_{in}/2a)^2R_{in} = \frac{1}{2}(I_{in}/2a)^2a^2R_p = \frac{1}{8} I_{in}{}^2R_p$.

The network has no losses, and hence this power is delivered entirely to the load circuit. This power is given by

$$P = 2\,E_b{}^2/R_L$$

whence

$$E_b = \tfrac{1}{4}\, I_{in}\sqrt{R_pR_L}$$

Thus for maximum output for a given value of Δf, R_p and R_L should be large, and ΔF small. But R_L is directly proportional to Q_w, and it was shown

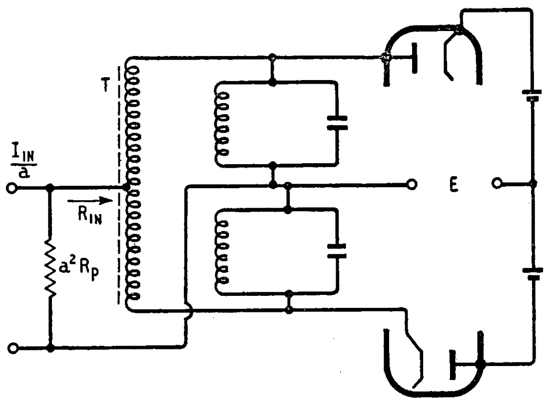


Fig. 9. Circuit for determining division of input current I_{in}/a.

earlier that for good "downward" a.m. handling capacity, Q_w should be small. This is diametrically opposed to the condition for maximum sensitivity as shown by the expression above, which requires R_L large. The expression shows also that a wide-band discriminator can only be secured at the expense of sensitivity, and as shown earlier, at the expense also of the "downward" a.m. handling capacity.

(*To be continued*)

New "Wireless World" Books

Foundations of Wireless by M. G. Scroggie, B.Sc., M.I.E.E. This well-known book on the basic theory of radio transmission and reception has now reached its sixth edition. An introductory section on the use of algebraic symbols, graphs and circuit diagrams clarifies the small amount of mathematics that is included. The fundamental laws of electricity and the theory of valves are discussed and no previous technical knowledge on the part of the reader is assumed. Subjects which are treated include television, radar and transmission lines. There is a new chapter on semi-conductors, which, with other additions, keeps this book right up-to-date. The book has 349 pages and costs 12s 6d (postage 1s).

Television Receiving Equipment by W. T. Cocking, M.I.E.E. The advent of Band III and other new developments in television have necessitated almost complete rewriting, and the addition of 169 pages of new material to this, the fourth, edition of a book which has become one of the classics of the subject. Topics discussed in fuller detail in this edition include magnetic deflection (greatly expanded) and the increasing problems of interference. The comprehensive treatment covers both theoretical and practical aspects of the subject. Modifications necessary to deal with systems other than the British are also discussed. The book has 454 pages and costs 30s (postage 1s 6d).

Television Engineering, Vol. III by S. W. Amos and D. C. Birkinshaw. This volume in the series of B.B.C. Engineering Training Manuals covers the properties, generation and application of the various waveforms used in television (sinusoidal, rectangular, sawtooth and parabolic). The treatment is mainly devoted to the generation of these waveforms, and being more fundamental and descriptive, is less mathematical than the two previous volumes. Vol. IV (in preparation) dealing with the various circuit techniques, will complete the series. The book has 226 pages and costs 30s (postage 11d).

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Electroluminescence

A NEW "COLD LIGHT" AND ITS APPLICATION TO ELECTRONICS

By D. W. G. BALLENTYNE*, B.Sc.

PHOSPHORS have been used extensively in the electronic industry for television and radar displays for many years. A phosphor is a substance which absorbs quanta of energy from an exciting source and converts part of this energy into visible light. The primary excitant may be either a photon (e.g., ultra violet light) or a charged material particle (e.g., an electron). The lighting industry is concerned with the manufacture of phosphors of the first type, photoluminescent phosphors, which have a strong absorption for one of the lines of the mercury arc spectrum, whilst the electronic industry is interested in phosphors which are excited by an electron beam, i.e., cathodoluminescent phosphors. In general, phosphors of both these classes are inorganic crystalline solids consisting of a "host" crystal which, of course, must be transparent and which has incorporated in it by heat a small quantity of another substance, the activator.

It is intended to discuss in this article a relatively newly investigated type of luminescence produced by the application of an alternating field. As long ago as 1920 Gudden and Pohl noticed that the decay of an ultra violet excited zinc sulphide phosphor activated with copper was affected by the application of a steady field, and during the intervening years much work has been done on this phenomenon, which has become known as electrophotoluminescence. In 1938 G. Destriau noticed that sustained emission of light could be obtained from a previously unexcited phosphor by the application of an alternating field to the phosphor suspended in the dielectric of a capacitor. This phenomenon is known as electroluminescence. This work was reported fully in a series of articles in 1947[1]. At the time, however, the efficiency of the phosphors was so low and the electroluminescent device so cumbersome as to be of no practical importance.

In 1950, E. C. Payne *et al*[2] indicated how electroluminescence could be put to practical use and, since this time, an increasing volume of work has gone into the production of more efficient phosphors and their incorporation in panels for use as lighting sources. Unfortunately, however, at the voltages and frequencies available domestically the light output is poor and electroluminescent panels are of use only as large-area low-level light sources. The same limitations in voltage and frequency do not exist in electronic equipment, where the brightness of the emission is limited only by the breakdown voltage of the dielectric in the electroluminescent capacitor—and thus it may be that this phenomenon will be found more useful in flat displays or light amplifiers for television and radar.

A large number of different inorganic compounds have been used as the host crystals for luminescent materials but only one of these classes has been found to be efficient when excited by an alternating voltage. All electroluminescent phosphors used industrially are zinc or cadmium sulphides or selenides activated with copper. The original electroluminescent phosphors prepared by Destriau were mixed crystals of zinc oxide-zinc sulphide containing copper but, as has already been pointed out, the light output of these was feeble. Phosphors containing copper normally give a greenish light, but other colours—notably yellow, blue and orange—can be obtained by varying the amount of copper and adding very small quantities of other substances such as aluminium, manganese and lead. It is obvious that an additive white may be obtained by mixing together a blue, green and orange phosphor. A better rendering of white could be obtained if an efficient red phosphor could be prepared, but at the moment the red phosphors, usually containing zinc selenide, are not efficient.

The electroluminescent effect was first demonstrated by Destriau in a cell as shown in Fig. 1. A suspension of the phosphor in castor oil placed upon a copper block was covered with a mica sheet. The upper surface of the mica sheet was wetted with glycerined salt solution and the field was applied between this electrode and the copper. This device could not be of practical importance.

The practical light source generally used is shown in Fig. 2. The phosphor suspended in a dielectric is applied to a sheet of conducting glass, another opaque conducting layer being applied to the back of this film. Conducting glass is easily prepared by the application of stannic chloride vapour to the glass sheet, heated to a temperature just below the softening point of the glass when atoms of tin diffuse

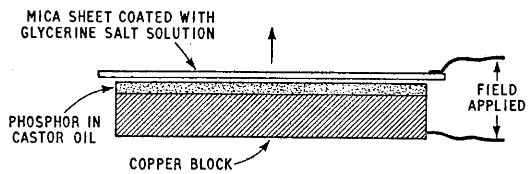


Fig. 1. Destriau's original electroluminescent cell.

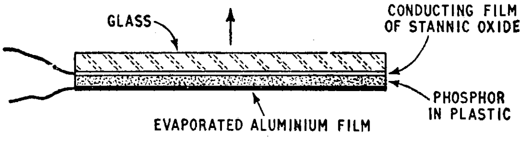


Fig. 2. A conventional electroluminescent light source.

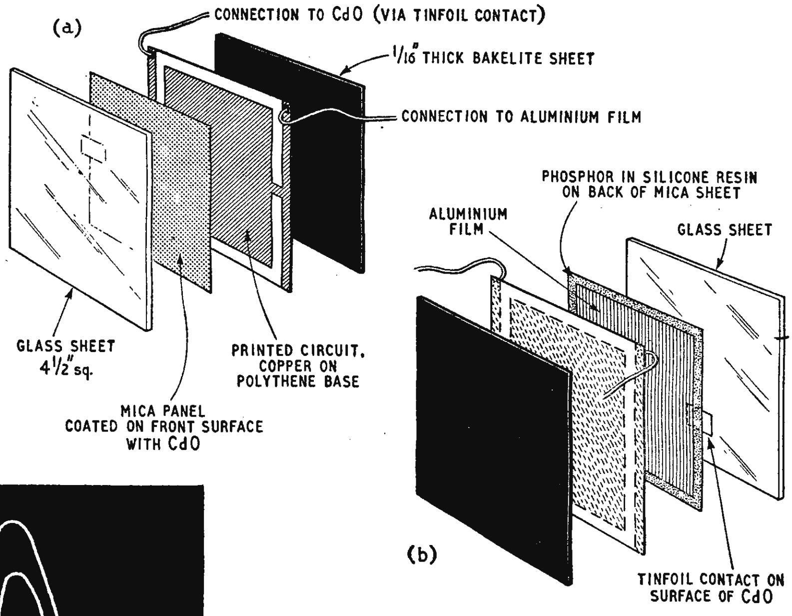
* Marconi's Wireless Telegraph Company. This article is based on a paper which appeared in *The Marconi Review*, 19, No. 123 (4th Quarter 1956).

into the surface and form a semi-conducting layer. The conducting back electrode can be either an evaporated film of aluminium, or a sprayed layer of silver or graphite. The last-mentioned two substances have the disadvantage that they absorb part of the light, while, of course, an aluminium layer reflects the light and so produces an apparent increase in brightness.

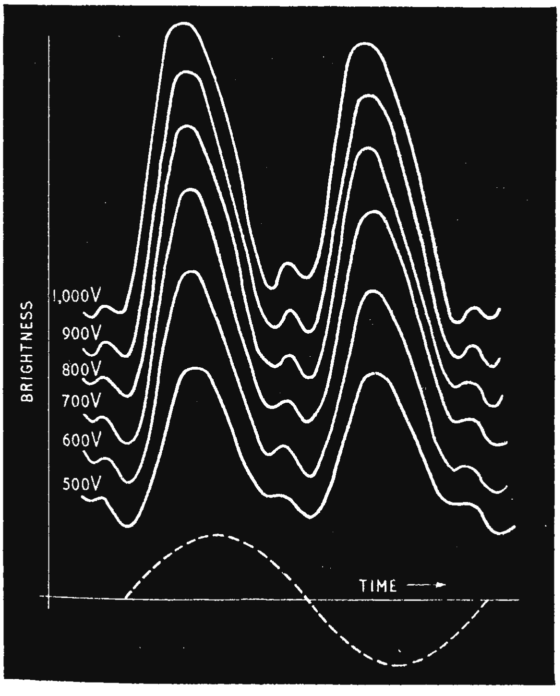
The continued life of such panels depends upon the dielectric strength of the plastic layer and although such panels are easily prepared for use at low voltages[3] we feel that a more robust panel may be necessary for continued operation at higher voltages. The design of the panel used by us is shown in Fig. 3 (*a*) and (*b*) in an exploded view. The phosphor suspended in a silicone resin is applied to one side of a mica sheet, and an aluminium electrode is evaporated on to this film after it has been cured. A conducting layer is then applied to the other side of the sheet. A number of substances have been used for this layer. The best film for the purpose appears to be a sputtered layer of cadmium oxide. This layer is susceptible to fingermarking and should be protected by a film of silicone lacquer. Contact is made to both the front and back electrodes by means of a printed circuit on a flexible base. The whole cell is clamped together and beeswax is poured between the Bakelite backing sheet and the glass. Panels constructed in this fashion can be excited by voltages of up to 1,500 but at 230 volts and 50 c/s are of the same order of efficiency as commercially available panels.

It was shown by Destriau that the application of an alternating voltage to an electroluminescent panel produced a light output whose amplitude varied with time. The exact nature of the variation depends to some extent upon the phosphor. Thus Fig. 4 shows the variation of the amplitude of the brightness with time for various voltages for a zinc sulphide phosphor activated with copper. In this case

Right. Fig. 3. Exploded views, (a) front and (b) back, of an electroluminescent panel constructed in the author's laboratory. In (b) there is a tinfoil connection between the printed circuit contact and the cadmium oxide surface of the mica panel.



Below. Fig. 4. Brightness waves for a zinc sulphide phosphor actuated with copper and aluminium. The relative phase of the exciting voltage is shown by the dotted sine wave.



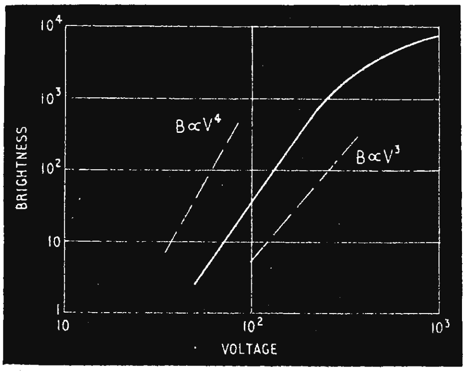
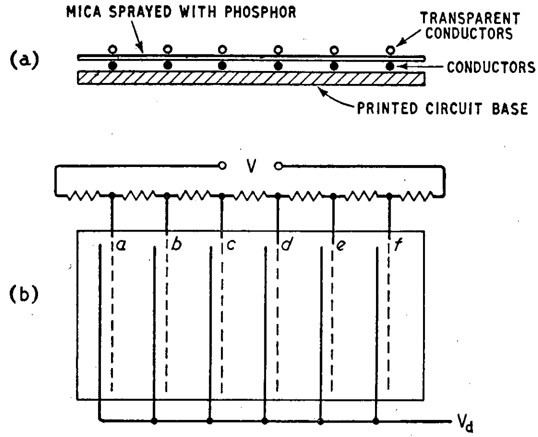


Fig. 5. Variation of mean brightness of an electroluminescent panel with applied voltage.



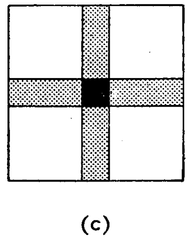


Fig. 6. *A black-spot electroluminescent display system: (a) edge view, (b) front view showing electrical connections, (c) a black spot produced by two non-emitting strips at right angles.*

it can be seen that there are two primary brightness maxima and two so-called secondary maxima for each cycle of voltage.

For all practical purposes the variation of brightness with mean applied voltage can be expressed by the relation

$$B = a\,V^n \quad .. \quad .. \quad .. \quad (1)$$

where n lies between 3 and 4 (Fig. 5). It is obvious that this relation is true only at low voltages and, in fact, the variation of voltage with brightness more exactly follows a law of the form

$$B = a\,V^n \exp(-b/V) \quad .. \quad (2)$$

where a, b and n are constants and n has a value between 1 and 3, depending upon the phosphor, but which is generally equal to approximately 2.

Although the brightness is considered above as a function of voltage it must not be forgotten that electroluminescence is a field effect and the effective quantity is not voltage but voltage/distance. As the panels are of constant thickness the use of voltage rather than field will not affect the theoretical considerations except to the extent of introducing a numerical proportionality constant.

