Wireless World

RADIO, TELEVISION AND ELECTRONICS

43rd YEAR OF PUBLICATION

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In This Issue

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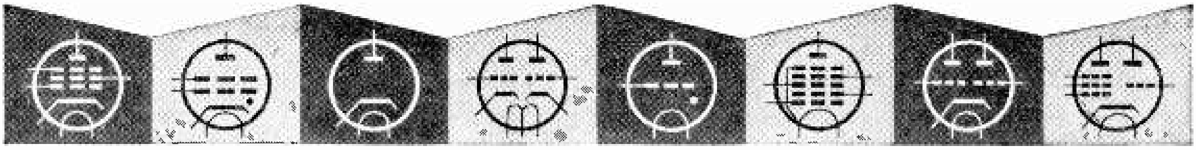

VALVES, TUBES & CIRCUITS

11. PRE-AMPLIFIER PENTODE TYPE EF86

In most audio amplifier applications it is necessary to provide at least one stage of voltage amplification in which any hum, noise or microphony which could be introduced by the valve must be reduced to a minimum. This is particularly important in the early stages of high-gain amplifiers, in microphone pre-amplifiers and in magnetic tape recording applications.

These requirements have been specially considered in the design of the Mullard voltage amplifying pentode type EF86 which is recommended for all audio-frequency applications where low levels of hum, noise and microphony are essential. This valve is in the miniature all-glass range having a single-ended construction and a B9A (noval) base. Its heater, rated at 6.3V, 0.2A is suitable for series or parallel operation with either a.c. or d.c. Typical conditions of operation are given in the accompanying table of data.

HUM

In the design of the EF86 special precautions have been taken to reduce possible sources of hum in the valve. A bifilar heater construction minimises the effect of hum due to the magnetic field of the heater. Effective internal screening assists in reducing hum due to both internal capacitances and external fields. In addition the internal control grid lead is surrounded by a guard ring which is connected to pin 7 and is normally earthed. This reduces leakage to the grid across the base of the valve and also reduces the capacitance between grid and heater.

When used as a normal voltage amplifier with a line voltage of 250V, an anode load of 100 kΩ and a grid resistor of 470 kΩ the maximum hum level of the valve alone is 5 μV, the average value being about 3 μV when operated with one side of the heater earthed. This can be further reduced by centre-tapping the heater to earth. Under these conditions the maximum hum level is 1.5 μV.

The low levels of hum attained with this valve can be completely masked by an unsuitable choice of valve-holder in which leakage and capacitative coupling between pins can introduce considerable hum. For most applications it is found that a low-loss type of holder such as nylon-loaded phenolic or P.T.F.E. is adequate.

NOISE

The low-frequency noise generated by a valve is most conveniently specified as an equivalent voltage on the control grid for a specific bandwidth. For the EF86 under normal conditions, *i.e.* line voltage of 250 V and an anode load of 100 kΩ, the equivalent noise voltage is approximately 2 μV for the frequency range 25-10,000 c/s.

MICROPHONY

Care in the design of the valve to ensure that the electrode structure and its mounting are as rigid as possible has reduced the microphony of the EF86 to a very low level. There are no appreciable internal resonances at frequencies below 1,000 c/s. At higher frequencies the effect of vibration is usually negligible on account of the damping provided by the chassis and the valve-holder. In high-gain applications such as tape recording care should be taken in siting the valve, particularly when a loudspeaker is present in the same cabinet or when a motor is mounted on the same chassis. In such cases a flexible mounting for the valve-holder or a separate weighted sub-chassis is advisable.

VALVE DATA

HEATER

V_h	6.3	V
I_h	0.2	A

CAPACITANCES

c_{out}	5.5	μμF
c_{in}	4.0	μμF
c_{a-g1}	0.025	μμF
c_{g1-h}	0.0025	μμF

LIMITING VALUES

V_a	max.	300	V
p_a	max.	1.0	W
V_{g2}	max.	200	V
p_{g2}	max.	0.2	W
I_k	max.	6.0	mA
V_{h-k}	max.	100	V

CHARACTERISTICS

V_a	250	V
V_{g3}	0	V
V_{g2}	140	V
I_a	3.0	mA
I_{g2}	0.6	mA
V_{g1}	-2.0	V
g_m	1.8	mA/V
r_a	2.5	MΩ

DIMENSIONS

Max. seated height	49	mm
Max. over-all length	56	mm
Max. bulb diameter	22.2	mm

BASE B9A

TYPICAL OPERATING CONDITIONS AS R.C. COUPLED A.F. AMPLIFIER.

V_b (V)	R_a (kΩ)	I_k (mA)	R_{g2} (MΩ)	R_k (kΩ)	$\frac{V_{out}}{V_{in}}$	V_{out} (V)	D_{tot} (%)	R_{g1}* (kΩ)
PENTODE CONNECTION.								
300	100	2.45	0.39	1.0	116	64	5.0	330
250	100	2.05	0.39	1.0	112	50	5.0	330
200	100	1.65	0.39	1.0	106	40	5.0	330
150	100	1.0	0.47	1.5	95	22	5.0	330
300	220	1.1	1.0	2.2	188	54	5.0	680
250	220	0.9	1.0	2.2	180	46	5.0	680
200	220	0.75	1.0	2.2	170	36	5.0	680
150	220	0.55	1.0	2.7	150	24.5	5.0	680
TRIODE CONNECTION.						†		
300	100	1.5	—	2.2	28.5	50	3.8	330
250	100	1.25	—	2.2	28	39	3.7	330
200	100	1.0	—	2.2	27.5	27.5	3.3	330

*Grid resistor of following valve.

†V_{out} at commencement of grid current.

Mullard

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MULLARD LTD., Technical Publications Department, Century House, Shaftesbury Avenue, London, W.C.2

MVM 249

Wireless World

NOVEMBER 1953 VOL. 59 No. 11

Speeding Up the Telegrams

WRITING in a rather pessimistic mood just over a year ago, we expressed the view that radio was failing to attune itself to the tempo of modern travel; in other words, we were failing in our task of keeping up with the Comet. These strictures were particularly directed towards radio telegraphy, but, as wire and wireless are now so closely integrated, they might better have been applied to telegraphy as a whole. The inland telegraph service, conducted at a heavy financial loss, is predominantly wire-borne, and so, perhaps, is not quite our concern. At home the telegram has almost acquired an antiquity value, and by its rarity rather than its speed, compels attention where other means of communication fail to do so.

Overseas Commonwealth telegraphic communications are fortunately in a healthier state, but clearly every advantage must be taken of technical developments if the transit time of telegrams is to beat by a sufficiently wide margin the speeds of modern jet aircraft. And speeds of other kinds of transport are going up as well.

The present state of Commonwealth telecommunications was ably surveyed recently by J. A. Smale, Engineer-in-Chief of Cable and Wireless, the new Chairman of the Radio Section of the I.E.E., in his inaugural address. Most of the developments foreshadowed by Mr. Smale were in the direction of faster service. For instance, he envisaged a direct sender-to-addressee service for telegrams, comparable with the existing telephone system. Many of the developments envisaged are those applicable to submarine cables rather than to radio circuits, but the radio man can take heart in the thought that they will be essentially of a radio-like or electronic nature.

Mr. Smale said: "It is a firmly held belief among old telegraphers that the biggest fool in the world sits at the other end of his circuit." In that light-hearted way he introduced a very serious plea for common executive control of all the ends of the Commonwealth circuits. Freedom from errors and delay could, he maintained, best be attained by those means. He expressed the belief that "force of circumstances will eventually produce agreement among the self-governing nations of the Commonwealth to compromise with sovereignty to the extent necessary to bring their telecommunications systems under unified control of a body possessing the confidence of all."

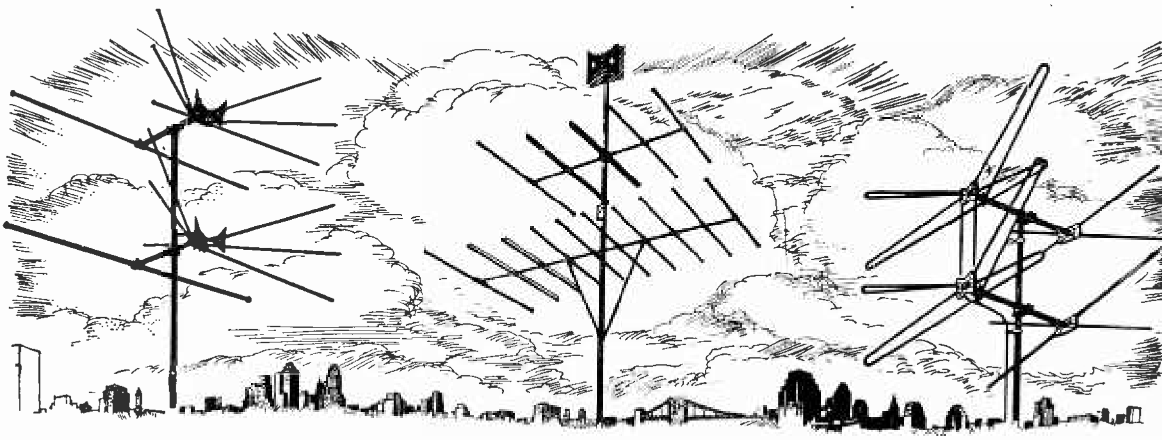
B.B.C. Progress

THE B.B.C. compels our admiration by the way in which it refuses to be shaken by the gusts of political controversy of which it is the storm centre. In spite of long-drawn-out uncertainty as to the way in which the Government will exercise powers of control over its future, the Corporation is calmly going ahead with plans for engineering extensions.