The marked dependence of brightness on voltage is of great importance for, as the voltage applied to a panel need not be limited in an electronic device, a great improvement in the brightness of the panels can easily be obtained. The ultimate limit to the applied voltage will be set, as pointed out above, by the strength of the dielectric layer.

The frequency of the applied alternating voltage also affects the brightness of the panel, and according to Destriau the way in which it does so varies from phosphor to phosphor. In general, at low frequencies and for singly activated phosphors most workers agree that the effect is linear. At higher frequencies some saturation occurs and even in some extreme cases a maximum is observed. Multiple activated phosphors behave in a different fashion, for the intensity of light due to the emission band of each activator may vary differently with frequency and thus the colour of the phosphor may change as the frequency increases. Hence a zinc sulphide phosphor activated with copper and manganese is orange at low frequencies due to the manganese emission and green at high frequencies when the colour is determined by the copper emission. This dual dependence on frequency leads, in general, to a variation of brightness with frequency which is not linear[4].

The efficiency of an electroluminescent panel is not affected appreciably by increasing frequency. At low frequencies there is a slight increase in efficiency while at higher frequencies the efficiency decreases slightly, probably due to the impedance of the conducting glass film. The variation of electroluminescence efficiency with voltage is more difficult to understand. At low voltages it increases roughly as a third power of the voltage but it reaches a maximum at voltages of the order of 500 volts/mil and then decreases. This effect is most noticeable at low frequencies.

Many attempts have been made to devise an equivalent circuit which will explain the various properties of these phosphors. Some of these circuits[5] are most complicated. Probably the simplest circuit which will represent the behaviour of an electroluminescent panel is a resistor in series with a capacitor which has another resistor in parallel with it. In a previous paper[6] it has been demonstrated that if the parallel resistor is assumed to be voltage dependent, a relationship between brightness and voltage of approximately the correct form can be deduced, provided the assumption is made that the brightness is proportional to the power available for dissipation. A calculation of the efficiency to be expected under these conditions leads to the result that at low frequencies the efficiency should approach unity and it should decrease as the voltage increases. The reason for the experimentally observed initial increase in efficiency is not clear.

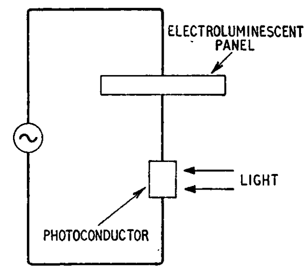


Fig. 7. *An elementary light amplifier.*

Destriau's original conception of a capacitive electroluminescent light source has not been advanced significantly since the announcement of a practical panel in 1950[2]. In general, until the brightness of the panels is increased by an order of magnitude when excited at 230V and 50 c/s they will not constitute a serious threat to the more conventional types of light source. There are, however, a number of uses to which panels have been put which depend upon two unique properties of these lights—their thinness and the fact that no heat is dissipated during operation. Hence electroluminescence is suitable for low-level lighting where space is restricted, for lighting in silhouette and for luminous signs and dials.

A specialized and important application of this phenomenon is in photographic processing. As is well known, only non-actinic lights can be tolerated in the darkroom and, conventionally, such lighting is provided by the light transmitted by a suitable filter placed in front of a light box. Because white light must not be allowed to escape from the box, cooling presents a difficult problem and inefficient cooling results in a rapid deterioration of the filter. An electroluminescent panel is a considerable improvement on the conventional light box.

Illuminated signs in cinemas and theatres are another application of this type of light, for exit signs, indicating obstructions such as the risers of a staircase, and in general for lighting the gangways.

Electroluminescence offers an improved method of lighting instrument dials, as the lettering on the dial itself is illuminated and thus distortion and errors in reading caused by parallax are reduced to a minimum. Uses of this kind are increasing in the aircraft industry where a 400-c/s supply is available in the aircraft with its attendant increase in brightness of the panel. A comprehensive review of these uses is given by Bowtell and Bate[3].

Television Display

The most obvious use for a light source which can be made to emit by the application of a field is for the display of information and here one naturally thinks of television. Display of information can be accomplished in two ways, either by applying a voltage sufficient to make the phosphor luminesce at a point (x, y) or to apply this voltage to the whole panel and to remove it at the point (x, y) by the application of a biasing voltage.

The first method, which requires that the electrodes of the panel shall consist of two sets of orthogonal strips, is in essence the easier way but the problems of commutation of the strips is formidable. Mechanical commutation, although possible, is obviously so cumbersome as to be an unattractive solution of the problem. A line of investigation worthy of study would appear to be the use of a scanned cathodoluminescent phosphor in conjunction with a set of photoconductor elements, one element actuating each strip in the grid. Such a method waits, however, on the preparation of a photoconductor with a rapid decay, as the persistence of the image on the display screen will be determined by the rate of decay of the photoconductor or, if this is very fast, by the decay time of the cathodoluminescent phosphor. Such a decay is essential when using electroluminescence to display information, as electroluminescent phosphors themselves have an undetectable persistence.

A device of the other type has been described[7]. Fig. 6(*a*) and (*b*) show one-half of such a device. It consists of a printed circuit on which a set of conductors is laid down, a piece of mica on which the phosphor has been sprayed, and another set of transparent conductors evaporated on to the other surface of the mica sheet. The voltage at *a*, *b*, *c*, etc., is determined by the resistors and varies from V_a to V_f, whilst the voltage applied to the continuous electrode can be set between V_a and V_f but is always 180° out of phase with the voltage on the other strips. In the diagram it has been set at V_d. The voltage at *d* is zero, while a residual voltage appears on each of the other strips and light will be emitted from all strips except *d*. If it is supposed that another such cell is placed in contact with the first cell but with the conductors orthogonally disposed to those on the first cell, a

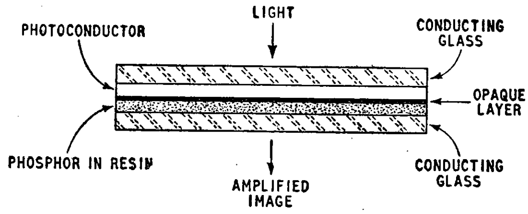


Fig. 8. Conventional construction of a light amplifier.

black spot will appear as shown in the diagram at (*c*).

Experiment has shown that such a device will only become feasible with phosphors of greatly increased efficiency which will give an appreciable amount of light at low fields, otherwise the resolution of the device becomes poor. An increase in resolution is limited by the dielectric strength of the material, for a voltage approaching $V \times f$ is applied to strip *a* when strip *f* is extinguished, and for a device with a reasonable number of strips using phosphors available to-day such a voltage is prohibited by the dielectric strength of the panel.

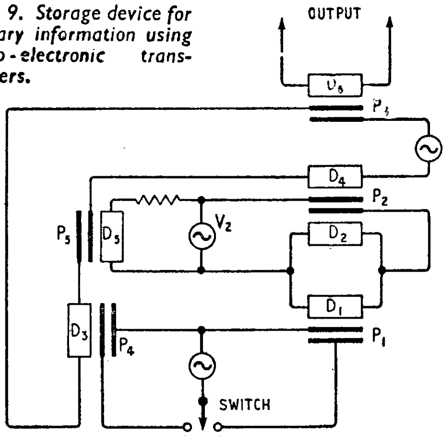
The consideration of an electroluminescent panel in series with a photoconductor leads to many new devices of great importance.

Suppose that a source of light is focused on to the photoconductor in Fig. 7; the impedance of the circuit will decrease, current will flow and light will be emitted. The intensity of the emitted light will be independent of the intensity of the exciting light. The construction of a light amplifier now becomes possible. A number of such devices have been described and amplifications of between five and 24 have been claimed. In essence such devices are simple to construct and a light amplifying panel such as that shown in Fig. 8 should produce an image of a projected picture. The amplifier consists of a sheet of conducting glass on to which a phosphor is applied, suspended in a resin. An opaque layer is applied to the baked resin and then a thick layer (20 mils) of a photoconducting cadmium sulphide is laid down. Finally a transparent backing electrode, usually another sheet of conducting glass, is applied to the back of the device. Light incident on the photoconductor will reduce its resistance and therefore the voltage applied to the phosphor layer will be determined by the intensity of the light. Under these conditions a picture projected on to the photoconductor will be reproduced on the electroluminescent panel and, as the brightness of the emitted light is independent of the exciting light and is only dependent on the exciting voltage, light amplification may be achieved. In fact, of course, the resolution of such a simple device is poor but many more complicated systems have been devised to overcome this defect and some of them are reviewed by B. Kazan and F. H. Nichol.[8] A promising field of application of the light amplifier is as an image converter to convert ultra violet or infra red radiation into visible radiation.

Binary Storage Devices

F. E. Loebner[9] has discussed the use of electroluminescent panels in series with crystalline cadmium sulphide photoconductors in various devices to which the generic name "opto-electronic transducers" has been given. The physical dimensions of these devices

Fig. 9. Storage device for binary information using opto-electronic transducers.



are small. They consist of an electroluminescent panel ($\frac{1}{4}$in $\times$ $\frac{1}{4}$in) in contact with a cadmium sulphide crystal to which electrical contact is made by a catswhisker. There are many uses for devices of this type—for instance, in the construction of storage cells and shift registers for computers.

Fig. 9 shows diagrammatically an elementary storage cell. The information is supplied in the form of a pulse by throwing the switch to A. This causes panel P_1 to light for a short period of time. Panel P_1 illuminates detector D_1 and causes its resistance to decrease and panel P_2 to light. The illumination from P_2 reduces the resistance of D_2 and thus, although the resistance of D_1 returns to its static value, panel P_2 remains on. Thus the information is stored. If the switch is thrown to B panel P_4 becomes illuminated, causing the resistance of D_3 to fall. The system is so arranged that a fall in the resistance of D_3 or D_4 on its own is not sufficient to light the panel P_3. Thus if no information is stored in P_2 the connection of the switch arm to B will not produce a light pulse at P_3 but if P_2 is on, P_3 will light up and a voltage will appear at the output. Simultaneously P_5 will light up, reducing the resistance of D_5 to a small value and shorting the voltage source V_2. Panel P_2 is now extinguished and the whole system returns to an unlit condition ready to receive further information.

From a consideration of this elementary circuit the endless possibilities of devices of this type are apparent. For most uses, however, it is necessary that the decay time of the detector elements should be very rapid and at present this cannot be achieved practically.

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Nine-Kilowatt Audio System

EVEN the most rabid high-power audio enthusiast should be satisfied with the power available from a system described recently.* This uses three 3-kW amplifiers to drive an array of 240 loudspeakers.

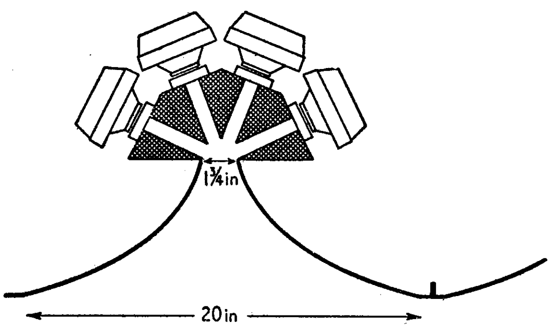
The system is installed in a B26 aeroplane for transmitting speech to the ground. Within a quarter of a mile of the projected flight path it provides what is referred to as "marginal" intelligibility for a period of fifteen seconds when the aircraft is flying at 150 m.p.h. at a height of 6,000ft.

The loudspeakers are horn loaded, three separate twin horns being used to decrease the distortion produced by excessive air pressures, and also to fit into the space available. A section of one such horn with the beginning of its corresponding twin is shown in the accompanying drawing. There are ten loudspeakers in each of the four rows; and the throat from each loudspeaker is exponentially flared in a direction at right angles to the cross-section plane.

The horns cut off at 400 c/s and from here to the designed upper frequency limit of 4 kc/s response is flat within $\pm$5 dB. At the full input of 37 watts to each speaker their operating life is several hours. They are connected in a series-parallel arrangement to give an impedance of eight ohms. In this arrangement some of the voice coils have high instantaneous audio voltages on them ($\approx$ 150 volts), and there was a tendency for these coils to arc-over to the earthed magnet. This was avoided by initial testing and selection of speakers.

Response of the special lightweight amplifier is flat from 400-4,000 c/s within $\pm$0.1 dB, and the distortion at full output is about 10%.

As the loudspeakers are rather directional, an increase in the intelligibility period to thirty seconds is obtained by partially rotating them to follow the objective of each



Cross-section of half-twin horn with drivers.

transmission. The directivity is somewhat irregular at high frequencies owing to the use of twin horns. This irregularity could be avoided by using the same arrangement of throats and driver units combined to feed a single horn which has been developed. Although this single horn has a larger throat area, the rate of flare is decreased, since it has the same length; and the distortion arising in the horn is unfortunately increased.

The input system contains a high-pass filter to protect the loudspeakers, and a symmetrical peak clipper to protect the amplifiers. In the conditions of use high-frequency air losses are considerable. The speech is therefore high-frequency pre-emphasized to give an equal output at all frequencies. This only partially compensates for the air losses; but any further pre-emphasis would decrease the available power at the lower frequencies, and these are the most useful for speech reproduction.

* D. W. Martin *et al.* "An Experimental 9,000-watt Airborne Sound System." *I.R.E. Trans. Audio*, Nov.-Dec. 1956.

Series or Parallel?

In Which Negative Resistance Again Raises Its Head

By "CATHODE RAY"

QUITE a long time ago* I offered a small collection of very simple circuit problems of the kind that are apt to provoke considerable controversy. The first of them, Fig. 1, is repeated here. I was reminded of it by the negative resistance problem discussed in the last two issues, which arose out of Thomas Roddam's article of the same name more than two years earlier (July 1954, to be exact). Mr. Roddam started his article with exactly the same Fig. 1 as I did in 1946 (and here now), but he added considerable spice to the question by supposing R_1 to be negative.

Quoting me, he agreed that the parallel combination as a whole is negative if the *smaller* of the two resistances is negative. The values we tried were $R_1 = -15\,k\Omega$ and $R_2 = 20\,k\Omega$; then the resistance of the two in parallel, by the usual formula, $R_1R_2/(R_1 + R_2)$, is $-60k\Omega$. So the combination would be unstable. But he also pointed out what I did not on that particular occasion, that the two resistances in Fig. 1 can equally well be regarded as being in series, in which case the resistance of the whole combination is $R_1 + R_2 = -15 + 20 = 5\ k\Omega$, which, being positive, means that the thing is stable. So it is both stable and unstable at the same time!

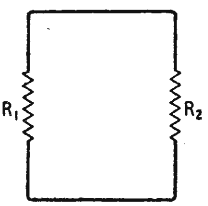


Fig. 1. Are R_1 and R_2 in series or in parallel?

Just to make this absurdity even more convincing, let us follow up this particular example. The value of any resistance, of course, is the ratio of voltage across it to current flowing through it. This applies whether the resistance is positive or negative, the sign being decided by which way the current flows. Resistance is regarded as positive when it absorbs power, which it does when the current flows from high to low potential within it; that is to say, from the positive to the negative end. So when we find a part of a circuit where current is coming out from the positive terminal instead of going in, so that it can be used as a source of power, we can regard it as a negative resistance.

In Fig. 2 let us suppose that 1 mA is coming out of the positive end of R_1. The voltage across it must therefore be 15 V. So it is supplying $15 \times 1 = 15$ mW of power. That much is the same in both (a) and (b). But how do we make the ratio of voltage to current right for R_2? The direction is right, of course, for what comes out of the positive end of R_1 goes into the positive end of R_2. If the whole 1 mA went in, the voltage across R_2 would be 20, whereas it must actually be 15. We can make things balance by bleeding off $\frac{1}{4}$ mA, as at (a); the negative resistance is then supplying not only the $11\frac{1}{4}$ mW represented by the $\frac{3}{4}$ mA going into R_2 down a 15-V slope, but can spare $3\frac{3}{4}$ mW wherever the $\frac{1}{4}$ mA goes. The resistance of the combination is therefore negative, as we calculated at the start.

An alternative method is to supply the extra 5 V needed to drive the full 1 mA through R_2, as at (b). Here, the 15 mW provided by R_1 is insufficient for the 20 mW absorbed by R_2, and needs a supplementary 5 mW from the voltage generator—the 5-V battery.

In one case the system has power enough and to spare; in the other (which is really the same, for the component values are identical!) it has to be subsidized. The question is, once more, how the circuit decides whether it is a power exporting or importing unit. On paper it can be either, as Fig. 2 shows. What decides whether its net resistance is $R_1 + R_2$ or $R_1R_2/(R_1 + R_2)$; positive or negative?

This paradox is just another form of the problem of how two voltage/current graphs crossing one another at an angle—one representing a positive resistance and the other a negative—can together represent either a stable or unstable condition. Readers of the last issue will, I hope, be clear that the key to the question is that negative resistance comes in two kinds. With ordinary positive resistance, in which voltage and current are in direct proportion, either voltage or current can be the cause and the other its effect. But negative resistance means that an increase in one corresponds to a decrease in the other. Such conduct being, as it were, "agin' Nature," does not result from normal properties of materials as in resistors, but from some kind of secondary effect, which introduces a one-way causative direction not found in ordinary resistance. Until we grasped this, our interpretation of V/I graphs went badly astray, for they can be the opposite of true if cause and effect are assumed to be interchangeable for negative slopes as well as

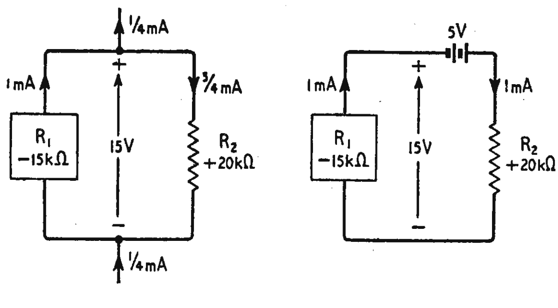


Fig. 2. Although the values for R_1 and R_2—the only circuit components—are the same in both diagrams, and the voltages and currents are correct for both, (a) can be seen to export power, while (b) has to import it from a 5-V battery. How can this be?

*"Conventions and Viewpoints," *Wireles. World,* September 1946. (Chap. 30 in *Second Thoughts on Radio Theory.*)

positive. The slope itself doesn't show which; one has to look to see which way the slope bends back to positive resistance at its ends.

Let us try the same key on Fig. 2. When graphical treatment let us down, we discovered the nature of its limitations by examining typical negative-resistance devices—dynatron and point-contact transistor. Both of these probably being unfamiliar in practice to most readers, it may be a good idea this time to take a simple valve circuit which can easily be arranged to provide both kinds of negative resistance (Fig. 3). It is in any case a particularly useful and versatile circuit, which everyone ought to know*. The components required are few and common: almost any twin triode, connected as a resistance-coupled stage and cathode follower.

Disregarding very low and high frequencies, at which C_1 and stray shunt capacitances respectively cause phase shifts, we find that the impedances between terminals S_1 and S_2 and between P_1 and P_2 are both negative resistances. The circuit can be made into an oscillator by connecting a simple LC tuned circuit between either pair of terminals. But if it is connected to P_1 P_2 the other pair must be joined together and L and C must be in parallel (rejector circuit), whereas if connected to S_1 S_2 they must be in series (acceptor circuit) and P_1 P_2 left open-circuited. As a negative-resistance device, Fig. 3 resembles the dynatron between P_1 P_2 and the transistor between S_1 S_2.

Technician's Viewpoint

If we pause to ponder this distinction, the circuit technician will no doubt point out that P_1 P_2 is obviously a high-impedance part of the circuit—R_3 is usually of the megohm order, to have just enough conductance to stabilize the potential of the grid, where current is practically zero—and a rejector circuit provides the high impedance needed to prevent loss of amplification; whereas the reverse applies at S_1 S_2, where an acceptor provides the low impedance needed to feed back enough of the said amplification to cause oscillation. Since we would appear to him very dim-witted to be having any hesitation at all about the series and parallel natures of the two connections, he might (if a kind chap, tolerant of others' mental handicaps) draw Fig. 4 for us, showing with almost painful simplicity essentially the same system as Fig. 3—an amplifier with part of the output fed back from across a potential divider. Taking care to use easy words, he would point out that oscillation is promoted by *high* resistance between P_1 P_2, in *parallel* with the amplifier-feedback loop, in order to pass on an operating *voltage*, and that the same tendency results from *low* resistance between S_1 S_2, in *series* with the loop, in order to pass on an operating *current*.

That is all very obviously true, but when in the early days I enquired about the essential difference between a voltmeter and an ammeter, and I was informed that a voltmeter has many turns of fine wire, giving it a high resistance, whereas an ammeter is wound with few turns of thick wire, giving it a low resistance, it seemed to me rather unconvincing that a mere matter of degree—of how much resistance—should account for a difference in kind, between volts and amps. So I am

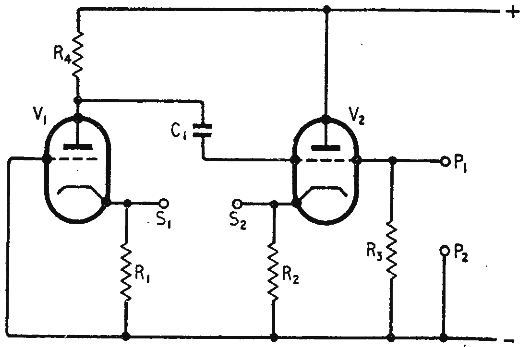


Fig. 3. Practical circuit suitable for providing two different kinds of negative resistance.

anxious that our circuit technician should leave no one with the idea that the distinction between the S and P connections depends on the amount of resistance involved. We know that there is something more far-reaching than that, because increasing the externally connected resistance increases the tendency to oscillate if the P terminals are used, but reduces it if the S terminals are used.

The more significant fact—both with this circuit and the meter question—is the method of connection: series or parallel. It is clear enough from Fig. 4 (or even Fig. 3) which is which, so that may be taken to answer our original Fig. 1 question. But with other types of negative-resistance device—the dynatron, for example—it may not be so obvious. What I would like to know is how one can tell the difference even if the negative resistance is in an unopenable black box and only the two terminals are accessible. If the Fig. 3 circuit were inside, how could one tell whether the terminals were S_1 S_2 or P_1 P_2? (We can assume that if they were P_1 P_2 then S_1 S_2 would be shorted.) An obvious and simple practical way would be to test whether there was an oscillatory voltage between the terminals (in which case they would be P_1 P_2) or had to be joined by a low resistance to obtain an oscillating current through it. But that wouldn't get at the underlying principle.

We still haven't used our cause-and-effect key. Let us try what happens when current and voltage are used as the cause, at each pair of terminals.

If the box contained just ordinary positive resistance, as in Fig. 5, any current made to flow would cause the terminal at which it entered to become positive, relative to the other. And any e.m.f. applied (E) would cause current to flow in the direction shown, out of its own + terminal and into the more positive box terminal. It doesn't matter which is regarded as cause and which effect.

Now suppose the box terminals happen to be S_1 S_2 in Fig. 3. Feeding current into S_1 certainly makes that terminal go positive, for R_1 and V_1 are both positive resistance. But there is a secondary action, for this positive "signal" is amplified by the earthed-grid valve V_1 and passed on via the cathode follower V_2 to S_2, which consequently goes more positive than S_1. So the ultimate result of making current flow from S_2 to S_1 is to make S_2 positive relative to S_1. This, being the opposite to events in Fig. 5, indicates negative resistance.

Next, let us reverse the order and apply an e.m.f. between S_1 and S_2, with the object of making S_2

*"Cathode-Coupled Amplifier," by K. A. Pullen, Jnr., *Proc. I.R.E.*, June 1946, p. 502.

more positive than S_1. If what was previously the cause of this effect now became the effect, current would flow from S_2 to S_1, again proving the contents of the box to be a negative resistance. But instead we find that current flows in the direction of the applied e.m.f., from S_1 to S_2, indicating positive resistance.

Clearly, then, the negative resistance must be of thc current-operated type only. Because the effect of current fed into S_1 is to make S_2 go positive, we can describe the device in the box as a current-operated voltage generator.

Now let us work out what the results of the same pair of tests would be if the terminals were in fact P_1 P_2. Feeding current into P_1 would make P_1 go positive, just as with S_1. The cathode would follow, most of the way, and being joined to S_1 would make that positive, as before. But this time the amplified positive would arrive at the terminals into which the current was flowing—P_1—which would lead us to conclude that the internal resistance was positive.

But the second test—applying an e.m.f. to make P_1 positive—would again make P_1 go more positive, by amplification, making current flow out from P_1 into the source of applied e.m.f. This would show that the box had negative resistance to voltage only —a voltage-operated current generator, in fact.

One can think of a rough sort of mechanical analogy by supposing a man standing facing one panel representing S_1 or P_1 and with his back to another, representing S_2 or P_2. Distance between them represents potential difference between terminals. If he were to press on the panel in front, and it happened to be S_1, its motion, amplified by a servo-mechanism, would be communicated to S_2, giving him a violent kick in the pants and sweeping him forward, with a minimum of space between the panels. But if it were P_1, that panel would be swept rapidly away from his astonished hands, causing a large inter-panel spacing.

Just as in this analogy the man could tell at once by the feel of the thing which type of mechanism he was up against, so an electrical signal can tell at once which sort of negative resistance it is connected to, even if the number of ohms be the same in both.

The question now (ignoring any hints Fig. 4 may have given, and not attempting to guess what might be behind the choice of letters for labelling the terminals in Fig. 3) is, which kind of negative resistance is which in Fig. 2?

Let us go back to the original question, Fig. 1.

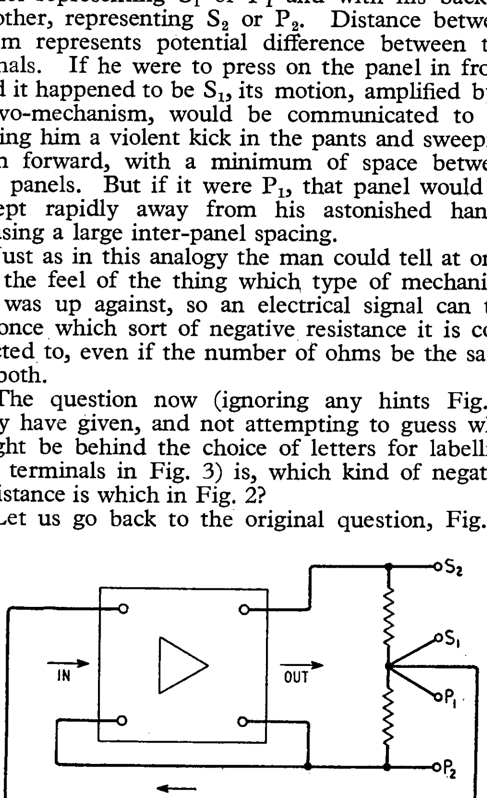


Fig. 4. That the circuit of Fig. 3 is an amplifier in which feedback is introduced by joining S_1 to S_2 is shown by this block diagram, where the respective roles of S_1 S_2 and P_1 P_2 are brought out more clearly by bringing them together into a potential divider.

If R_1 and R_2 were both positive resistances, the circuit would be a merely passive affair, with no current and no voltage anywhere. " Series " and " parallel " would then have no significance. To be in series, the same current must flow through both; to be in parallel, the same voltage must be across both. As I said about Fig. 1 in 1946, in order to answer the question one has to know the position of the generator. When it is in series with the resistors, they are in series with one another; when in parallel, they are in parallel.

If R_1 is a negative resistance, it must in effect contain a generator; otherwise it couldn't feed power into R_2. We have discovered that one kind of negative resistance is a current-operated voltage generator and the other a voltage-operated current generator. Now in Fig. 2(a) it is clear that the negative resistance is behaving as a current generator. It is supplying not only the $\frac{3}{4}$ mA needed to maintain 15 V across the circuit but also $\frac{1}{4}$ mA for export. This corresponds with the behaviour of the Fig. 3 device between the P_1 P_2 terminals. We can therefore say that when that device is connected via P_1 P_2 to a resistor it is in parallel with it, and stability or instability must be calculated accordingly, by the $R_1R_2/(R_1 + R_2)$ formula.

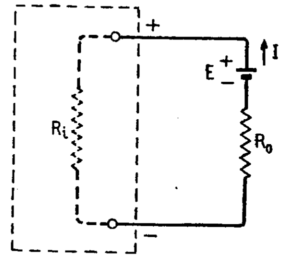


Fig. 5. Polarity of the potential difference between the terminals of a positive resistance when current is driven through it.

Since this type of negative resistance is voltage-operated, the current generated in Fig. 2(b) must be regarded as caused by the 15V across R_1 and R_2. If that voltage is altered, the current alters in direct proportion, in accordance with the meaning of R_1. With our 20-kΩ R_2 connected straight across a 15-kΩ R_1 between terminals P_1 P_2, there is no other parallel path for the surplus current, so it is bound to go through R_2. That raises the p.d. across it, and since the p.d. is the operating agent for the R_1 current generator, more current comes. The p.d. rises more, and so on, until the valves are overloaded, bringing up the value of R_1 until it exactly balances R_2.

If R_2 were less than $-R_1$, say, 10kΩ, it would need 1.5mA to sustain a p.d. of 15V across it; and since that amount of current is not forthcoming from -15kΩ at 15V the p.d. would keep on dropping until it ceased altogether. But at least R_1 would reduce the amount of power that would have to be fed in from elsewhere to maintain any required p.d. across R_2. Of the 1.5mA at 15V, that 15V calls forth 1mA from R_1, leaving only $\frac{1}{2}$mA to be found. Half a milliamp at 15V represents 30kΩ. So the effect of putting a *negative* resistance in parallel with R_2 is to *raise* the combined resistance; in this case, threefold.

If, on the other hand, R_1 happened to be Fig. 3 via S_1 S_2, it would be a current-operated voltage generator. In this event, the 15V across it is the result of the 1mA through it. If this 1mA is to go through the 20-kΩ R_2, however, 5V must be imported to bring the 15V from R_1 up to 20V.