A useful survey of recent developments and of the existing state of broadcasting was recently given by Harold Bishop, director of technical services of the B.B.C., in his inaugural address as President of the Institution of Electrical Engineers. Mr. Bishop then went on to discuss proposed developments, first explaining at some length the present limitations on the medium-wave services. He admitted that reception of the Home programme was difficult or impossible during the hours of darkness for some 5M listeners. The position is deteriorating and such palliatives as can be used could not apparently be expected even to maintain the *status quo*.

Mr. Bishop then briefly outlined the B.B.C.'s plan for providing v.h.f. sound coverage by a system comprising 51 f.m. transmitters at 19 sites. This, presumably, would be the first stage of the Stockholm Plan, described in detail elsewhere in this issue. The first stations to be installed would be in those districts where medium-wave reception is bad. This is all subject to approval by the Government.

Few will quarrel with the general idea of reinforcing our present sound service in this way. We cannot imagine at this stage there will be very much support for the idea that the proposed v.h.f. service will come too late, and, with television growing at the present rate, will be outmoded before it starts. All this takes us into the sphere of prophecy rather than intelligent anticipation, and it would be indeed rash to hazard any guess as to the future position of sound *vis à vis* television.



Television Aerials of the Future

—*Not Forgetting V.H.F. Sound Broadcasting*

By F. R. W. STRAFFORD,* M.I.E.E.

ULTIMATELY the outcome of the Television Advisory Committee's first report will take the form of a mixture of politics, economics, and techniques and it is not the purpose of this article to gaze into the crystal ball, but to assume that all five bands internationally allocated to television and v.h.f. sound broadcasting will eventually be used.

To refresh the reader's memory, these bands are split up as follows:—

Band No.	Frequency Range (Mc/s)	Proposed use
1	41–68	Television
2	87.5–100	Sound broadcasting
3	174–216	Television
4	470–585	Television
5	610–960	Television

The United States are operating television in Bands 1, 3 and 4 and v.h.f. sound broadcasting in Band 2. The frequency range is in the ratio of about 10 to 1. Because the stations are not transmitting a common programme, receivers are expected to tune continuously through all channels and the aerial system must therefore be effective over the receiver tuning range. It is not the purpose of this article to deal in detail with the various types of American wide-band aerials excepting to point out that they appear to be inefficient compared with single-channel optimized aerials, and take various forms. The title illustration, which depicts only a few of the dozens of variants, leaves the rest to the reader's imagination.

One significant fact must be observed, namely: that all television and v.h.f. sound transmissions in the U.S.A. are based on *horizontal polarization*, which at least gives the designer some common basis upon which to engineer his broad-band aerials.

It is with some dismay that one notes that the T.A.C. recommendations for Band 3 television envisage the use of vertical and horizontal polarization, according to the siting of the transmitter. This can only complicate the aerial design and render it more bulky than its U.S.A. counterpart unless some outstanding development is forthcoming.

The use of vertical and horizontal polarization for two television transmitters is confined to the case in which they operate on a common frequency channel (shared-channel operation), and is based upon evidence (so far as Band 1 is concerned) that, during anomalous propagation† a greater freedom from mutual interference results.

This technique may be fully justified on Band 1, where all stations are radiating a common programme, and no one minds a single aerial installation whether vertically or horizontally disposed. But consider the case of a viewer situated so that he is within range of one station in Band 1 and, say, four stations in Band 3, each radiating its own programme. The viewer will naturally require that his receiver be capable of selecting individual programmes and the aerial must be efficient at the frequencies involved.

Providing a common polarization is used, whether vertical or horizontal, it is not difficult to devise the necessary wide-band aerial, but on the present recommendations these four stations in Band 3 can all be vertically polarized, or horizontally polarized, or can be a mixture of both. Clearly, the only solution in this event is a pair of broad-band arrays, one erected vertically and the other horizontally, which just doubles

* Belling and Lee, Ltd.

† *Wireless World*, March 1953.

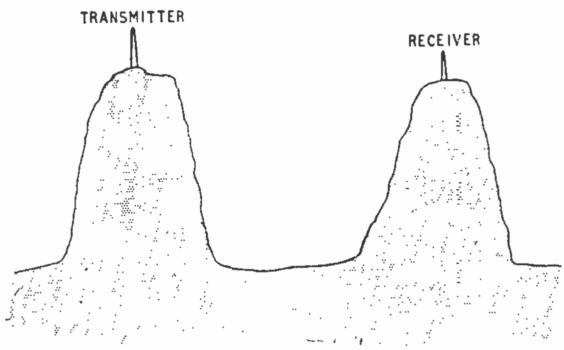


Fig 1. Example of practical "free space" conditions on the ground.

the total amount of equipment required for any one aerial installation!

Bearing in mind the fact that the frequency of Band 3 is, on the average, four times that of the Band 1, it is suggested that ample experimental evidence must be furnished that mixed polarization on shared-channel operation is an advantage before it is adopted. This is really the crux of the whole matter.

Clearly, it is impossible to enter into a detailed discussion on aerial design until this basic problem is fully resolved, but there are certain fundamental aerial concepts which may be discussed with advantage.

It is usual in theory to refer to "free space" conditions and, mathematically, this is essential in order to get exact solutions for wave-energy equations. But it may be taken that, at the frequencies concerned, a transmitting and receiving site respectively located on the peak of two mountains as shown in Fig. 1, and in direct line of sight, will approximate very closely to ideal "free space" conditions.

Assume that the transmitter is Alexandra Palace on channel 1 (45 Mc/s), and that a conventional "H"-type receiving aerial is used. Now scale the transmitting aerial down by a factor of 10 so that it is a resonant system at 450 Mc/s (which places it in Band 4) and energize it with exactly the same power. The field strength at the receiving site will be unaffected. Now scale down the receiving aerial by a factor of 10 so that it is again a resonant system at 450 Mc/s. The amount of energy received by the aerial will be only one-hundredth of the original, even though the field strength at the aerial has remained constant. This is because the effective height of the aerial is proportional to the wavelength. Thus if the wavelength is reduced by a factor of 10 the induced e.m.f. in the aerial is reduced by the same factor, so that the energy, which is proportional to the square of the e.m.f., is reduced one-hundredfold.

It is obvious that something must be done to compensate for this very high loss, and it is satisfactory to know that quite a lot of signal may be recovered. If the space originally occupied by the transmitting aerial is filled with 450-Mc/s dipoles, all correctly phased and the same is done in the space previously occupied by the receiving aerial, then there is, theoretically, a net gain.

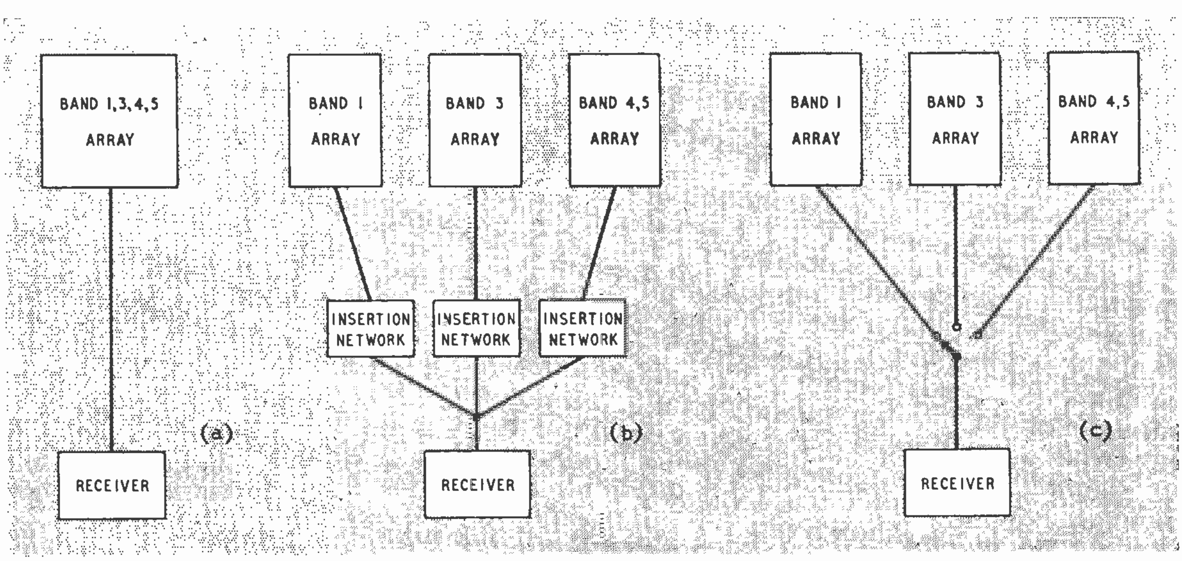
In practice there are certain difficulties on the transmitting side, and there is insufficient space to spare on the receiving side, bearing in mind that Bands 1, 2 and 3 aerials may also be required.

Even in the ideal case of the transmitting and receiving sites being located within line of sight and under "free space" conditions the net result is not likely to be better than that which would have been obtained at 45 Mc/s.

The problem is worsened in practice where the average receiving installation is on the usual type of undulating terrain and is surrounded by other buildings and structures. In these circumstances there are greatly increased propagational losses at 450 Mc/s due to diffraction and ground reflection effects and increased absorption of energy from intervening objects. In addition, there must be included the greater difficulty of exciting the transmitting aerial with anything like the same amount of radio-frequency power, and the higher noise-factor and lower conversion-efficiency of detectors employed in the receiver.