It is interesting to consider how the source of this import affects the situation. If it were a fixed-voltage source with negligible internal resistance, its voltage—unlike that of R_1—would be independent of the current flowing through it. This would mean that the current could not be other than 1mA. The 1mA situation would be definitely stable. Without the 5V there would be no current at all, for R_1 alone is unable to maintain any. So the 1mA *appears* to be due entirely to the 5V, leading one to reckon the resistance it is up against as $5/1 = 5k\Omega$, which of course is the same as one gets by adding $-15k\Omega$ to $20k\Omega$.

If, on the other hand, the 5V came from a $-5k\Omega$ resistance—or, what comes to the same thing, R_1 were increased to $-20k\Omega$—the current could be anything. In practice this would not be so, because any practical negative resistance is negative only over a limited range of current, and even within that range is not perfectly linear. So although in theory the current through a circuit having zero resistance would stay indefinitely at any value it was set to, in practice this setting would be unstable, the slightest disturbance causing it to grow or dwindle, according to the way the negative-resistance characteristic curved.

If R_2 were lower than $-R_1$, there would be a net surplus of volts, which could be used elsewhere.

These actions should all be reviewed in relation to some actual negative-resistance device, such as Fig. 3 via S_1 S_2. The voltage across the terminals (15V in Fig. 2(b)) due to the current is easily identified as the amplified voltage delivered at S_2. If S_1 S_2 were bridged by a 20-kΩ resistor, the negative resistance being $-15k\Omega$, any initial current disturbance would at once die out. A 5-V source would however drive 1mA, as if the 20kΩ had been only 5kΩ. What really happens, of course, is that for every volt applied externally the "black box" contributes 3 volts unseen. But since we aren't supposed to know what is in the box, the credit for the 1mA goes entirely to the external 5V. Which is why the resistance seems so low.

Note that in order to measure negative resistance by observing the amount of negative current it yields from an applied voltage (or vice versa) it is necessary to prevent it from affecting the measuring gear. So the parallel type must be measured by applying a voltage from a zero-resistance source—a perfect voltage generator—and the series type must be measured by feeding in a current from an infinite-resistance source—a perfect current generator. In practice, this means either approximating so closely to these perfect sources that the difference is negligible (sometimes rather difficult with the current source) or allowing for the imperfection. The plotting of the characteristic curves of the dynatron and transistor was a method of allowing for the imperfection. But the resistance of the source must at worst be respectively lower and higher than the negative resistance to be measured, or the circuit would be unstable. That was why voltage was applied to the dynatron through a low resistance and to the transistor through a high resistance.

It should hardly need mentioning that all the currents and voltages we have been talking about are "signals," over and above any that may be needed to bring the negative resistance device to its working conditions. And with a negative resistance device with reactive couplings, such as Fig. 3, these signals must necessarily be alternating, within a certain range of frequency. To obtain oscillations containing only a single frequency (i.e., of pure waveform) it is necessary to arrange that R_2 is on the stable side except at that one frequency.

This at once suggests acceptor and rejector circuits, for the acceptor has a low resistive impedance at one frequency and a higher impedance at all others (Fig. 6(a)), and the rejector has a high resistive impedance at one frequency and a lower impedance at all others (b). The trick, of course, is to adjust the amount of this resistive impedance —or, more usually, the negative resistance—until it is just balanced out by the negative resistance. If that were done too perfectly, the amplitude of oscillation would fluctuate at every slight change of resistance, so in practice the net circuit resistance is given a reasonable margin on the negative side, making the oscillation amplitude grow until it restores the balance itself; by driving a valve round its bend, for instance.

The lower a negative resistance of the parallel type, the easier it is to get high-loss (i.e., low-impedance) LC circuits to oscillate. It may seem rather surprising that a circuit that cannot be made to oscillate by connecting directly to the negative resistance can be made to do so by adding positive resistance in series. Take an LC circuit whose resistance at resonance is only 12kΩ, in parallel with a negative resistance that cannot be made numerically less than $-15k\Omega$. Total parallel resistance is positive; no oscillation. But if 3kΩ is put in series with the LC circuit the total positive is brought up to 15kΩ, enough to bring it to the threshold of oscillation. By this means it would seem possible to make the most inefficient circuit oscillate with the feeblest negative resistance. But, as one always suspects when one seems to be getting something for nothing, there are snags, which increase with the resistance gap to be filled. The resonance curve of the LC is made even flatter, and there may be trouble with stray reactance in connection with the series resistance.

With series negative resistance, an acceptor circuit with too much resistance to oscillate can correspondingly be persuaded by resistance-shunting it.

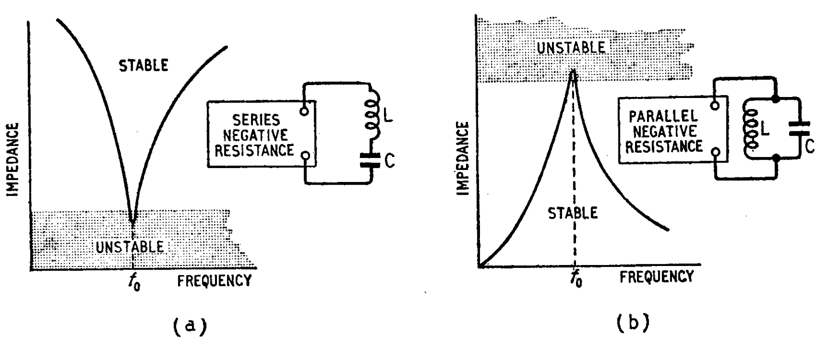
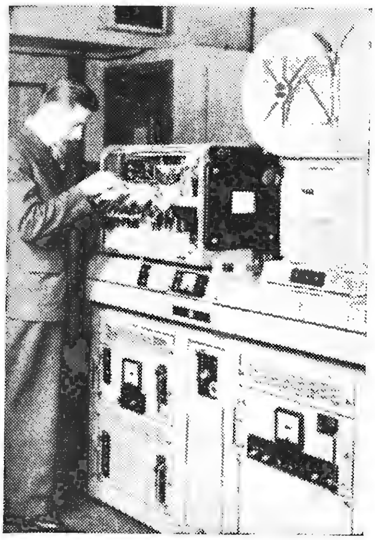


Fig. 6. Arrangement of frequency-determining circuit LC to oscillate at frequency f_0 with (a) series and (b) parallel type of negative resistance.

Technical Notebook

High-Quality TV Recording is obtained with a new Marconi equipment in which the 16-mm film is mechanically pulled down in the brief blanking period between television frames. This is only 1.4-1.8 milliseconds. Hitherto the pull-down times in conventional interrupted cameras have been too long to make this possible, and the usual practice has been to record only alternate television frames and use the intervals between for pulling down the film. This means that only half the picture information is recorded in the picture period and there is consequently a reduction in quality. Another system of recording, in which the film is moved con-



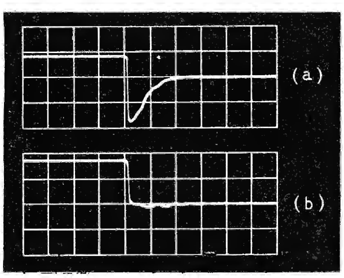
tinuously, does give the full picture information, but has mechanical and optical disadvantages from the operational point of view. The B.B.C. have recently installed one of the new Marconi equipments for test purposes.

Cyclotron Type Valve used for detecting presence of electromagnetic waves at about 3,000 Mc/s. An analysis of the performance is given by P. G. Baird in a D.S.I.R. unpublished report.

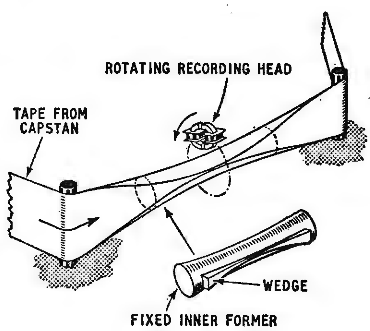
Ferrites for V.H.F., with initial permeabilities of the order of 10, at all frequencies up to 500 Mc/s, have been developed and are reported by G. H. Jonker, H. P. J. Wijn and P. B. Braun, in *Philips Technical Review* for November 1956. The new materials, to be known as Ferroxplana, are more closely allied to Ferroxdure (a permanent magnet ceramic) than to the "soft" Ferroxcube, and have a hexagonal rather than a cubic crystal structure. But whereas the Ferroxdure materials have a *preferred* direction of magnetization along the hexagonal axis, in Ferroxplana this is an *abhorred* direction and magnetization is easiest in any direction in a plane at right angles to the hexagonal crystal axis. Of greater practical importance is the fact that the ferromagnetic resonance frequencies of the Ferroxplana materials, for a given initial permeability, are five times higher than Ferroxcube, with a corresponding extension of the working range. The resistivity and saturation magnetization of the new materials are said to be of the same order as in Ferroxcube.

Feedback Stabilized Servo system using the back e.m.f. of the d.c. drive motor, separated from the power supply circuits, as the feedback signal. A D.S.I.R. unpublished report by J. Leeder.

Avalanche Junction Diodes are semiconductor devices, generally used for switching or pulse work, which utilize a current-multiplying "breakdown" effect rather like the sudden ionization in a gas discharge tube. Normally, junction diodes have a slow response when they are rapidly switched from forward voltage to reverse voltage, because storage of current carriers prevents the diode current from immediately falling to its normal reverse-voltage value, as shown at (a). A certain recovery time is necessary, which sets a limit to the operating p.r.f. The avalanche diode, however, works with a reverse bias just short of the breakdown voltage, instead of at zero voltage, and the applied switching pulse initiates the avalanche effect. But since the diode voltage is never reversed and there is a strong electric field maintained by the bias, the time taken for the electron and hole products of the avalanche to be absorbed in the respective n and p layers is very short. There is no storage, in fact, and the recovery characteristic is improved as in (b), the time scale being 0.1 μsec per square. A discussion on the use of existing diodes in this way is published in a letter from J. E. Scobey, W. A. White and B. Salzberg in *Proc.I.R.E.* for December, 1956. Special avalanche diodes have been developed by Bell Telephones, however, with closely controlled characteristics. Their breakdown voltage, for example, can be predicted and controlled in production to within about 5 per cent.

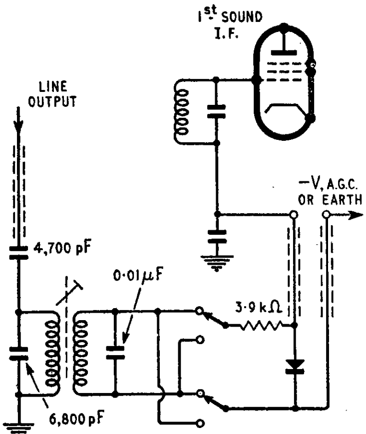


Television on Tape.—The main problem in recording signals of 3-Mc/s bandwidth by conventional methods on magnetic tape is, of course, the high speed at which the tape must run in order to resolve the information. In the RCA recording equipment, for example, it is 20 ft/sec. Various suggestions have been made for avoiding this by recording transversely with a moving head *across* a wide tape, the idea being that while the effective speed remains high the actual longitudinal motion of the tape over the capstans can be reduced to about 15 in/sec. The Ampex equipment in America uses this principle. All the schemes depend on rotating heads or fixed heads with rotating pole-pieces. One suggestion on how the tape can be arranged for a rotat-



ing head has been sent to us by R. M. Larsson. After leaving the capstan the tape is fed between formers (only the inner one is shown) which bend it round into a tubular shape. Beyond the recording head it returns to its flat state. The information is actually recorded on the "tube" in the form of a spiral, but on reverting to the flat state this becomes a series of almost straight rows across the tape. To keep the tape in contact with the recording head Mr. Larsson suggests that compressed air should be fed into the inner former (which would be hollow) to emerge through a circumferential gap corresponding with the head rotation. This would then press the tape gently against the rotating head assembly.

Bilingual Television.—A French system for providing two different sound accompaniments to the picture was described in our last issue (p. 79) and it was mentioned that only a very simple and inexpensive "decoder" unit was required in the receiver. A full account of this gating device has actually been published in the January, 1957, issue of *Télévision* (see diagram). An LC circuit is shock-excited from the line output stage and is coupled to another LC circuit which gives an almost pure sine wave shifted in phase by 90°. The switch is used to reverse the phase of this sine wave (depending on which of the two interlaced pulse trains in the sound channel is to be gated), while the semi-conductor diode limits the positive peaks to produce flat-topped gating pulses. These are available at the output terminals of the unit, which, as shown, are simply wired into the grid circuit of the first sound i.f. stage.

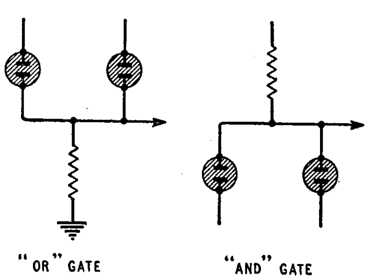


Multi-Element Diodes and bi-stable devices constructed from semiconductor materials. A brief summary by E. B. Dale, M. W. Aarons, M. Pobereskin and J. E. Gates in a D.S.I.R. unpublished report.

Vertical Scanning Radar for aircraft has been suggested by L. J. Battan, of Chicago University, as a means of avoiding icing conditions and for giving a continuous picture of the terrain below for clearance purposes. Normally, of course, airborne cloud-and-collision warning radar scans in azimuth, though it can be tilted up and down slightly. In a report in *Aeronautical Engineering Review* for December 1956, Mr. Battan discusses the results obtained from a 3-cm airborne equipment modified so that it scans in a plane perpendicular to the flight path, and he gives photographs of typical responses on the c.r.t. screen. The height of clouds and terrain can be measured in this way, while the detection of possible icing conditions in the clouds depends on the fact that ice particles have only one-fifth of the reflectivity of water droplets of the same size. The ideal arrangement, of course, is a radar set which will scan in both vertical and horizontal planes.

Magnetic-Coupled Multivibrator in which the magnetic core is used for controlling the frequency of operation in inverse proportion to the magnetic flux. Unpublished report by R. L. Van Allen, available from the D.S.I.R.

Neon Computing Elements.—The ordinary neon tube, as an "on-off" two-state device, may have advantages for use in the logical "OR" and "AND" gates required in great numbers in electronic digital computers. It is considerably cheaper than the semiconductor or thermionic diodes commonly used, and in the gate circuits it is relatively insensitive to variations of characteristics between different tubes. The two circuits illustrated are taken from a comprehensive study of the possibilities by C. E. Hendrix in *I.R.E. Transactions* CP-3 for September, 1956. In the "OR" circuit, a positive pulse is produced at the output if either of the tubes is fired by a positive pulse applied to its upper plate. In the "AND" gate, a positive output pulse is only produced if both of the neons have positive pulses applied to their lower plates to reduce the p.d. and prevent them from firing. (Otherwise, when either of the neons is fully conducting, the output is reduced to the voltage across the tube.) One disadvantage arises from the "stabilizing" voltage across the tubes when they are fully conducting. This means that the output level in the "OR" circuit is always a good deal lower than the highest input voltage, while in the "AND" circuit it is always a good deal higher than the lowest input voltage. Another difficulty is the comparatively slow response of the glow discharge, which limits the operating p.r.f. to about 30 kc/s.



Semiconductor Camera Tube for television, devised by J. R. Pierce, of Bell Telephones, is comparable with the image orthicon except that its target consists of a thin wafer of germanium or silicon instead of glass. This is coated on the lens side with a thin transparent layer of metal through which the optical image passes, while the other side is scanned by a low-velocity electron beam. An image focused on the target produces hole-electron pairs in the semiconductor. The electrons move towards the metal layer while the holes are repelled towards the semiconductor surface, where they become trapped. This gives a positive charge pattern, corresponding to the optical image, which modulates the scanning beam. The return beam therefore carries the video information, and it passes through an electron-multiplier (near the cathode) which gives the video signal at its output. High sensitivity, output and resolution are claimed for the tube, of which a diagram is given in the January 1957 issue of *Radio-Electronics*.

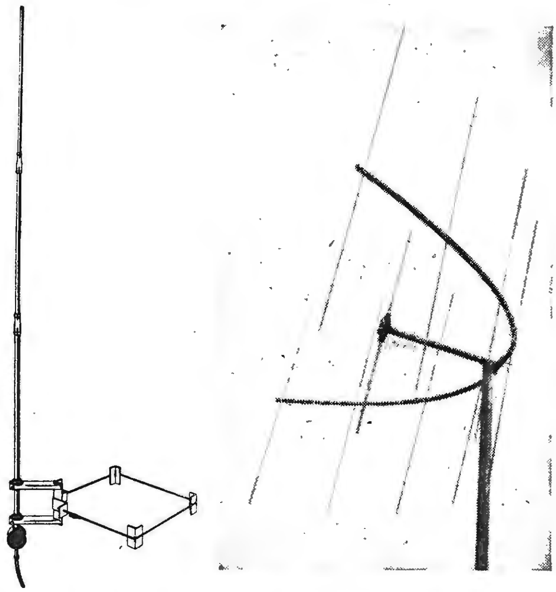
Magnetic Field Regulation by a feed-back control system using the phenomenon of nuclear magnetic resonance for sensing purposes. A D.S.I.R. unpublished report by F. A. Hadden.

"Through" Electron Multiplier, in which the secondary electrons are generated not from the front surface of the dynodes but by transmission *through* a series of thin insulating layers, has been developed by E. J. Sternglass and M. M. Wachtel, of Westinghouse in America. The insulating dynodes consist of layers of potassium chloride spaced 0.2 inch apart. They are faced with very much thinner layers of gold, which serve to scatter the incident electrons so that they expend more energy in the insulator and give a greater yield of secondaries. The device has advantages for amplification of high-speed pulses, since the uniform length of all electron trajectories and the close dynode spacing (as well as higher accelerating voltages between dynodes) result in a greatly reduced "spread" of the pulse rise-time during multiplication. The main disadvantage at present is the high rate of deterioration of the dynodes under electron bombardment. A full account is given in *I.R.E. Transactions*, NS-3, for November 1956.

Unpublished Reports mentioned above come from various sources but can be obtained from the Technical Information and Documents Unit of the Department of Scientific and Industrial Research, 15, Regent Street, London, S.W.1.

Manufacturers' Products

NEW EQUIPMENT AND ACCESSORIES FOR RADIO AND ELECTRONICS



Left: New "Extat" vertical rod aerial made by Antiference. Right: Dale parabolic Band-III television aerial.

Whip Aerials

THE latest whip aerials made by Antiference are fitted with a new type vertical rod consisting of three 6ft lengths of tough aluminium alloy tube tapering from $\frac{3}{4}$in at the base to $\frac{1}{2}$in at the top and joined by reducing ferrules designed to withstand winds up to 80 m.p.h.

One model, known as the "Extat," is fitted with screened downlead and matching transformers covering 10 to 2,000 metres and is for use where electrical interference is troublesome. Elsewhere the companion "Vra" model, which is a plain whip type, is suitable.

With chimney lashings the "Extat" costs £9 12s and the "Vra" £4 3s 6d; with wall brackets the prices are slightly less.

The makers are Antiference, Ltd., Bicester Road, Aylesbury, Bucks.

Parabolic Band-III Aerial

THE illustration shows an unusual type of Band-III television aerial. It consists of a single vertical dipole mounted at the focal point of a parabolic array of eight reflectors. Relative to a plain dipole the forward gain is given as 14 dB, its back-to-front ratio as 36 dB and the acceptance angle 20°, measured to the half-power points.

The comparatively narrow acceptance angle (in azimuth) ensures rejection of unwanted signals and interference of one kind and another, over an unusually wide angle.

Mechanically the aerial seems soundly designed and should stand up well to all weather conditions. It is made by The Meadows-Dale Manufacturing Co., Ltd., The Dale, Willenhall, Staffordshire, and the price is £10 10s with a 10ft mast and double chimney lashing.

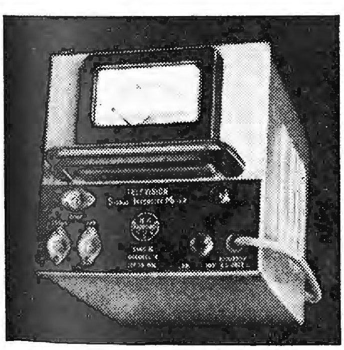
Band-III Signal Intensity Meter

A COMPACT and portable a.c.-operated meter for measuring the average television signal intensities on Band III has been introduced by Radio-Aids. It can easily be taken to the site where it is proposed to erect the aerial in order to ascertain the type of aerial required and whether the chosen site is the best one or not.

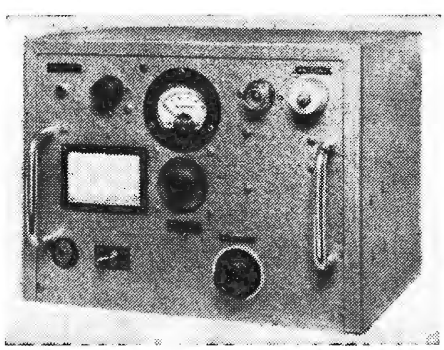
Similar in general design to the Band-I model introduced some time ago, it uses a t.r.f. circuit consisting of four cascode r.f. stages, a germanium diode detector, sensitive microammeter and voltage-stabilized power supply. Thermistor compensation for temperature variation is included.

Full-scale meter readings are 200 μV, 2 mV and 20 mV respectively, the three ranges being selected by plugging the aerial feeder into one of three sockets used in place of switching.

Known as the Type SIM III, the instrument weighs 8 lb, measures 7in × 6in × 6in and costs £33. It is obtainable from the sole distributors, W. J. Picton (Heath Electronics), Ltd., 57, High Road, Bushey Heath, Watford, Herts.



Radio-Aids Band-III TV signal intensity meter.



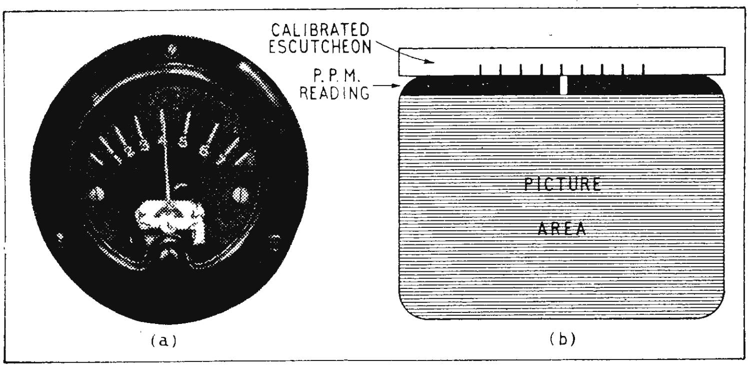
Sea Wave Communications marine transmitter, Type MTX25.

Compact Marine Transmitter

A VERY compact 25-watt 'phone and c.w. marine transmitter, measuring only 12in × 9in × 10in, has been introduced by Sea Wave Communications for use in the smaller types of vessel. It provides immediate choice of any one of six crystal-controlled frequencies in the band 2 to 18 Mc/s and the marine distress frequency of 2,182 kc/s is separately marked for instant selection. Aerial matching on changing channel is reduced to the simplest possible operation.

A land-station version of this marine MTX25 model will be available shortly and this will provide 25 watts telephony and 40 watts c.w. and both variable master oscillator and crystal control will be embodied.

The transmitter is obtainable from Sea Wave Communications, Ltd., 13, South Molton Street, London, W.1. The price of the marine transmitter, MTX25, is £65 complete.



Picture-

By

J. R. GREENWOOD, B.Sc.*

Fig. 1. (a) Dial of the B.B.C. peak programme meter; (b) the corresponding display on the monitor tube face.

WHEN monitoring television programmes it is difficult to keep both sound and picture monitors in view at the same time. The reason for this is, of course, that while the picture is displayed on the screen of a cathode-ray tube the peak levels in sound output are indicated by the pointer of a separate meter movement operating as a peak-reading voltmeter.

Obviously, presenting the indication of programme sound intensity on a portion of the monitor tube face is the logical way to overcome the difficulty. Viewing a constantly changing sound waveform on the face of a c.r. tube, however, causes a good deal of eyestrain. Before the war a special sound processing circuit which lessened eyestrain was developed by the B.B.C. This piece of equipment is called a "peak programme meter" and has proved very satisfactory in all respects when driving the meter movement mentioned previously. This article will describe the additional equipment required to display the peak-programme-meter readings on the c.r. tube without interfering with the c.r. tube's primary purpose of showing the transmitted television picture.

In Fig. 1 can be seen the dial of the existing peak programme meter, while alongside is a sketch of the corresponding type of indication provided on the c.r. tube face. Modifications to the front panel of the picture monitor entail only the provision of a calibrated escutcheon, which takes the form of an approximately evenly tempered scale calibrated from 1 to 7, that is, a 6 dB step between 1 and 2, and 4 dB steps per division over the rest of the scale.

Fig. 2 is a schematic diagram of the existing sound processing circuit. The main objective is to have a continuous indication of the peak voltages to which the main programme chain equipment will be subjected when a sound signal is being transmitted, and, at the same time, to avoid affecting the performance of the main chain. The indications of most value are:—

(a) The line-up condition, which represents 40% modulation of the transmitter. This is on meter reading "4," when 1000-c/s line-up tone is fed along the programme chain prior to transmission.

(b) Maximum signal condition, which represents 100% modulation. This is on meter reading "6."

(c) Minimum permissible signal condition, which is controlled by the optional minimum signal/noise ratio thought to give satisfactory radio reception. This is on meter reading "1."

Sound Processing Systems

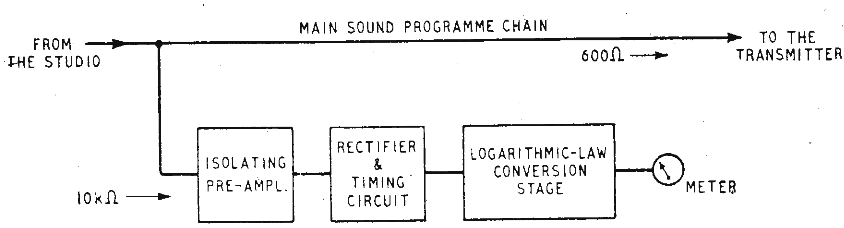
The isolating pre-amplifier protects the signal proceeding along the main programme chain from being affected by the non-linear input impedance of the double-diode rectifier and timing circuit, which would otherwise cause harmonic distortion to appear on the sound signal fed to the transmitter. The rectifier and timing circuit takes the sound signal and processes it so that the feed to the law conversion stage carries only the information necessary to ensure the accurate registration of peak voltages on the meter. The circuit will be dealt with in more detail later.

The logarithmic law conversion stage is necessary on account of the ear's logarithmic response to varying sound intensities, which implies a very wide range of audible sound intensities to be compressed within the permissible programme dynamic range. In consequence, the broadcast engineer is concerned with obtaining as wide a dynamic range as possible; the accepted figure, for the present, being in the region of 30 dB, with possibilities of slight extension where only f.m. transmitters and receivers are used. The programme meter has to give accurate indication of peak voltages over the entire dynamic range with some divisions to spare at either end of the scale.

In order to avoid a long technical description of the peak programme meter (which is only incidental to this article) it is sufficient to show the type of

* B.B.C. Engineering Training Dept.

Fig. 2. Schematic of B.B.C. sound processing circuit used for the peak programme meter.



Tube Sound Monitoring

METER-TYPE DISPLAY ON THE RASTER OF A TELEVISION MONITOR TUBE

waveform which will be fed into the system as the "processed sound signal." Fig. 3 shows the response of the peak programme meter to a given input signal. The waveforms demonstrate that the timing circuit has a fast registration time, so that peak values are recorded faithfully, and a slow discharge time constant (1 second), so that extraneous meter-needle movement is reduced to an extent where eyestrain is greatly diminished. A signal of approximately 215 volts peak value having a waveform as in Fig. 3(a) is available at the output terminals of the programme meter, the generator impedance being approximately 150 kΩ.

From Fig. 1(b) it can be seen that the type of indication required necessitates a number of beam brightening pulses being formed. These will have to occur during a portion of each of the first few lines of each frame of the raster. The objective is to form a vertical bright bar covering a portion of the first 10 successive picture lines. The bar has to be positioned relative to the escutcheon so that the instantaneous value of the processed sound signal voltage can be seen clearly.

The phasing of the brightening pulse with respect to the line scan is actually achieved by a coincidence circuit. Each value of voltage on the processed sound waveform has an equivalent value on the slope of the line sawtooth, and the coincidence circuit produces a beam brightening pulse of short duration whenever the equivalence is satisfied. The general principle can be followed with the aid of Figs. 4, 5 and 6. In Fig. 4, one signal input is derived from the line sawtooth generator and the other from the processed sound signal source. The points of coincidence are shown in Fig. 5(a) and (b). Here, A and C are the ones of interest; B and D have no significance and occur during flyback. Fig. 6 shows the effect as seen by the observer, illustrating that the spot moves from position A at time t_1 to C at t_2 according to the value of V_2 at the respective times.

Independent Sound Presentation

The television waveform is of a highly complex nature. One feature of the waveform which initiated this idea is that, prior to the commencement of active picture elements of the signal, 8 broad pulses and 10 suppressed lines are radiated in order that the average receiver or monitor frame timebase will have more than ample time to return the electron beam to its starting position at the top of the tube before the next frame becomes "active."

That is the reason why the sound indicating system can be superimposed on the television picture monitor tube face without interfering with the picture. However, up to this point no mention has been made of the suppressor circuit which is included in the complete schematic diagram of the system, Fig. 7.

The action of the suppressor circuit and pulse amplifier combined is to suppress brightening pulses from the coincidence circuit whilst the active lines

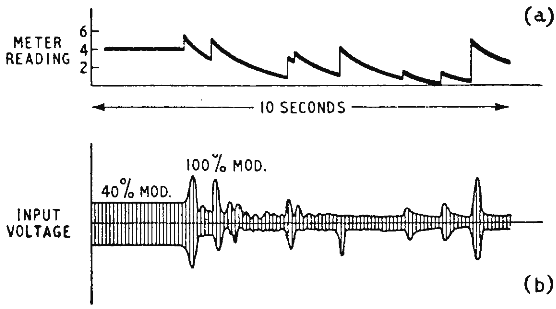


Fig. 3. (a) The response of the peak programme meter to an input signal (b).