It is difficult to be hard and fast about the overall result of these added problems, but they all add up to a greatly reduced range, and an increased number

Fig. 2. Three basic designs for a multi-band v.h.f. aerial.



of pockets of low field strength within a given area as compared with a service on a lower frequency radiating the same power.

The same remarks apply to Band 3, but here the average frequency is only four times greater than that of Band 1; hence the effects are not so serious. Nevertheless, for a given system the results to be expected, so far as coverage is concerned, will be less than on Band 1.

From all this we may deduce one important point. If we neglect the Band 2 aerial, which is for sound-broadcast reception only, and assume that three separate aerials will be required for Bands 1, 3, 4 and 5 their respective heights should be in the same order—that is, the Band 4 and 5 aerial should be at the top of the mast, with the Bands 3 and 1 aerials progressively lower.

Forgetting the problem of mixed polarization, and assuming that everything is either vertically or horizontally polarized, the design of a suitable all-band aerial may be attacked in three ways.

First, an attempt may be made to devise a single multi-element array which will respond efficiently over all the bands. So far all that has been done has resulted in inefficient systems particularly as regards front-to-back ratio which is very important when "ghosts" are present. It must be remembered that the "ghost" problem is likely to increase as the wavelength is decreased because of the greater reflectivity of surrounding structures.

A second method is to devise a moderately broad-banded array for each channel and feed into a single transmission line via suitable isolating filter networks so that impedance matching may be maintained.

A third method is identical with the second, excepting that the isolating filters are removed and a separate and switchable feeder is used with each aerial.

These arrangements are depicted (in block diagram form) in Fig. 2. Obviously method (a) is ideal if it is capable of achievement. Method (c) would be frowned upon by receiver manufacturers and installers on the grounds of cost, so that the problem resolves itself into either (a) or (b) or some combination of both, but that is a matter which must be left to the ingenuity of the aerial designer and cannot be disposed of prematurely. It is sufficient to note that the U.S.A. has made varied attempts to solve this problem, and the reader is again referred to the title illustrations.

Aerial Feeder

The question of feeders can now be discussed. The popular type at present employed in this country on Band 1 is of coaxial construction and, typically, has a loss when matched of about 3.5 db per 100 ft. The average suburban installation uses about 50 ft of this feeder so the loss (1.75 db) is not serious. It is well known that this loss increases as the square root of the frequency; hence, it is doubled on Band 3 and more than trebled on Bands 4 and 5. Bearing in mind the progressive deterioration of reception with increasing frequency there is a strong suggestion that the existing type of feeder is just about acceptable up to, and including, Band 3 but is completely unacceptable so far as Bands 4 and 5 are concerned.

An examination of data for coaxial feeders shows that a feeder for use at 500 Mc/s (Band 4) will require an outside diameter of nearly 1 in if its loss is not to exceed that at present accepted on Band 1 installations with the conventional feeder. The cost of such a

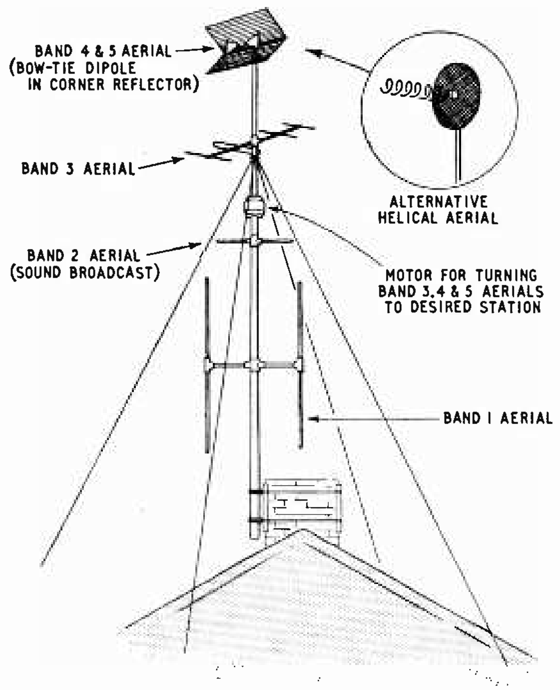


Fig. 3. A multi-band television and v.h.f. broadcasting aerial system might conceivably take this form.

feeder rises alarmingly and can far exceed the cost of the aerial, particularly on Bands 4 and 5 where the material content of the aerial may be fairly small.

Further, the matching of a single wide-band aerial to a feeder is rendered more difficult when the characteristic impedance is low (say 80 ohms), and it is difficult to design a low-loss coaxial feeder of higher impedance—in fact, anything greater than 100 ohms becomes economically impossible.

The Americans have long recognized this fact, and for this reason have almost invariably adopted 300-ohm twin feeders. It is a simple matter to design these for a characteristic impedance up to 400 ohms. They have the advantage of being much cheaper than an 80-ohm coaxial feeder for the same loss and a typical example will consist of a pair of parallel conductors of 7/30 s.w.g. copper wire separated about 0.4 in by a web of low-loss flexible insulating material such as polythene. The characteristic impedance is 300 ohms and the lost at 450 Mc/s (when dry) is about 3 db.

The disadvantage, due to the open construction of this (so-termed) ribbon feeder is that it must be spaced a few inches from walls and other semi-conducting surfaces, or the inherent attenuation loss increases, and the characteristic impedance decreases, thereby causing additional mis-match losses.

Measurements have shown that the installation of 300-ohm ribbon feeder in close proximity to a conductive surface doubles the inherent attenuation loss and reduces the impedance to about 240 ohms. Also, ribbon feeders, on account of their open construction, are very susceptible to nearby interfering fields unless they are electrically balanced; in practice this is difficult, if not impossible, to attain over a wide frequency range.

For a given conductor size the inherent attenuation is almost inversely proportional to the characteristic impedance. By closing the spacing so that the conductors are separated by about 0.1 in the characteristic impedance will fall to about 150 ohms. This feeder is cheaper because less insulation is used, but the loss will be double. At some increase in cost the conductors may be increased in diameter and the losses reduced somewhat, so, at about the same overall cost, a twin feeder may be converted from 300 to 150 ohms with about $30\frac{1}{2}$% increase in loss.

What is more important, however, is that it is far less influenced by proximity effects. It can be installed without stand-off insulators (these are always used in U.S.A.) and the loss, under the most adverse conditions when routed close to a conductive surface, will increase by only 20 % and the impedance will fall by about 10 %. This is confirmed by experiment. Additionally, its susceptibility to local interference is reduced and the balancing problem is simplified somewhat. It is hoped that designers of converters, or broad-band receivers, will give these suggestions careful consideration.

Some idea of the shape of things to come may be gleaned from Fig. 3. In accordance with the best technical ethics the Bands 4 and 5 aerial will be at the top of the mast. A typical broad-band aerial may consist of a "bow tie" dipole (already popular in the U.S.A.) located in a wire mesh corner-reflector. Alternatively, a bowl-type reflector may be used, or the helical aerial, with reflector mat, as devised by J. D. Kraus of Ohio State University (see inset). Bearing in mind the increased propagation losses and other sources of inefficiency in the receiver, and the increased "ghosting" problems, it is unlikely that anything so simple as a dipole or even "H" type array will be satisfactory in Bands 4 and 5, excepting line-of-sight conditions. Even then "ghost" elimination may require highly directional arrays, and for wide-band operation the usual parasitically excited rod elements can only work over a fairly restricted frequency band and must be replaced by a surface such as a corner reflector, bowl or mat.

The Band 3 aerial may take the form of a multi-element Yagi with folded dipole to provide the necessary frequency coverage, which is beyond the capabilities of the simple dipole array. The centre impedance of a folded dipole is of the order of 300 ohms, but by the time the parasitic reflector and director elements have been added this will be reduced and is another good reason why a 150-ohm feeder is to be preferred. There will be variants of this aerial (see title illustration) but it cannot be pointed out too strongly that, in the present state of the art, the gain of an aerial is uniquely related to the space it occupies, and that increasing gain without increasing physical size is as impossible as pouring a quart from a pint pot.

The Band 2 aerial is not very ambitious because it is required for sound-broadcast reception and there are no "ghosting" problems, and very little directional effect is likely to be required. At extreme ranges it may need the addition of a reflector and, perhaps, director elements, in which case it will look like a larger version of the Band 3 aerial.

There follows, finally, the conventional (and largest) aerial for Band 1. For reception of the horizontally polarized transmitters (e.g., Belfast) it may be combined with Band 2 and 3 aerials to provide a much more presentable installation occupying far less space. Fig. 3 has, however, been drawn purposely to bring out this point in considering vertical polarization on Band 1. Bearing in mind that the present plan envisages mixed polarization in Band 3 the earlier remarks on the effect on aerial design may be added (in imagination) to Fig. 3!

Fig. 3 also shows a motor drive located above the Band 2 array so that Band 3, 4 and 5 arrays may be rotated for the purpose of selecting the desired alternative programme, or finding one that is free from "ghosts" (a typical U.S.A. practice, incidentally). This expensive motor drive could be eliminated if the various services had their transmitting aerials on the same site, a point which should not be overlooked in future planning.

The U.S.A., with horizontal polarization throughout and plenty of experience, have achieved nothing by way of compact aerial design beyond what can be seen from the title illustration. In the present circumstances it must be concluded that the British problem is far more difficult. Suggestions for simplifying this may be in conflict with problems relating to transmitter and receiver design and may contain much which lies within the confines of politics—a subject which the author wishes to avoid. For this reason the article must close without drawing any conclusions, but enough has been said to indicate that the problems are not simple, and need weighty considerations from all directions.

Overlapping Television Channels?

NOW that the allocation of television channels is becoming such a problem in the small amount of ether-space available for them, technical people are getting rather worried by the inefficient nature of the television system as a means of conveying information. Measured against Shannon's formula giving the maximum capacity of a communications channel, a television channel consumes far too much bandwidth for the amount of information it conveys.

This subject came up for discussion recently at a Brit. I.R.E. meeting when D. A. Bell gave a lecture on "The Impact of Information Theory on Television." Dr. Bell put some emphasis on the fact that whereas the frequency spectrum of a television transmission was usually represented on paper by the pass-band characteristic of the transmitting and receiving equipment, the actual distribution of sideband energy in the signal tended to fall off quite rapidly away from the carrier frequency in an exponential curve. This suggested that the outer sidebands of two adjacent television channels could be overlapped without serious interference, so that less space would be occupied in the band.

The idea had already been tried out in France and it was also helpful in the N.T.S.C. system of colour television (see page 524) for reducing interference between the two sets of interlaced sidebands. Several speakers were of the opinion, however, that the principle was not very good because the exponential curve of sideband energy was only an average one and in practice the outer sidebands often contained large peaks of energy which could cause mutual interference.

Apart from this, Dr. Bell thought that the shape of the sideband energy curve could be exploited in another direction. The best way to secure error-free transmission was to distribute the signal over the frequency band in the same way as the interfering noise—that is, more or less evenly. This suggested that some form of "pre-emphasis" should be used at the transmitter to lift the outer, high-frequency sidebands of the signal to the same amplitude as those near the carrier frequency. Then at the receiver "de-emphasis" could be used to restore the energy distribution to its original form.

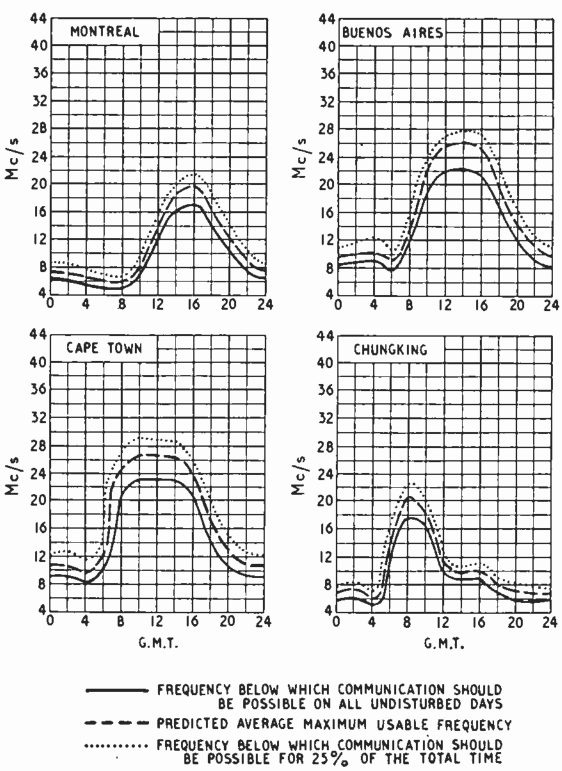
The lecturer considered that synchronizing pulses were a very redundant feature of the television signal because of their repetitive nature. Nevertheless, a large frequency band was required to transmit them properly. All we really needed in principle for synchronizing was a single sideband frequency, with an apparatus at the receiver which would work from a sine wave instead of pulses. In view of the experience that had already been gained with flywheel synchronization this would not be very difficult to arrange.

Short-wave Conditions

Predictions for November

THE full-line 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 November.

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



BOOKS RECEIVED

Fundamentals of Electronic Motion, by Willis W. Harmon. Mathematical treatise on the interaction between electrons and electric and magnetic fields with practical illustrations of their application in electron optics, travelling wave amplifiers, linear accelerators, etc. Pp. 319+x; Figs. 252. Price in U.K., 46s 6d. McGraw Hill Publishing Company, 95, Farringdon Street, London, E.C.4.

Principles of Electronics, by L. T. Agger, B.E. Elementary textbook on vacuum and gas-filled valves and their associated circuits. Pp. 340; Figs. 307. Price 18s. Macmillan and Company, St. Martin's Street, London, W.C.2.

A First Course in Wireless, by "Decibel." Revised third edition of a collection of articles reprinted from *World Radio*. Pp. 231+vii; Figs. 93. Price 12s 6d. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2.

Magnetic Amplifiers, by George M. Ettinger. Broad survey of principles and applications with an 82-item bibliography. Pp. 88+viii; Figs. 48. Price 6s 6d. Methuen and Company, 36, Essex Street, London, W.C.2.

Measurements of Radio Interference in the Frequency Range 0.15 to 30 Mc/s. Technical Report M/T116 "A Portable Measuring Set," by S. F. Pearce and D. C. G. Smith. Pp. 9; Figs. 5. Price 10s 9d by post; and Technical Report M/T117 "A Mains Isolating Unit," by J. Miedzinski and S. F. Pearce. Pp. 7; Figs. 11. Price 12s 10d. Both designs in accordance with performance characteristics prescribed in British Standards Specification BS.727. The Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

Traité Pratique des Antennes, by E. Rolin. Elementary theory of short-wave aerials (10-100 metres) for reception and transmission, including directional aerials and their orientation for great circle paths. Pp. 216; Figs. 104. Price 1,380 francs. Dunod, 92 rue Bonaparte, Paris VI.

CLUB NEWS

Birmingham.—A demonstrated talk on "Some Experiments in the Application of Cold Cathode Tubes" will be given by A. B. Watt (G2DRG) to members of the Slade Radio Society on November 13th. The annual general meeting of the club will be held on November 27th. Meetings are held at 7.45 on alternate Fridays at the Church House, High Street, Erdington. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

Cleckheaton.—At the meeting of the Spen Valley and District Radio and Television Society on November 18th, E. A. Smith, of the Post Office, will talk on microwave radio links. Meetings are held on alternate Wednesdays at 7.30 in the Temperance Hall, Cleckheaton. Sec.: N. Pride, 100, Raikes Lane, Birstall, Nr. Leeds.

Hounslow.—Meetings of the Hounslow and District Radio Society are held on alternate Thursdays at 7.30 at Grove Road Junior School, Grove Road, Hounslow. The next meeting will be on November 12th. Sec.: R. J. Parsons, 16, Cypress Avenue, Whitton, Twickenham, Middx.

Nottingham.—The Nottingham and District Short Wave Club meets every Monday and Thursday at 7.0 at Woodthorpe House, Sherwood, Nottingham. A basic radio course occupies part of Monday evenings and morse practice is given on Thursdays. Sec.: N. D. Littlewood, 129, Standhill Road, Nottingham.

Two-Call Club.—Membership of the British Two-Call Club, which is restricted to British amateurs having been allocated a call in two or more countries, continues to increase. New members include P. R. Golledge (G3EDW, VQ2W, D2DW), D. R. Wilde (G3EBA, DL2BA), R. D. Raley (G3IDR, DL2SR) and C. W. Liversidge (G3ERF, YI2GQ). The president of the Club is Major D. A. MacDonnell (G8DK), who is in the six-call section. Sec.: G. V. Haylock (G2DHV), 63, Lewisham Hill, London, S.E.13.

Point Contact Germanium Rectifiers

Principles of Operation and Their Relation to Performance and Reliability

By R. T. LOVELOCK,* A.M.I.E.E.

THE point-contact germanium rectifier, consisting of a springy metal wire making end-on contact with a germanium surface, has been available in commercial quantities for several years. During that period some manufacturers have used it very successfully in a variety of electrical equipments, while others have been disappointed in its performance. Failure to obtain satisfactory performance can be attributed either to an imperfectly developed component, which was still suffering from faults not realized by the manufacturer, or to lack of comprehension by the user of the fundamental characteristics of the rectifier, with consequent failure to adopt an optimum circuit design for its inclusion.

In the historical development of the rectifier, the various faults experienced have often led to a better appreciation of the conduction mechanism. However, to obtain a clearer grasp of the faults and limitations of the component, it is better to depart from the historical order and first to outline such principles of operation as will assist understanding of its performance, then to note the electrical characteristics of the rectifier, and finally to examine the major faults of manufacture which may cause premature failure in an equipment. For obvious reasons the treatment must be general, and specific constructions cannot be cited. An appreciation of the possible weaknesses, however, will enable an intending user to devise tests which will discriminate between the good and bad examples of design which may come into his hands.