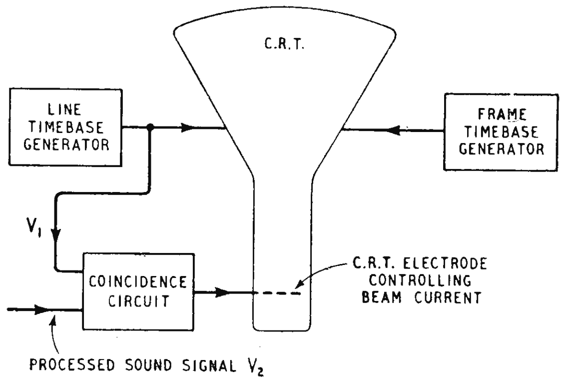
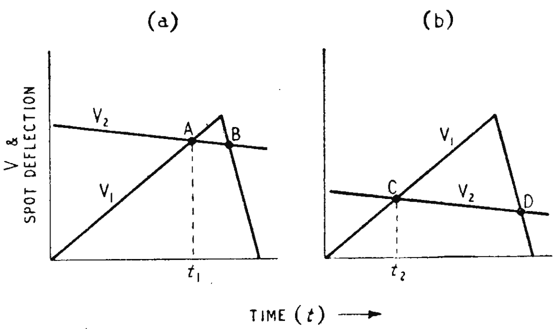
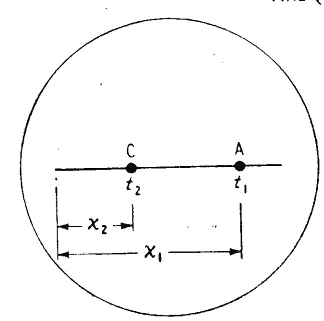


Fig. 4. Schematic showing the basic principle of the c.r. tube indication system.



Above: Fig. 5. Points of voltage coincidence on the waveforms of the frame timebase and the processed sound signal, at two different times (a) and (b).



Left: Fig. 6. Positions of the brightened spot across the tube face at times corresponding to t_1 and t_2 in Fig. 5.

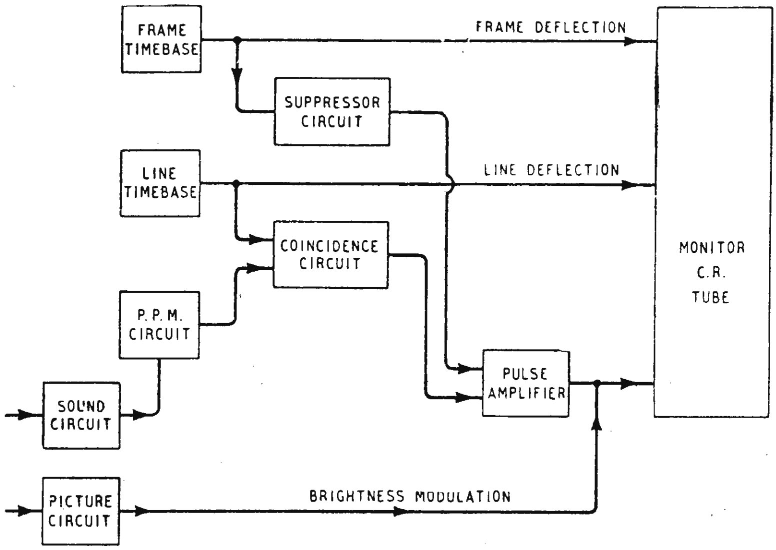


Fig. 7. Schematic of the complete indicating system.

constituting the centre of the picture are being displayed. The suppressor is fed from the frame timebase and is arranged to derive a signal of approximately 1 to 2 milliseconds duration. Only during this time does the pulse amplifier pass the brightening to the appropriate electrode on the c.r. tube to give the indication shown in Fig. 1(b).

Whilst the sound signal is being processed in the peak programme meter circuit to provide one signal input to the coincidence circuit, the output signal from the monitor line timebase is used to deflect the c.r. tube beam and as a second signal input to the coincidence circuit. The sound signal input has a registration time-constant of 1 millisecond and a discharge time-constant of 1 second. The two input signals act on the coincidence circuit so that a pulse of the order of 1-μsec duration is produced. The coincidence circuit takes care of the phasing of the pulse so that the positions of the brightened spots on the tube face are related to the peak programme meter output.

The pulse amplifier is normally biased-off during the active lines of the picture and only becomes operative immediately after the suppressor circuit receives the frame flyback signal. During the period of flyback the suppressor is supplied with a voltage pulse from the frame timebase circuit. The voltage so derived is stored in a CR circuit having a time-constant of 1 to 2 milliseconds. The time-constant of the storage circuit is so chosen that the normally inactive pulse amplifier comes into operation over the period of the remainder of 10 following inactive lines of the raster.

Since the line frequency is approximately 10 kc/s (the total duration of 10 lines is about 1 millisecond and the time-constant of the peak programme meter discharge circuit is one second), the 10 consecutive brightening pulses for each individual frame will be in the same phase relationship to the line sweep voltage and the 10 spots produced will be in a vertical line.

The phase relationship will not change greatly between frames except at times when a sound peak is in the process of being registered. So that, on a long-term basis, the visual effect will be one of observing the moving bright bar slowly drifting from right to left whilst the peak programme meter registration circuit is discharging after each successive charge brought about by a peak of programme volume. The times when the bar will be visible are separated by only extremely short intervals during which time the peaks are being registered, therefore the indication is almost continuous as shown by the thickened lines in Fig. 3(a).

One of the advantages of the system is that the space occupied by the extra information on the tube face is utilized only on those monitors which need to be fitted with the sound indication. The television waveform in the main chain and in all subsidiary chains remains unaffected and the 10

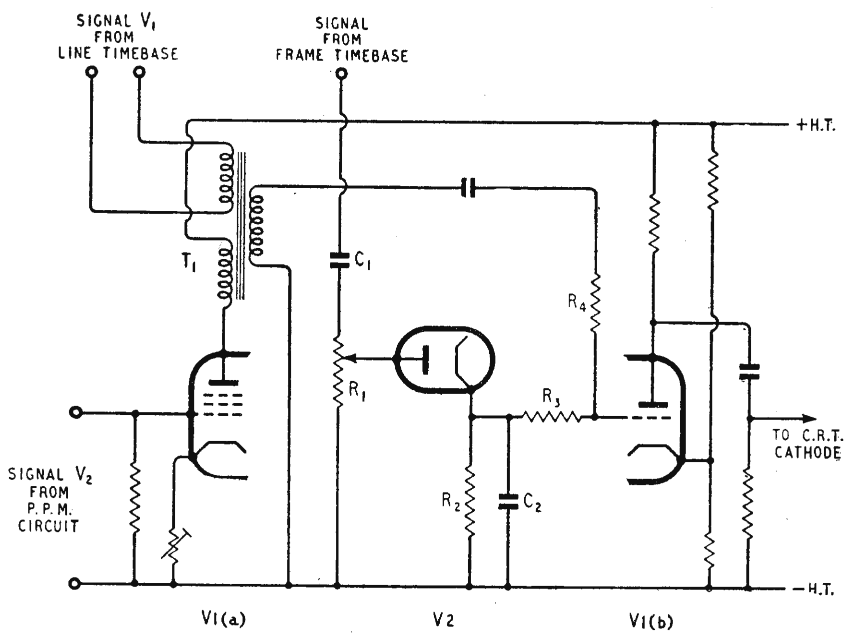
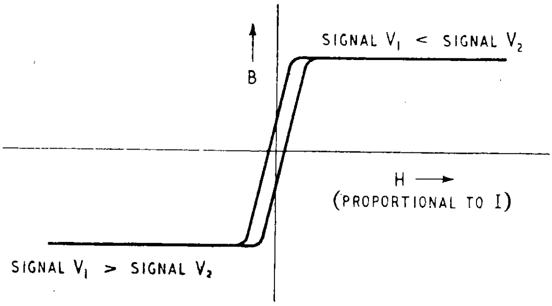


Fig. 8. Circuit for the coincidence detector, suppressor and pulse amplifier shown in Fig. 7.

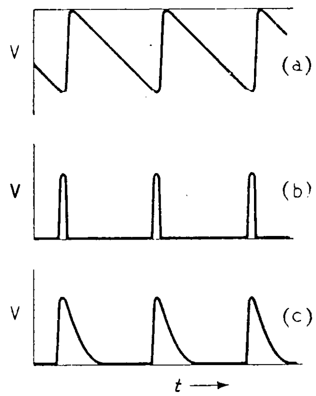
suppressed lines would remain available for carrying other information such as stepped light wedges. Also, if the facility is no longer required at a particular point it can be readily discontinued simply by disconnecting the sound input.

In the following part of the article a scheme is suggested upon which the design of the subsidiary apparatus required to convert an existing monitor can be based. The design is in its most basic form and is only one of many systems which would probably work quite successfully.

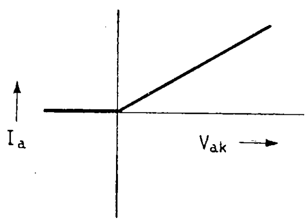
The problem to be solved, then, is one of producing pulses, for trace brightening purposes, in the period when the picture signal is suppressed at the start of each picture frame. In order to obtain pulses in the correct time sequence to provide an intelligible visual indication of sound output, a coincidence circuit has been suggested. During the part of the frame made up by active lines the above pulses will have to be suppressed.



Above: Fig. 9. Change-over of magnetic flux in T_1 of Fig. 8 from one state of saturation to the other when signals V_1 and V_2 become equal.

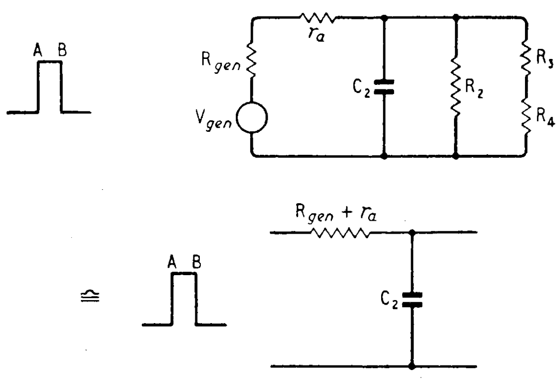


Right: Fig. 10. Voltages derived from the frame sawtooth (a) for gating purposes: (b) after differentiating, (c) after lengthening.



Left: Fig. 11. Characteristic of the diode V2 in Fig. 8.

Below: Fig. 12. Equivalent circuit of the diode gating system.



Brightening-pulse Circuit

The circuit in Fig. 8 is one example of the many that could be used. Here, T_1 is the heart of the circuit, and should possess a good high-frequency response together with a magnetic core which is easily saturated. Ferrite cores such as Ferroxcube seem to have the desired properties. Also, peaking transformer techniques appear to be of assistance.*

The two input signals are arranged to oppose each other and the one which predominates produces a saturating magnetic flux in the core. The core is, in fact, saturated over almost all of the cycle of events. However, just at the point of change-over, when the signals are very nearly equal, the polarity of the magnetic flux will reverse (Fig. 9). The third winding of the transformer is connected so that the change of flux at the coincident point A (Fig. 5) produces a positive-going pulse at the grid of valve V1(b). This polarity of connection ensures that pulses produced at coincidence point B will be negative-going and therefore have no effect. It is arranged so that the amplitudes of the positive-going pulses alone are insufficient to cause V1(b) anode current to flow. V1(b) has a high positive bias on the cathode (say 50 volts) so that it is cut off.

It is required that the pulses will only take effect on the part of the frame immediately following flyback. This is taken care of by deriving a voltage from the frame timebase generator, Fig. 10(a), and differentiating it by the action of R_1C_1 (b), then sustaining the positive-going pulse by the action of R_2C_2 in conjunction with V2, as at (c). The action of V2 is of particular interest because it operates in the same way in both the rectifier and timing circuit of the peak programme meter and in the suppressor circuit. Its action can be easily followed if we think of the input signal in terms of a squared pulse.

If the frame timebase waveform is such that flyback takes a time equal to the duration of two lines the voltage across R_1 will be a squared pulse of 0.2-msec duration occurring at the rate of 50 pulses per second. And if the diode is considered to have a characteristic as shown in Fig. 11 its r_a will be a constant corresponding to the slope of the line. Then for the duration of each pulse the equivalent circuit will appear as in Fig. 12. And since R_2, R_3 and R_4 (as will be shown later) are greater than $R_{gen}+r_a$ the simplification of the circuit to series CR does not unduly affect the issue.

Whilst the charging voltage is present between times A and B, capacitance C_2 will be charged with an exponential rise in terminal voltage and, if the time-constant is chosen correctly, will charge to 90% of the applied voltage in 0.2 msec. As soon as the charging pulse has ended the cathode retains its positive potential after the potential has disappeared at the anode. Hence the diode V2 presents an open

* "The Design of a Peaking Transformer," by Adin B. Thomas. *Brit. I.R.E. Journal*, October, 1953, p. 486.

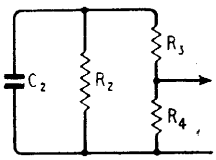
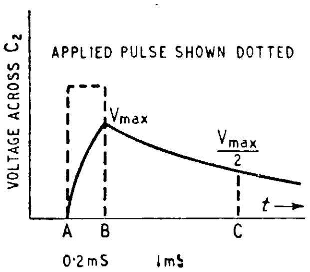
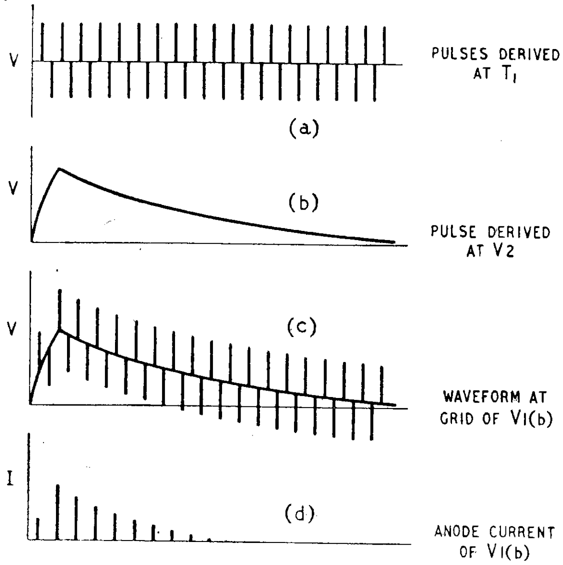


Fig. 13. Effective portion of the gating circuit remaining when the diode presents an open circuit.



Right: Fig. 14. Behaviour of the circuit in Fig. 13.

Below: Fig. 15. Combination of waveforms from T_1 and V2 producing the waveform (c) at the grid of V1(b) and the resultant anode current pulses (d).



circuit, and the effective portion of the circuit remaining, being of the form shown in Fig. 13, behaves as shown in Fig. 14.

It has to be arranged that the discharge of C_2 will take 1 msec to reach 50% of maximum value in order that the grid of V1(b) will become positive with respect to the cathode when each of the first 10 beam brightening pulses arrives from T_1.