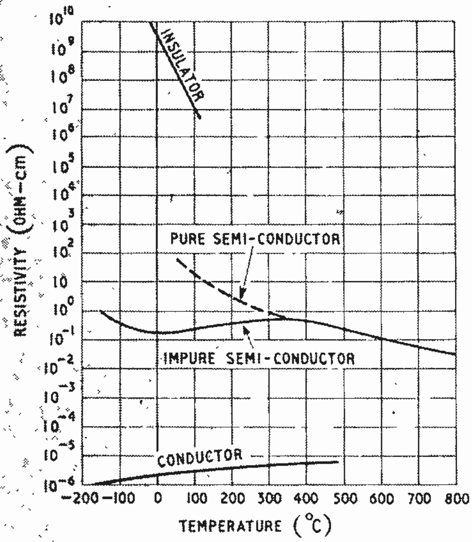
Electrical Conduction in Solids.—In a solid material the atoms are bonded together by forces resulting from a sharing of electrons in the outermost orbits by two or more atoms. In some materials the arrangement of electrons is such that a large number are free to move at random within the volume occupied by the atomic lattice, and they form an assembly analogous to a gas in a closed container. If an electric field be established within the material, a steady component of drift velocity will be superimposed upon the random thermal movement, and electrical conduction will occur: materials which possess this type of structure are called electrical conductors. There are other forms of material in which all the electrons are bound within the vicinity of their parent nuclei, and no general drift is possible upon application of a potential gradient, but only a certain straining of the system from its passive distribution, which we interpret as a "dielectric constant." Such materials are insulators, and the small leakage current which they do exhibit is due to the drift of a very small number of free electrons which are present as slight imperfections in the material structure.

The behaviour of these two types of material with variation of temperature is radically different. Increase of temperature in a conductor causes an insignificant increase in the number of electrons able to conduct, but the increase in thermal energy reduces the mean free path of an electron within the volume. Resistivity is inversely proportional both to the number of electrons and also to the mean free path, and the decrease of mean free path greatly outweighs the increase of electrons, resulting in an increase of resistivity with increasing temperature. In an insulator however, the very small number of electrons present causes the decrease in mean free path to be insignificant compared with the increase of available electrons, and the resistivity falls with rising temperature.

A semi-conductor, as its name implies, is a material intermediate in type between the two extremes: it has many more mobile charges than an insulator, but several orders less than a conductor. In a pure material in the crystalline form the number of free charges available for conduction increases rapidly with increase of temperature, and resistivity falls; the resulting flow of current is said to be due to "intrinsic conduction."

If, in the crystal lattice of the semi-conductor, a very

Fig. 1. Typical variation of resistivity with temperature.



* Murphy Radio, formerly General Electric Company.

small percentage of the atoms are an impurity material possessing either one less or more electron in the outermost orbit than does the semi-conductor, such impurity atoms will each be capable of contributing one free current-carrying charge to the material; these charges will be liberated by the impurity at a much lower temperature than will those of the semi-conductor, and over the temperature range in which the major component of conduction is provided by the impurity charges, conduction is said to be "extrinsic."

Hence, over the low temperature range in which the number of charges liberated by the impurity is rapidly increasing with rising temperature, the material will exhibit a negative temperature coefficient; when the majority of such charges have been liberated, and those provided by the semi-conductor are still only an insignificant fraction of the total, further increase of temperature, by reducing the mean free path without significant increase of free charges, will result in a positive coefficient; when, once more, the number of charges liberated by the semi-conductor becomes comparable with that from the impurity, the increase in number will once more mask the decrease in free path, and the coefficient again becomes negative. Typical behaviour of all four types of material is illustrated in Fig. 1.

An impurity with one more electron in the outermost orbit is said to be a donor type impurity, since it is capable of donating one extra electron to the assemblage, and the mixture is said to be an "*n*" (negative) type of semi-conductor. An impurity with one less electron is said to be an acceptor impurity, since it results in a space (positive hole) into which an electron can fall (or be accepted): conduction can occur due to the successive falling of bound electrons into these holes, and they behave as though they were free current-carrying agents with a positive charge. Such a material is said to be a "*p*" (positive) type material. By a critical temperature processing of a semi-conductor it is possible to produce a lattice imperfection (cause a small percentage of spaces in the crystal lattice which should be occupied to become vacant) and such imperfections act as if they were a "positive hole" and result in a behaviour similar to that of *p*-type material; such behaviour is not identical with that resulting from the presence of acceptor impurity, but differs from it in several important ways, not perfectly understood as yet. It is probably this possibility of modifying the behaviour of a material by deforming the lattice which makes possible the construction of the high-reverse-voltage type of point-contact germanium rectifier.

The Germanium Rectifier.—During the last few years the germanium rectifier has sprung into prominence as one of the most important applications of the semi-conducting elements. The intrinsic resistivity of pure germanium at 20°C is between 60 and 100 ohm-cm, but in the high-reverse-voltage type of rectifier it is usually employed with sufficient donor impurity to reduce this to 10 ohm-cm. For making the low-impedance type of rectifier it is used with about a thousand times this impurity concentration. The two contents represent 0.1 parts per million, and 100 parts per million respectively.

If a bar of germanium be prepared in which one end consists of high-resistivity *n*-type material, and the other of low-resistivity *p*-type material, and a low-resistance contact be attached to each end of the bar so that current may be caused to flow across the inter-face where the two types meet, the bar will behave as a rectifier, and this form is known as a *p-n* junction rectifier. It may be shown on theoretical grounds that the static characteristic of the junction, ignoring the bulk resistance of the bar, can be expressed at 20°C by the law :—

$$i = I_0 \ (1 - e^{39V}) \quad .. \quad .. \quad .. \quad (1)$$

where I_0 is a constant and V is the applied voltage.

Rectifiers have been constructed which exhibit very close agreement with this theoretical law. The junction type of rectifier is being very actively developed in this country, but is not yet available in production quantities.

The point-contact type of rectifier, which has been freely available for some years, consists of a small block of *n*-type germanium, to one side of which is attached a low-resistance contact, and on the other side it is contacted by a pointed springy wire, pressed firmly against it. This device also exhibits a rectification characteristic, but a characteristic which does not agree exactly with that forecast on theoretical grounds for the plain contact between metal and germanium.

Recently, when experiments in connection with the germanium transistor had thrown considerable new light on the mechanism of conduction at a metal-germanium contact, it was realized that the reason for failure to agree with the older theoretical law was because that law had not taken into account the modification to the germanium material which occurs due to the passage of current through the contact. American workers in the Bell Telephone Laboratories have now established that passage of a heavy current pulse through the contact, such as is used to "electroform" the rectifiers, so modifies the germanium in the immediate vicinity of the contact that it exhibits *p*-type characteristics. It is presumed that this modification occurs partly due to the creation of lattice defects in the material, and although the matter is still controversial Fig 2 shows the most likely form which the point-contact rectifier takes in practice. During manufacture the whisker point is pressed firmly against a specially etched surface of germanium, and a heavy pulse of current passed which serves to form a semi-weld between the metal and germanium, and to produce a small volume of *p*-type germanium between this weld and the bulk *n*-type germanium. Thus a *p-n* junction will be formed at the inter-face, which will be "shunted" by any conducting layer of oxide residues which may be formed on the surface during heating of the contact by the current.

The Rectification Characteristic.—In Fig. 3 are shown typical characteristics of representative rectifiers. Both current and voltage scales are shown proportional to the cube root of the parameter as a convenient means of opening out the scale of small values while still allowing the zero point to be plotted. Experiment has shown that the body life of free charges is not greatly affected by variation of impurity content over the range used for the rectifiers plotted, and it follows from this fact on theoretical grounds that if two rectifiers with different impurity content but identical low-frequency capacitance be chosen, the characteristics of the *p-n* junctions formed will be nearly identical, except for the lower breakdown voltage of the one with higher impurity content. In Fig. 3 the characteristics of two point-contact rectifiers are plotted with equal capacitance, but widely differing impurity content, and also the theoretical characteristics of the junctions formed under the whisker points.

The forward current is seen to be less than that of the junction, and the reverse current greater: the forward current of the low-resistivity rectifier is nearer to that of the junction than is that of the high-resistivity component, but this relationship is reversed in the case of the inverse currents. Although it is very difficult to devise and control experiments to prove the matter, an obvious explanation of this divergence from the theoretical form is that the rectifier comprises a complex system such as that shown in Fig. 4. Such a system could account for all the departures from the junction characteristic, including the rather puzzling negative resistance slope exhibited by the high-reverse-voltage types. Although it must be emphasized again that this matter is still controversial, this explanation will be adopted for simplicity in the following treatment as a suitable framework on which to erect a picture of rectifier behaviour.

Cyclic Temperature Coefficient.—As the temperature of the germanium block varies, the characteristic undergoes major changes of shape; such variations may or may not be cyclic and reversible. In this section only those which are cyclic will be considered, leaving those which are not to be considered later as faults. When negligible power is being dissipated in the rectifier, the temperature of the contact is that of the ambient conditions, but when appreciable power is dissipated a considerable temperature rise above ambient may occur, due to the small physical size, and should be allowed for. If, therefore, a slow variation with time, which is not related to the variation of ambient temperature, is observed, this effect should be suspected, and when measuring rectifiers care should be taken to avoid it.

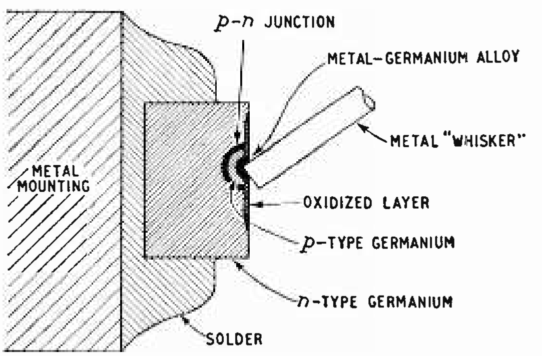


Fig. 2. Diagrammatic representation of point-contact type rectifier.