Then $C_2\left[\frac{R_2(R_3+R_4)}{R_2+R_3+R_4}\right]$ is 1 to 2 msec

and $C(R_{gen}+r_a)$ is about 0.1 msec

and the initial assumption that $\frac{R_2(R_3+R_4)}{R_2+R_3+R_4}$ is greater than $R_{gen}+r_a$ is correct.

At this point it requires little imagination to see how a full-wave rectifier can be used in the peak programme meter rectifier and timing circuit to produce the waveform shown in Fig. 3(a) from that in (b).

To continue the argument, the waveform seen in Fig. 15(b) is applied to the grid of V1(b) via R_3 and that seen in (a) via R_4. The resultant effect is to allow pulses of anode current to flow in V1(b) at times corresponding to the times of the first 10 scanning lines as shown in (d). Without going into too great an amount of detail, it can be said that the pulse width of pulses derived at T_1 will have to be in the region of 1 μsec, otherwise the visual indicating bar will be too large on the monitor tube face. It can also be deduced that C_2R_2 will have to be in the region of 1 to 2 milliseconds.

An interesting point to notice is that with this circuit, unlike some others, the size of successive pulses of V1(b) anode current are in diminishing order. The effect on the tube face will be to produce a bar of unequal brightness, the bottom end of the bar being least bright and blending into the top of the picture below it. This is advantageous because it means that the spot may be allowed to stray on to the top few active lines of the picture without causing too great a distraction.

Finally, the author would like to express his thanks to Dr. K. R. Sturley, head of the Engineering Training Department of the B.B.C., and his staff, for their helpful criticisms and suggestions.

CLUB NEWS

Birmingham.—The March programme of the Slade Radio Society includes "Circuit applications of transistors" by J. Chandler and A. Wates, of B.T.H. (1st); a talk on the radio amateur emergency network by A. E. Matthews (15th); and "Radio direction finding" by N. B. Simmonds (29th). Meetings are held at 7.45 at Church House, High Street, Erdington. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

Bury.—A. A. H. Moss (G8VF) will give a talk on receivers at the March 12th meeting of the Bury Radio Society to be held at the George Hotel, Kay Gardens. Sec.: L. Robinson, 56, Avondale Avenue, Bury, Lancs.

Chester.—March meetings of the Chester & District Amateur Radio Society include a description of a double superhet on the 19th. The club, which meets at the Tarran Hut (Y.M.C.A.), has decided to grant free membership to "juniors who have no income." Sec.: D. Rickers, 97, Ruabon Road, Wrexham, Denbigh.

Derby.—Meetings of the Derby and District Amateur Radio Society are held each Wednesday at 7.30 at 119, Green Lane. The March meetings include "My recent trip to U.S.A.," by T. Darn (G3FGY) on the 6th, Mullard film strip "The story of television" (13th) and a demonstration, film and discussion on frequency modulation (27th). Sec.: F. C. Ward (G2CVV), 5, Uplands Avenue, Littleover, Derby.

Newbury.—"Colour television—the problems" is the title of the paper which C. A. Marshall, of *British Communications and Electronics*, is reading at the March 22nd meeting of the Newbury and District Amateur Radio Society. The meeting begins at 7.30 at Elliott's Canteen, West Street. Particulars of club activities are obtainable from 83, Newtown Road, Newbury, Berks.

Wellingborough.—At the March 7th meeting of the Wellingborough and District Radio and Television Society M. Homer will deal with television interference. Meetings are held each Thursday at 7.30 at Silver Street Club Room. Sec.: P. E. B. Butler, 84, Wellingborough Road, Rushden.

During the International Jamboree at **Sutton Coldfield** (August 1st-12th) to mark the jubilee of the foundation of the Boy Scout movement, an amateur radio station will be operated at the camp by a group of amateurs. Arrangements are in the hands of an organizing committee including representatives from the Slade Radio Society, Midland Amateur Radio Society and the Birmingham group of the British Amateur Television Club.

WIRELESS WORLD INDEX

The index to the material published in Volume 62 of *Wireless World* (1956) is now available. It includes both general and classified indexes and is obtainable from our Publishers price 1s (postage 2d).

Ionosphere Review, 1956

Approaching Sunspot Maximum

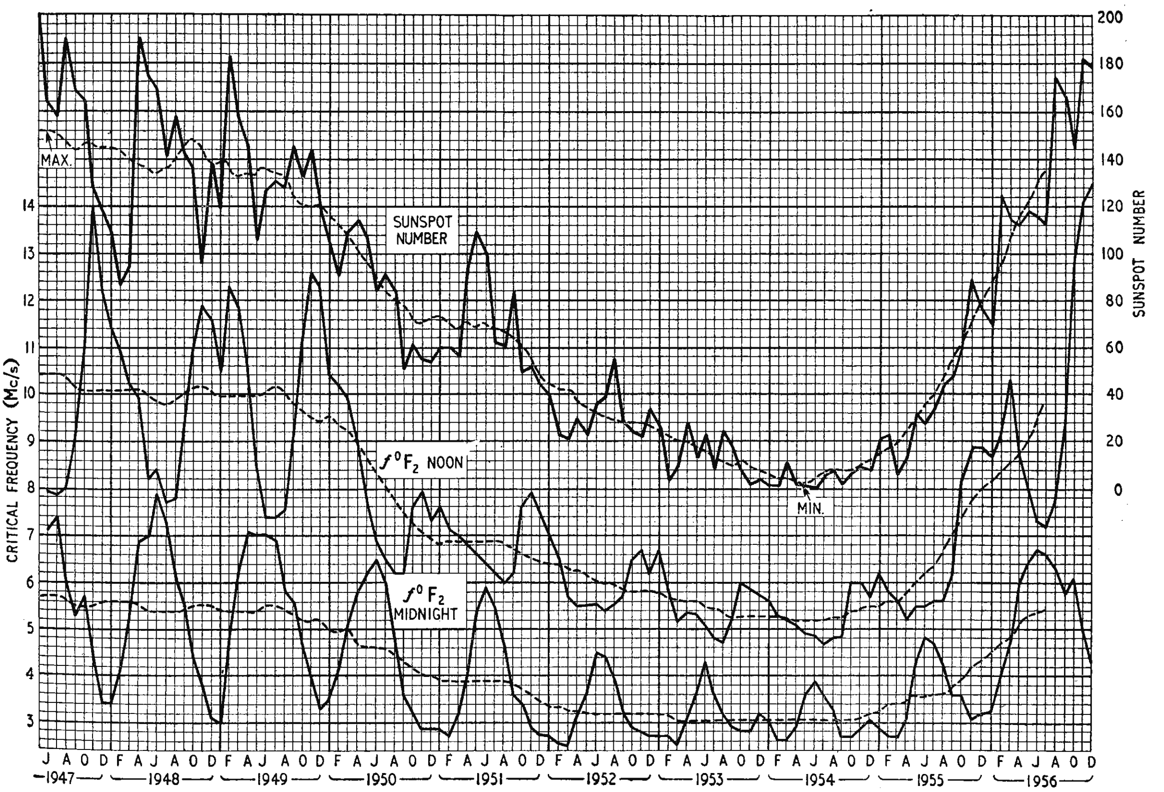
By T. W. BENNINGTON*

DURING 1956 the extremely rapid increase in solar activity, which had become apparent early in 1955, continued in its course. By the end of the year the activity had reached a level comparable with that recorded at the last sunspot maximum, in 1947. So far as radio propagation is concerned "quasi maximum" conditions may be said to have prevailed throughout most of the year, for from February onwards the daytime ionisation of the F_2 layer, over one or another part of the earth's surface, reached those high levels which render it capable of sustaining the propagation over long distances of frequencies well into the v.h.f. band. In fact the year must have been the record one for such propagation since high-frequency radio communication first began. During its last few months, frequencies of 50 Mc/s and higher, which hitherto have seldom been propagated to long distances, were being often so propagated at certain times of day. At the end of the year the solar activity was still increasing, though it now seems likely that the epoch of sunspot maximum is not far distant.

Course of the Sunspot Cycle.—The variations in the solar activity during the past few years, and their effects upon the F_2 layer ionisation, may be seen from the chart. The top full-line curve gives the monthly values of the sunspot number (the last twelve values are provisional numbers), and the *average* level of the sunspot activity is given by the top dotted line, which is a plot of the twelve-month running average of the monthly sunspot numbers.

The two lower full-line curves give respectively the monthly values of the F_2 layer critical frequency for noon and midnight, as measured at the D.S.I.R. ionospheric station at Slough. These curves exhibit large seasonal fluctuations, such that high noon values exist during winter with low values during summer, and high midnight values during summer with low values in winter. Superimposed upon the seasonal fluctuations is the long-period variation due to the changes in solar activity, and the two lower dotted lines, which give the twelve-month running average of the monthly values of noon and midnight critical frequency, illustrate this long-period variation clearly. They show a close correlation between the average level of solar activity and the average value of the F_2 layer critical frequencies, between which there is, in fact, an *approximately* linear relationship, at least up to a sunspot number of about 100. Since the

* The Research Department, British Broadcasting Corporation.



Course of sunspot cycle, with corresponding variations in ionospheric conditions throughout the period.

maximum usable frequencies for long-distance communication are directly related to the F_2 layer critical frequencies, the former may be assumed to have a long-period variation approximately proportionate to that shown by the dotted lines, and correlated in a similar way with the variation in solar activity.

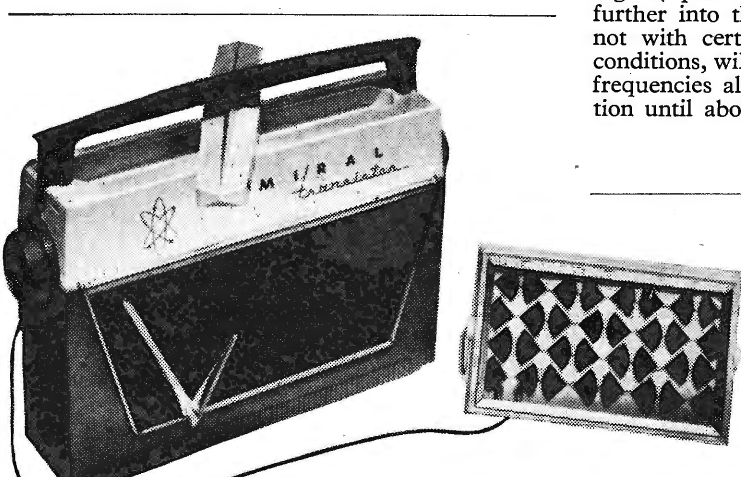
Highest Maximum Recorded.—From the sunspot maximum in May/June, 1947, to the minimum in April/May, 1954, there was a time lapse of 6.8 years, during which period the average sunspot number fell from about 152 to about 3, and the critical frequencies and m.u.fs. decreased by about 2 to 1 at the season and time of day when they are highest. Since the minimum only 2.7 years has elapsed, and during this short period the sunspot number has increased at a rate, which if maintained, points to a higher value being reached than at the last maximum. The average sunspot number (its exact value cannot yet be estimated) also appears to have reached a greater value than at the last maximum. Solar cycles with high maxima are, in fact, nearly always of a "sawtooth" shape, having a short increasing phase followed by a long decreasing one. In this respect they are quite unlike those with low maxima.

During 1956 there was a remarkably rapid increase in the average solar activity and in the average F_2 layer ionisation, and at the end of the year both were still increasing. The highest sunspot maximum so far recorded is that of 1778, when the average sunspot number was about 159. The coming maximum therefore promises to be the highest ever recorded, for it looks as if the 1778 value will almost certainly be exceeded. During 1957 solar activity may thus reach the highest level it has had for at least 208 years. Nevertheless, according to the astronomers, sunspot maximum is likely to occur early in 1957, perhaps as early as February. Thereafter solar activity will begin to decrease, though there may be large short-period fluctuations. The point is, though, that the *average* activity is likely to decrease at a far lesser rate than that at which it has lately been increasing.

Usable Frequencies.—During 1956 the usable band of frequencies for long distance communications was extended considerably at the high-frequency end. Throughout the year frequencies in the 26-Mc/s broadcast band were successfully used for long distance broadcasting and the 28-Mc/s amateur band was very frequently usable. During March U.S.A. police and business radio transmissions on frequencies up to 35 Mc/s were frequently received here, whilst the Channel 1 television signals from this country were being received regularly in various parts of southern Africa. During the summer there was, as usual, a considerable decrease in the occurrence of this v.h.f. reception, but towards autumn it was again renewed. During November and December U.S.A. business radio transmissions were receivable here almost daily on frequencies up to 43.5 Mc/s, the American amateurs on 50 Mc/s were very frequently heard and occasionally frequencies up to 57 Mc/s were propagated across the Atlantic. At this time the British Channel-1 television signals were being received in the U.S.A., and pictures, of a kind, were obtained, whilst, for the first time, the sound channel was received in Australia. These few cases of long-distance v.h.f. reception are cited as examples of the practical effects of the high level of F_2 layer ionisation, which is the result of the present high solar activity. They indicate that, under such conditions as now prevail, frequencies far exceeding those normally used for the purpose do become usable for long-distance communication over certain paths at the appropriate times of the day.

As for 1957 we may expect that, taking the year as a whole, there will be little alteration in the propagation conditions over the various paths as compared with the latter part of 1956.

About February the maximum daytime frequencies may be slightly higher even than those quoted above, and it may be that the sunspot maximum will occur during that month. But, since after that event the solar activity is likely to decrease quite slowly, the usable frequencies are likely to remain very high throughout the year. During the summer the daytime m.u.fs. (from this country) will, of course, decrease somewhat from the present values, but they will rise again to high values in the autumn. Highest night-time frequencies will be reached during the period May to August. And looking even further into the future we may anticipate, though not with certainty, that "quasi maximum" radio conditions, will permit the regular use of the highest frequencies allocated for long-distance communication until about the end of 1959.



Courtesy: Catalin Corporation of America

SUN-POWERED PORTABLE

POWER for this transistor portable, made by the Admiral Corporation of America, is supplied by 32 silicon junction photocells which are sufficiently sensitive to operate the receiver even on overcast days. Alternatively the set can be energized by 6 dry cells. The rotable rod aerial fits into a recess in the high-impact styrene moulded case.

MARCH MEETINGS

LONDON

1st. R.S.G.B.—" Modern amateur communication receiver design" by R. G. Lane (G2BYA) at 6.30 at the I.E.E., Savoy Place, W.C.2.

4th. I.E.E.—" Electronics in administration—a survey" by Dr. D. C. Espley at 5.30 at Savoy Place, W.C.2.

7th. I.E.E.—" Cathodic protection" by L. B. Hobgen, K. A. Spencer and P. W. Heselgrave at 5.30 at Savoy Place, W.C.2.

7th. London U.H.F. Group.—Members' display of u.h.f. gear at 7.30 at the Bedford Corner Hotel, Bayley Street, W.C.1.

13th. Radar Association.—" The applications of radar techniques in science and industry" by Sir John Cockcroft at 7.30 at the Anatomy Theatre, University College, Gower Street, W.C.1.

15th. B.S.R.A.—" Ultra-linear amplifiers" by D. M. Leakey at 7.15 at the Royal Society of Arts, John Adam Street, Adelphi, W.C.2.