Over the temperature range −40° C to +100° C the effect of increasing temperature on the germanium rectifier is to increase both the forward and reverse current at a given potential, and also to decrease the "turn-over" voltage or the breakdown voltage. Germanium at a temperature of +20° C has already released all charges from the impurity centres, and over the range of impurity concentrations used in commercial rectifiers the number of charges released by the germanium itself at that temperature is sufficient to ensure that as temperature increases from +20° C to 100° C the resistivity falls rapidly. Below +20° C, however, the behaviour depends to a certain extent on the impurity concentration and the state of the germanium material: all rectifiers will show a greatly reduced rate of increase as temperature falls below this limit, while some may even be showing a slight tendency to fall again as temperature falls from −20° C to −40° C. This major variation of resistivity with temperature is a basic feature of germanium material, and it is impossible to make a rectifier using germanium which will not exhibit it: the only solution to the problem of obtaining a more stable rectifier is to utilize another semi-conducting material in which the major transition from extrinsic to intrinsic conduction occurs over a higher temperature range. Such a material is silicon, and considerable effort is being made to develop a high-reverse-voltage silicon rectifier, in which there is a possibility of obtaining an impedance as high at 100° C as is given by the germanium at 20° C.

The attempt to forecast the variation with temperature is fraught with complexity in the case of the point-contact type. It is comparatively easy to forecast the variation of the theoretical junction characteristic but the other two components causing departure from this characteristic are not subject to close control in manufacture, and will be present in varying degrees in commercial rectifiers of a given type. As a result of this, there will be a considerable spread of temperature coefficient among any given batch of components, and the only method of specifying it is for the manufacturers to measure a percentage of each day's production and to supply the user with information concerning the distribution of coefficients for the rectifier type being used.

The variation of junction current is fairly simple. In equation (1) the exponent or index (39 at +20° C) will vary inversely with absolute temperature (degrees Kelvin) decreasing to 31 at 100° C. The coefficient I_0

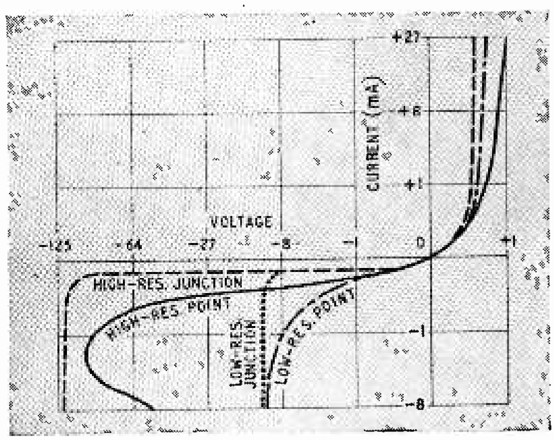


Fig. 3. Typical germanium rectifier characteristics.

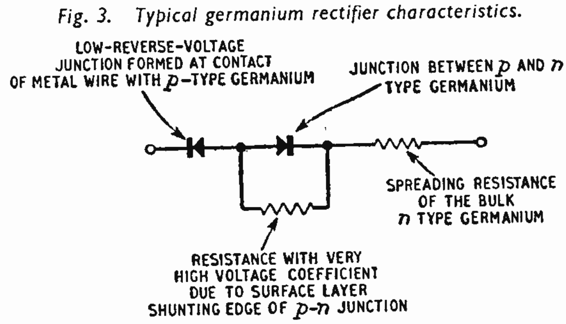


Fig. 4. Suggested equivalent circuit of point-contact germanium rectifier.

has a variation depending mainly on three factors; it is directly proportional to absolute temperature, it is inversely proportional to the overall conductivity of the germanium-impurity alloy, and it is directly proportional to the square of the intrinsic conductivity of pure germanium. The latter term increases so rapidly over the range from 20° C to 100° C that it is the major factor causing the large increase observed, and as a very rough approximation one may consider I_0 as increasing a little more rapidly than the conductivity of pure germanium. In the forward direction the current will increase less rapidly than I_0 due to the decrease in value of the exponent. In the reverse direction I_0 represents a saturation current which will flow at all values of voltage between 0.5 and the breakdown level.

The forward current of the point-contact rectifier is less than that of the junction due to potential drop both in the spreading resistance of the germanium, and also in the reversed rectifier formed by the metal-germanium contact; both these sources will give a smaller fall in potential for a given current as the temperature rises, and in consequence the increase in forward current in the overall rectifier is a little greater than would be that of a junction type. The reverse current will consist of two components, that through the junction, and that through the non-linear leak shunting the junction. Analysis of practical characteristics indicates that increase of the leakage component

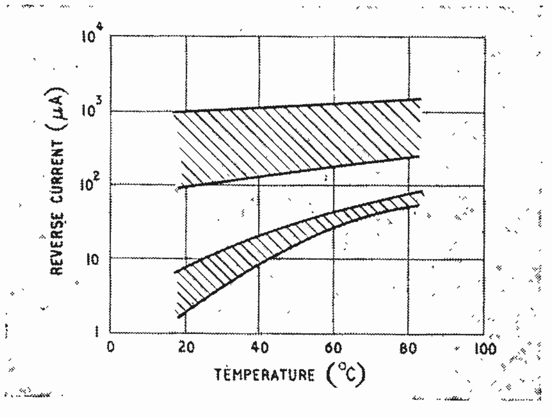


Fig. 5. Typical temperature characteristics of two germanium rectifier types.

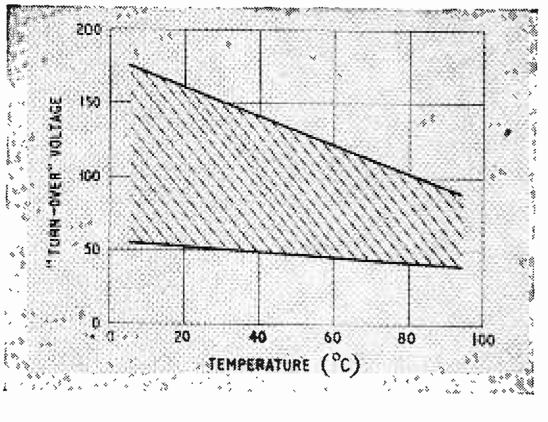


Fig. 6. Variation of "turn-over" voltage with temperature for typical germanium rectifier.

is less rapid than that of the saturation component, and in consequence the overall increase of reverse current is not so great as that of a junction. The leakage component can be analysed into two sub-components, one of which increases linearly with increase of voltage (ohmic) and the other which increases as a power (approximately two) of the voltage. The ohmic component decreases slightly as temperature increases, but the squared component increases and overweighs the ohmic, giving an overall increase of current for increasing voltage. Hence the temperature coefficient of the whole leakage component varies widely between samples due to the variation of ratio between ohmic and non-linear sub-components.

For a given impurity concentration the value of I_0 will be directly proportional to the low-frequency capacitance, and as this capacitance varies by as much as four to one over a batch of typical rectifiers, it follows that the value of saturation current will vary by at least as much. An even greater variation of the leakage component is encountered which is not directly related to I_0 and it follows that the value of reverse current at any particular voltage is no guide to the value of temperature coefficient. Three general rules may be stated, however, for the guidance of the user:—

(a). The more nearly horizontal the reverse characteristic between −1 and −50 volts, the greater will be the ratio of junction current to leakage current, and the greater will be the overall temperature co-efficient for a given value of reverse current.

(b). For a given value of capacitance, the greater the reverse current at a given voltage the greater will be the leakage component and the smaller the temperature coefficient.

(c). For a given capacitance and a given reverse current at a particular voltage, the greater the concavity of the characteristic the greater will be the ratio of non-linear to linear leakage, and the greater will be the temperature coefficient.

Since the capacitance is controlled within certain limits during manufacture, and the *average* value will remain fairly constant for any large batch, it follows that the *average* value of temperature coefficient for a given batch will be smaller the greater the average value of reverse current; in designing circuits to use these rectifiers it is necessary to design for the average value of coefficients, and allow for the spread of these throughout a representative batch. Typical spread of reverse characteristic for two types is shown in Fig. 5 where it will be seen that the one with highest current has lowest temperature coefficient.

The fall of "turn-over" voltage with rise of temperature is a composite phenomenon, due both to changes in the junction and also in the leakage shunting it. The theory of the negative resistance slope has not been fully evaluated yet, and the only reliable information comes from measurements on production rectifiers. Due to variation of ratio between junction and leakage currents the performance of a rectifier having a given value of "turn-over" voltage at 20° C will vary between the individuals in a batch, and the spread of a typical production batch is shown in Fig. 6. It will be noted that the average fall for a given batch will be less the smaller the average value of "turn-over" voltage, but no rules can be stated for the individual rectifier, and the batch must be considered as having a value which may lie anywhere inside the shaded area in the figure.