15th. Television Society.—" Return of electrostatic focussing" by Dr. R. Pearce (E.M.I. Research) at 7.0 at 164, Shaftesbury Avenue, W.C.2.

20th. I.E.E.—" Recent developments in X-ray and electron microscopy with some applications to radio and electronics" by Dr. V. E. Cosslett and C. W. Oatley at 5.30 at Savoy Place, W.C.2.

20th. British Kinematograph Society. —" A new approach to telerecording" by A. E. Sarson and P. B. Stock with an introductory survey by L. C. Jesty at 7.15 at the Royal Society of Arts, John Adam Street, Adelphi, W.C.2.

25th. I.E.E. (Students).—Address by Sir Gordon Radley, president, at 6.30 at Savoy Place, W.C.2.

27th. Brit. I.R.E.—" Disk recording" by Dr. G. F. Dutton at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

28th. Physical Society.—Annual general meeting of acoustics group and symposium on sound recording: " Factors limiting the performance of magnetic recording systems" by Dr. P. E. Axon, " Standardization of recording characteristics" by H. J. Houlgate, " Application of magnetic recording to computers and automation" by B. W. Pollard, and " Magnetic strip on cinematograph film" by J. Moir at 4.0 at the Royal Institute of British Architects, 66, Portland Place, W.1.

29th. Television Society.—" Studio production techniques" by Ian Atkins (B.B.C. Television) at 7.0 at 164, Shaftesbury Avenue, W.C.2.

BIRMINGHAM

25th. I.E.E.—" The B.B.C. sound broadcasting service on very-high frequencies" by E. W. Hayes and H. Page at 6.0 at the James Watt Memorial Institute, Great Charles Street.

CAMBRIDGE

5th. I.E.E.—" Cathodic protection" by L. B. Hobgen, K. A. Spencer and P. W. Heselgrave at 8.0 at the Cavendish Laboratory.

CARDIFF

11th. I.E.E.—" Transistor power amplifiers" by R. A. Hilbourne and D. D. Jones, and " Transistor d.c. convertors" by L. H. Light and P. M. Hooker at 6.0 at the South Wales Institute of Engineers, Park Place.

CHESTER

27th. Society of Instrument Technology.—" The future of semi-conductors in industry" by D. D. Jones (G.E.C. Research) at 7.0 at 5, King's Buildings, King Street.

EDINBURGH

15th. Brit. I.R.E.—" Applications of particle accelerators" by C. W. Miller at 7.0 at the Department of Natural Philosophy, University of Edinburgh.

FARNBOROUGH

27th. I.E.E.—" Frequency-modulation radar for use in the mercantile marine" by D. N. Keep at 7.30 at the R.A.E. Technical College.

GLASGOW

27th. I.E.E.—" The B.B.C. sound broadcasting service on very-high frequencies" by E. W. Hayes and H. Page at 7.0 at the Institution of Engineers and Shipbuilders, Elmbank Crescent.

LIVERPOOL

4th. I.E.E.—" Electronics and automation: some industrial applications" by Dr. H. A. Thomas at 6.30 at the Liverpool Royal Institution, Colquitt Street.

6th. Brit. I.R.E.—" The preparation of service and technical data sheets" by E. A. W. Spreadbury (*Wireless Trader*) at 7.0 at the Chamber of Commerce, 1, Old Hall Street.

MALVERN

11th. I.E.E.—" Vacuum techniques" by D. J. Taylor, " Temperature control" by J. P. King, and " Cutting of semi-conductors" by J. R. Walford at 6.0 at the Winter Gardens.

MANCHESTER

7th. Brit. I.R.E.—" Electronic musical instruments" by A. Douglas at 6.30 at the Reynolds Hall, College of Technology, Sackville Street.

13th. I.E.E.—" The electronic age" by Dr. R. C. G. Williams at 6.45 at the Engineers' Club, Albert Square.

NEWCASTLE-ON-TYNE

4th. I.E.E.—" An experimental study of high-permeability nickel-iron alloys" by C. E. Richards, E. V. Walker and A. C. Lynch at 6.15 at King's College.

PORTSMOUTH

6th. I.E.E.—" Germanium and silicon power rectifiers" by T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell at 6.30 at the Central Electricity Authority, 111, High Street.

29th. B.S.R.A.—" Hearing aids and audiometers" by S. Kelly at 7.15 at the Central Library.

READING

18th. I.E.E.—" The transatlantic telephone cable" by R. J. Halsey at 7.15 at the George Hotel, King Street.

RUGBY

12th. I.E.E.—" Ferrites" by Profesor F. Brailsford at 6.30 at the Rugby College of Technology and Arts.

WEYMOUTH

1st. I.E.E.—" Analogue Computors" by R. Postlethwaite at 6.30 at the South Dorset Technical College.

RANDOM RADIATIONS

By "DIALLIST"

No, No, Sir!

"CATHODE RAY" was considerably off the rails in his mild criticism of my use of monochrome as an alternative to black-and-white in describing the television picture. White, he suggests, is as far removed as it could be from monochrome, since it is a combination of all the colours of the spectrum. True; but if he'd thought for a moment, he'd have realized that the television "white" isn't white, but a very pale grey. The dictionary defines the word monochrome as referring to a representation or image in different tints of the same colour. The television picture exactly fits in with this, for it consists of nothing but greys, from the very pale to the very dark. As for his suggested alternative, "panchrome," words fail me, as I'm sure they do my *confrère* "Free Grid." "Pantochrome," if you like, "C.R.", but not such a verbal monstrosity as panchrome. Yes, I know there's a photographic term panchromatic; but that must have been coined by some fellow with "little Latin and less Greek."

Projection v *Large Tube*

A READER takes me to task for having said in these notes that a projected television picture is less obviously liney than that on the screen of a large cathode-ray tube. The number of scanning lines, he points out, is precisely the same in both instances. True enough, but, am I not right in saying that on the very small tube of a projection receiver the spot, no matter how sharply you focus it, is relatively a good deal larger than that painting the pictures directly on the screen of a 17-inch or 21-inch tube? Hence, if there are any gaps between the lines of an interlaced scan, they are narrower and less noticeable than those on the screen of a big-tube, direct-viewing receiver. Though he doesn't appear to realize it, my correspondent himself proves the truth of my contention. His projection set, he writes, gives a 36×27-inch picture and he and his wife sit 10 to 12 feet from the screen. Now, a useful rule of thumb for direct viewing is that, without spot-wobble, the minimum viewing distance in feet is just about half the size in inches of the c.r.t., say, 10 feet for a 21-inch tube. Well, my correspondent and his wife are sitting at about that distance from a projected picture more than twice the size of the image on a 21-inch tube and having no bother with lininess. To give a direct picture of the same size you'd need a 42-in c.r.t. (!) and would have to sit over 20 feet from it to get rid of the lines.

A Marine Radar Point

"DEAR Mr. Diallist," wrote a Birmingham reader, "weren't your radiations a little more random than usual when you wrote recently [December issue] of the need for a radar predictor?" He goes on to point out that if the bearing of another ship remains constant while the range decreases, you are on a collision course. Everyone who's had anything to do with marine radar knows that, for it's one of the basic rules. The trouble is that if officers don't plot it isn't always realized that the bearing is staying put and the range shortening. And this is particularly true when one or both ships make changes in course and speed. I remember attending one court case in which that's exactly what happened. Only one ship had radar. No plotting was done; but every order given by the navigating officer made a collision more and more inevitable. And this on the open sea and the "blip" of the victim first seen on the radar screen when the range was the best part of ten miles!

Television in France

YOU may recall that in the last issue I expressed surprise at the distribution of French TV stations. They seemed, according to the map in the December issue, to be mainly concentrated on the north coast and round the northern and eastern frontiers. Hardly had my copy gone to the printer when the post brought me from Paris the January issue of that excellent magazine *Télévision.* On its cover is a map showing the layout of the French television system as it will be when the nationwide plan, now well under way, is completed. It can't have been an easy task to devise a scheme for the TV coverage of the whole of France, for considerable parts of the country are mountainous and therefore "difficult," and, due to the bandwidth needed by the French system, only twelve channels are available in Bands I and III. As it now stands, the scheme is most ingenious. Amongst the big problems to be solved were those of inter-station interference, of blind spots and of a vast network of cable and radio links. Directional aerials will be used for at least 16 of the main stations so as to give a strong signal where it is wanted. The blind spots will be catered for by low-powered satellites or relays.

A Four-year Plan

Altogether 40 main stations are to be used, of which 17 will have an e.r.p. of 100 kW or more, in certain directions at any rate. Thirteen of these are rated at 200 kW and two at 300 kW. At least 20 main stations will be on the air by the end of this year, and the whole scheme completed by 1960. It's a bold step, for so far television sets have been slow in making their way into French households. The R.T.F. firmly believes—and I'm sure they're right—that there will be a snowball increase in the number of domestic TV receivers as more and more transmitters come into action. French television certainly deserves to succeed, for the courageous decision some years ago to adopt the 819-line standard means that France has potentially the best television pictures in the world to-day. Our own Television Advisory Committee originally had in mind that some similar standard should eventually come into use here; if you remember, they recommended years ago that research should go forward with a view to developing a system of the order of 1,000 lines. A pity that so far it hasn't come to anything and doesn't look like doing so.

A Question of Efficiency

HAVE you ever thought what hopelessly inefficient pieces of apparatus domestic sound and television receivers are from one point of view? The average mains-operated sound set needs about 30 watts input to its l.t. and h.t. circuits to produce an output of some 2 watts from its final a.f. stage. The ratio is better in battery sets. For television receivers the average input from the mains is some 150 watts for an audio output of 2-3 watts, and no great amount of power from the line-scan, frame-scan and e.h.t. circuits. What an improvement there'll be in a few years' time, when transistors come into more general use. Sooner or later, I suppose, sets drawing their power from the transmitter will be common in primary service areas. I hardly think that even now "Free Grid" need fear being run in for stealing electricity, the property of the B.B.C. What you have broadcast is surely no longer your property. Haven't you made a gift of it to anyone licensed to receive it?

UNBIASED

By FREE GRID

Electronic Torsothermer

ONE of the gossip-column writers of an evening newspaper has just discovered the principles of electronic cooking which was first dealt with in these columns and elsewhere many years ago. This particular writer has just heard of the invention from New York and has given his readers all the usual wonders about the ability of an electronic oven to cook the inside of a cake without burning to a cinder the outside.

Well, there is nothing new in that to readers of *Wireless World* but it has set me thinking about a problem of my own. For many years I have used an electric blanket. I have no complaints about it except that it is unnatural as it warms my outside and the heat then travels inwards. When I eat food it generates heat inside me and this heat travels outwards. By means of electronic cooking technique surely it would be possible for me to warm myself in the same manner as nature does it. To do the whole thing electronically, instead of merely electrically as I do at present, would, of course, give me great psychological satisfaction.

The only thing is that my knowledge of the techniques of electronic heating and cooking is rather slender, and I am not at all sure how to set to work with safety. As you will appreciate, an error whereby, say, the liver was raised to an inordinately high temperature might be fraught with serious medical consequences. If any of you have any real knowledge about this matter I shall be very glad to hear from you. This is, of course, really a question for electro-physiologists and maybe a paper on the subject has been presented at a meeting of the Electro-Physiological Technologists' Association.

Antenna in Excelsis

I SEE that Dr. R. S. Scorer recently told the Minister of Power that in his view domestic chimneys are responsible for far more pollution than a lofty factory chimney. One factory chimney will, of course, discharge far more smoke and other harmful substances than a domestic chimney and so to make a fair comparison several of the latter should be taken into account so that they are together discharging the same quantity of smoke as the factory chimney. Even so the factory chimney will do far less damage as, owing to its greater height, it disperses its noxious substances over a far greater area than do the domestic chimneys; in other words, the concentration is less.

Surely the logical theory to follow would be to make domestic chimneys illegal? A tall, factory-type chimney could be erected at the end of each road. To this chimney all domestic smoke could be fed by special underground ducts using forced draught.

This would at once make possible my favourite idea of a communal TV aerial for each road. The tall communal "factory" chimney would be an ideal site for it. Not only would its great height enable TV range to be greatly increased, but whole masses of unsightly roof aerials would be wiped away; indeed, the very disappearance of domestic chimneys would *literally* undermine the very foundations of our present aerial eyesores.

If any of you cavil at the ugliness of a factory chimney at the end of each road, I would point out that with proper architectural design it could be as graceful as the tall and slender campanile of Westminster Cathedral.

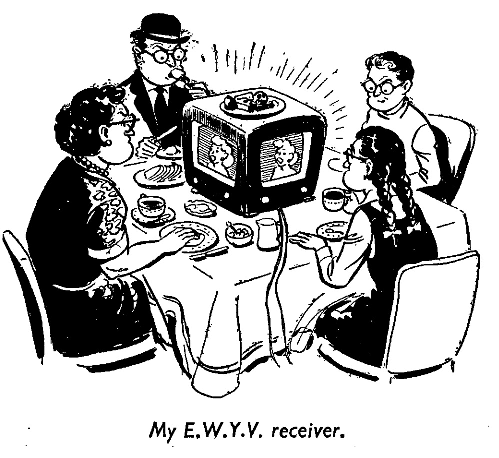
Eupeptovision

MANUFACTURERS of television sets in this country don't seem to have made any provision to enable their customers to view continuously throughout the evening now that the hour's interval between 6 p.m. and 7 p.m. has disappeared. All of us, no matter whether we belong to the U or non-U sections of the community, have hitherto been able to use that interval to snatch a hurried meal.

Now, of course, we eat and view simultaneously. What is needed is a set with four faces like Big Ben to "cover" each of the four sides of a dining table so that all members of the family can eat while they view. I have hastily knocked up a table set of this eat-while-you-view type and it is so successful that I should like manufacturers to make a similar type available to everybody.

But the four faces should not merely be paralleled up. Each tube should be independent and switchable to the B.B.C. or I.T.A. to cater for the differing tastes of various members of the family. In case any of you are asking, "But what about the sound for each service?" I would add that this can be easily catered for by the use of hearing-aid-type earpieces.

One of the greatest advantages I have derived from my own E.W.Y.V. set is that it checks any tendency for me to bolt my food in order to get back to the television programme. Thus it is greatly conducive to eupepsia.



My E.W.Y.V. receiver.

An Electronic Miss Smith

SOME years ago I had a few words to say about the sad day in the future when all the fair Miss Smiths in our offices will be replaced by electronic typewriters. That day is a lot nearer now judging by an article I have been reading about the research work that is being done in various parts of the world and more particularly at University College, London.

The monstrous machine which is being developed there has, so far, a vocabulary of only 140 words and it spells them in a manner not found in the O.E.D. In these respects it is, therefore, not unlike the dumb blondes which grace, or disgrace, some offices.

Another point of similarity between this machine and its human counterpart is that it gives of its best only when working for one particular person. In the machine, the reason is that it responds best to the particular type of pronunciation for which it has been developed; but with the ladies, there are other considerations.

However, nothing will induce me to persuade my directors to invest in one of these contraptions until it reaches the stage when it can take over *all* the duties of our deft-fingered dactylographers who, metaphorically speaking, smooth our brows and bring a humanizing influence into the soulless cathedrals of commerce.