(To be concluded)

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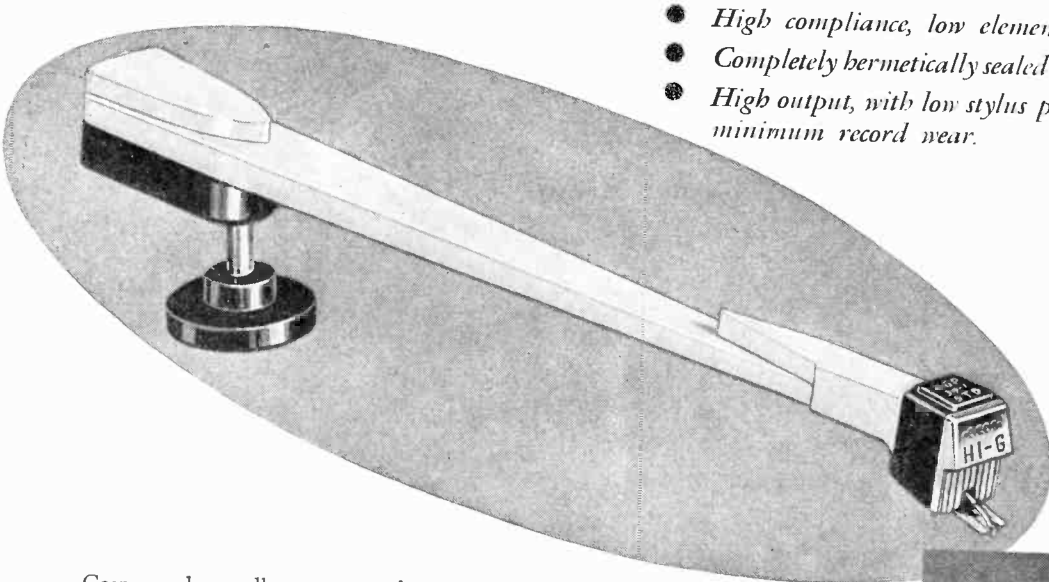

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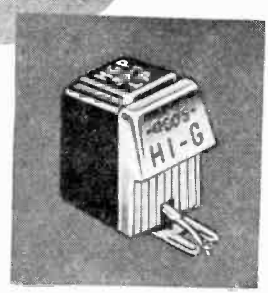

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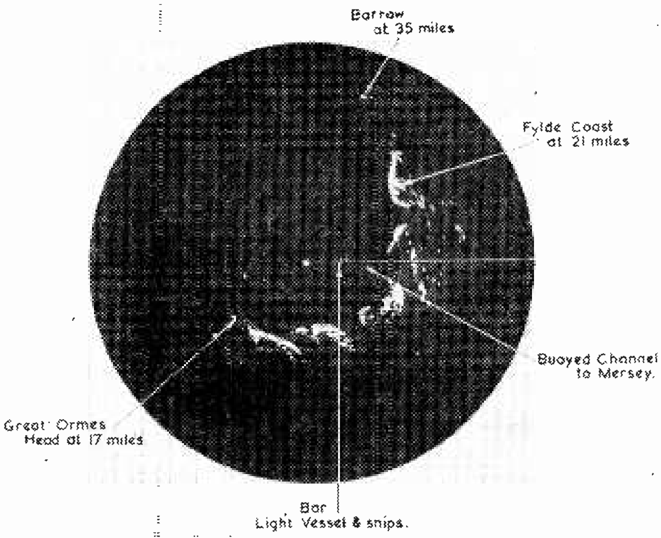
Long-Range Marine Radar

Features of the New Kelvin-Hughes Type 2C Equipment



Display showing responses on the 50-mile range from a vessel bound for Liverpool.

NORMALLY, marine radar sets are provided with a maximum range of 25 miles, which covers all targets within the ship's horizon. On some trade routes it is an advantage in hazy weather to get an early fix from high land which is "visible" to the radar at much greater distances, and to meet this demand Kelvin and Hughes (Marine), 99, Fenchurch Street, London, E.C.3, have produced an equipment with a 50-mile scale in addition to those normally available.

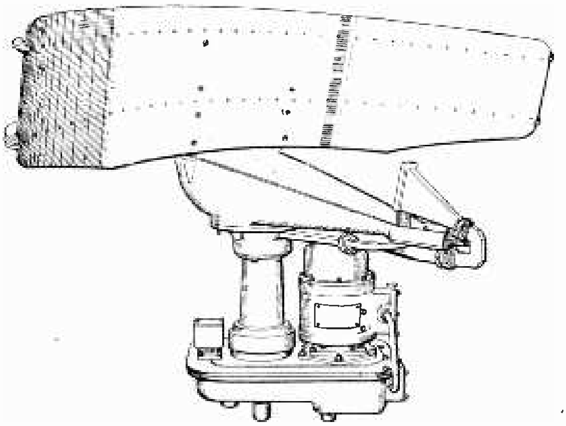
Increased power in the transmitted pulse is necessary, as well as the highest possible receiver sensitivity, in order to make the 50-mile range effective, and in the Type 2C the peak power is 60 kW with a pulse width of 0.2 μsec. The accompanying photograph shows that the waveguide "plumbing" has been cleaned up and now gives a straight outlet, and the layout has been sectionalized in "book" form giving ready access to components for servicing.

Another feature of this new model is the aerial system, which is of parabolic cylindrical form, and is fed on the focal line from a horn termination on the waveguide.* The reflector is tilted forward so that the horn feed is removed from the main reflected beam, with a consequent reduction of interference and side-lobe generation in the polar diagram of the aerial.

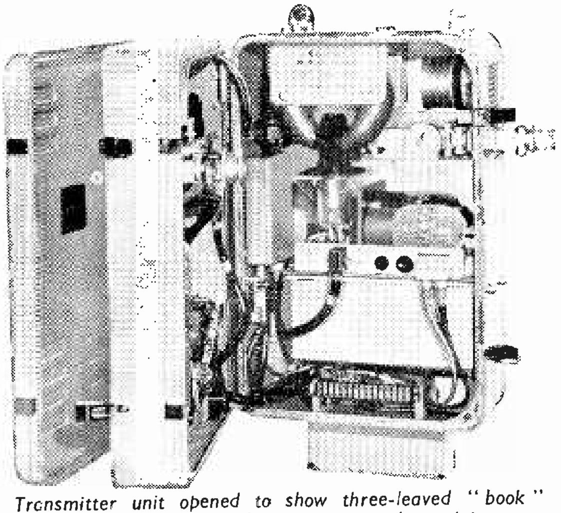
The display unit, which incorporates all the principal controls, uses a 12-in cathode-ray tube. In addition to an adjustable range calibration ring, fixed concentric rings can be superimposed at intervals of 8 miles on the 50-mile range, 4 miles on the 25-mile range, 2 miles on the 10-mile range and ½-mile on the 1-5 mile range. The last is continuously variable, so that the optimum range can be chosen for pilotage in congested waters. Range discrimination and minimum range are 40 yards, while the bearing discrimination claimed is 1.3 degrees.

Monitoring is effected by a cavity-resonator of high-Q, mounted aft in the blind angle formed by the masts and funnels. This resonator "rings" and gives a narrow lobe-like response on the display, the length of which is a measure of the overall efficiency of the equipment, and so gives early warning of any incipient faults.

The price of the new Type 2C long-range equipment is £2,200.



Tilted parabolic cylindrical reflector in the scanner gives an increased gain and reduction of side lobes in the polar diagram by removal of the feed horn from the main axis of the beam.



Transmitter unit opened to show three-leaved "book" construction for ease of inspection and servicing.

A Valve Megohmmeter

The Measurement of Resistance Up to More Than a Million Megohms

By M. G. SCROGGIE, B.Sc., M.I.E.E.

IN a previous article* some of the special precautions necessary when measuring very high resistances were explained, expecially the guard-ring technique. Details of an instrument suitable for measuring such resistances will now be given. It is assumed that the desired range of resistance extends from one megohm to one million or perhaps even ten million megohms—a range that opens up a new and fascinating field of study to any one hitherto equipped only with the ordinary type of ohmmeter or bridge. More over the instrument is a valve voltmeter with exceptionally high input resistance and therefore suitable for very-low-current or " open-circuit " investigations.

Nearly all ohmmeters are based on the principle of measuring the current flowing through the unknown resistance when a certain voltage is applied. The difficulty with very high resistances is the extreme smallness of the current. With 500 V applied to a million megohms it is one two-thousandth of a microamp. It is possible to buy a galvanometer sensitive enough to measure this, but such an instrument is expensive and delicate—what would happen if the thing being measured accidentally short-circuited does not bear thinking about—and involves a vibrationless mounting and optical accessories for projecting a moving spot of light, to say nothing of a shunt box to control the sensitivity. A cheaper and more convenient alternative is to measure the current as a voltage drop across a known standard resistance. Obviously the voltmeter ought not to shunt this standard resistance sufficiently to affect its value appreciably; in other words, it should pass negligible current compared with that flowing through the unknown. Assuming that d.c. is used, it might be supposed that a valve voltmeter would easily fulfil this requirement, for it is often stated that the d.c. input of a valve provided with suitable grid bias is negligible. And so it may be for most purposes, but not for this one. Supposing for the moment that the grid current is allowed to be 2% of the current used for the test (which is 0.0005 μA as suggested above) it would have to be limited to 0.00001 μA ($=10^{-11}$A). In general the grid current of a valve under working conditions is vastly greater than that.

Fig. 1 shows a simple method of measuring grid current. With S closed, adjust the grid bias to the proposed working point, observed by the anode microammeter; then open S, putting into circuit the high resistance R_g. To exclude any leakage other than via R_g, S is a clip lead and R_g is air mounted. It is also desirable to screen the grid lead and R_g from stray fields. Next, eliminate the resulting change in anode current by adjusting the grid bias; the amount of adjustment needed is equal to the voltage drop in R_g. Supposing for example, that R_g were 10,000 MΩ ($=10^{10}\Omega$) and the change is bias needed to restore the original anode current were -0.2 V, the grid current would be $-0.2/10^{10} = -2 \times 10^{-11}$ A.

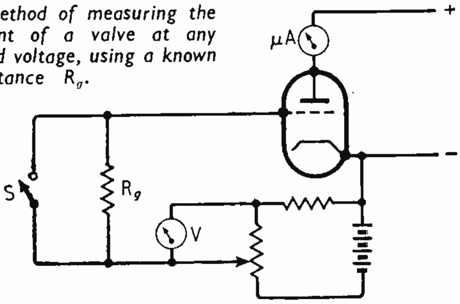
If the space between grid and cathode in the valve behaved as an ordinary ohmic resistance, the value of grid current thus measured and the value of grid bias at which it was measured would indicate the amount of that resistance, which could be allowed for when reckoning the effective value of the standard resistance. Fig. 2 however, which is a typical grid-current/grid-voltage graph, shows that it is nothing like an ohmic resistance (which of course would be represented by a straight line through the origin as shown dotted). This very non-linear characteristic is a combination of several distinct types of current. The peculiarity that a relatively large positive current flows when the voltage is zero is due to some of the electrons emitted from the hot cathode landing on the grid without any positive invitation and flowing back to the cathode via the external circuit. Something between one and two volts negative is needed to suppress this current completely, and the working bias must be not less. If it is more negative, a negative current flows; but instead of increasing with voltage it reaches a maximum not far from the cross-over point and then decreases. The reason is that most of this current is due to ions liberated by electrons on their way to the anode, and increasing negative bias reduces anode current and hence ionization. Other causes of negative grid current are internal and external leakage, and grid emission due to heat and light from the cathode and light from outside. In some types of valve, leakage from anode to grid may be serious.

Leakages are minimized by using a suitable type of valve. A top-cap grid connection is obviously a safeguard, but not absolutely essential if the valve is otherwise well insulated. The most important cause of current is then ionization, which can be tackled by reducing anode voltage and current to the lowest practicable. One type of valve in which grid current can be reduced to something like the right extent is the EF37 or EF37A, grid-current data for which have been given by K. D. E. Crawford**. It can be kept down to about 10^{-11} A by restricting anode voltage and current to below 50 V and 0.1 mA respectively, and in these circumstances it is allowable to reduce grid emission by running the heater at 4.5-5 V. Also the valve should be kept in the dark Not all samples of this type are equally suitable and some selecting may be necessary; or alternatively

* " Measuring High Resistance," *Wireless World*, June 1952, p. 236.

** " H.F. Pentodes in Electrometer Circuits," *Electronic Engineering*, July 1948, p. 227.

Fig. 1. Method of measuring the grid current of a valve at any desired grid voltage, using a known high resistance R_g.



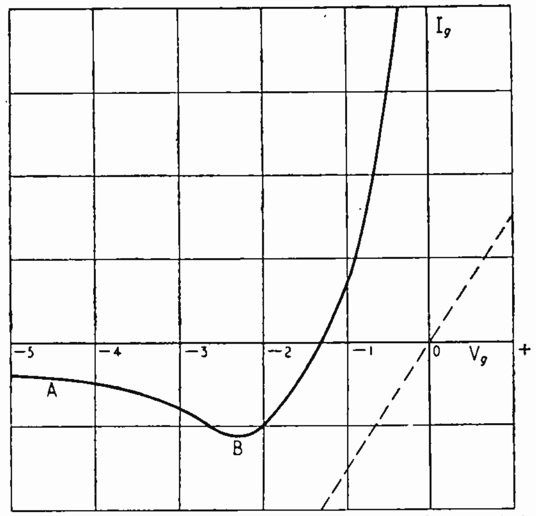
one may prefer to make sure of a grid current below 10^{-11} A by paying rather more for a ME1400 valve which is a special low-I_g version of the EF37A.

Fig. 2 shows that the grid current measured at any one bias voltage is not sufficient information to indicate the corresponding error in resistance measuring. In fact between A and B, where the working point is normally found, the grid-cathode resistance is negative. Instead of reducing the input voltage by its shunting effect, the valve would actually increase it. What happens is that when the grid voltage is made, say, less negative the resulting increase in anode current causes an increase in grid current, which flowing through R_g reduces the bias more, causing I_a to increase further, and so on. R_g has only to be sufficiently large and the system is unstable, so that the working point cannot stay on the negative slope AB but jumps straight to one end or the other.

Though the Fig. 1 method does not enable the grid-current error to be predicted, it does show how much the zero setting of the megohmmeter will be displaced by grid current, and, on the assumption that the greater the measured grid current the greater the error, it can be used for roughly comparing one valve with another. On the whole however it is better to test valves for grid current in the actual megohmmeter circuit.

With regard to that circuit: first, the tendency to instability can be nearly eliminated by using the valve as a cathode follower, because this keeps I_a much more nearly constant relative to V_g. In doing so, of course, it makes the changes in I_a more difficult to read directly, so a stage of current amplification is advisable. The general scheme thus turns out as in Fig. 3. The current passed by a known test voltage through the unknown resistance R_x is passed also through a known standard resistance R_s, and the resulting voltage drop is indicated by the two-valve voltmeter. For the sake of calibration stability the second valve (V_2) is also run as a cathode follower. The more sensitive the meter, the greater the resistance that can be used in series with it and the less the effect of changes in the characteristics of V_2, but the greater its cost. A 0-1 mA meter was chosen as a suitable compromise: the valve is then only about one-fifth of the total series resistance, and if the anode voltage is kept constant by stabilization the calibration drift is not likely to be appreciable for a long period of normal use.

To be precise, the full test voltage ought to be maintained across R_x alone, but as the standard British voltage for measuring insulation resistance is 500 and the input to V_1 need not be more than 5 V the error caused by not doing so is at most 1%. Moreover, the higher the value of R_s the more costly and inac-



Right: Fig. 2. Typical shape of grid current characteristic, compared with that of a linear resistance (dotted).

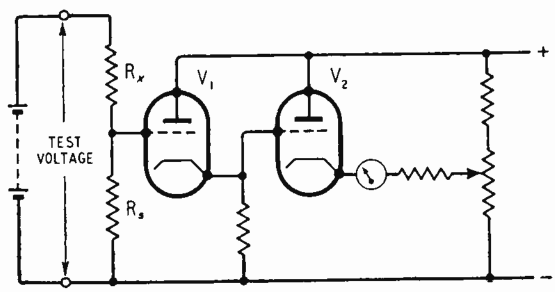


Fig. 3. General scheme of the megohmmeter described.

curate it is likely to be, and in any case the maximum value is limited by grid current. Experience with the EF37 class of valve suggests that there is no difficulty with 1,000 MΩ (1 kMΩ), across which a drop of 0.5 V is obtained through 10^{12} Ω (1 MMΩ); and with care the grid-current error need not be excessive even with 10 kMΩ, enabling at least rough measurements to be made up to 10 MMΩ. High-stability resistors of these values are obtainable, but if the price is to be reasonable a considerably wider tolerance than 1% will have to be accepted; 20%, say. Because resistances high enough to be measured therewith are likely to vary widely with the slightest changes in humidity, and for other reasons, there is not much point in attempting high absolute accuracy—in fact, above a few thousands of meghoms it is usually enough to determine the order of magnitude correctly—but the comparative accuracy is of course much better.

If the valves are set to give full-scale deflection with no input, and the test voltage is connected so as to make the grids more negative, then accidental excess input cannot over-deflect the meter; on the other hand, it is desirable to pass the least anode current through V_1—and thus have least grid current—when the highest resistances are being measured, and since meter protection is obtained by other means it was decided to use positive test voltage, which is more convenient in practice.

If the resistance being measured is shunted by capacitance—whether or not what is being tested is actually a capacitor—this capacitance causes any fluctuations in test voltage to be applied in almost full measure to the grid of V_1. Fluctuations of one or two volts, which would be quite harmless if reduced in the ratio R_x/R_s, thus become intolerable, and as such fluctuation is only a fraction of 1 % of the whole test voltage it is clear that if the voltage is derived from the mains it must be stabilized. Extensive smoothing is not a solution, because it can be shown that its time constant would have to be large compared with that of R_s in conjunction with the capacitance across R_x, and that is likely to be impracticable. Moreover a slowed-down drift of the reading is even more troublesome than rapid fluctuations.

The stabilizing system, shown in the full circuit diagram (Fig. 4), is conventional in principle,*** and serves not only the test voltage source but also the valve voltmeter, the anode supply for which is taken from across the stabilizer tube V_5. The total current does not exceed 8 mA, so comes within the ability of the 16HT series of metal rectifiers. The only disadvantage of a metal rectifier here is that it has no time delay, so during the warming-up period the valve V_4 has to bear an anode voltage of the order of 900. Any risk attaching to this unorthodox practice could be avoided by using a slow-heating valve rectifier, but no reasonable type rated to include 770 V, 8 mA output appears to be available. No trouble has actually been experienced with V_4, which can be almost any old medium triode one happens to have left over from the days when plain single triodes were the mainstay of the valve list; but it would be prudent not to pick on one with a high g_m in relation to heater current, achieved by reducing electrode clearances as much as the designer dared. Another reason for avoiding a small heater wattage will appear presently. A μ of about 20–35 is suitable.

Since the cathodes of V_2 and V_3 differ less than 100 V in potential these valves can be a double triode, but with a cathode at + 500 V V_4 needs a separate heater supply. An ordinary 350-0-350 receiver transformer does all that is needful—the h.t. winding provides about 740 V end-to-end at this load current, and its rectifier heater winding is available for V_4—but if its unnecessary size and weight are embarrassing a special transformer suitable in the alternative half-wave rectifier circuit shown, can be obtained from the Majestic Winding Co., 180 Windham Road, Bournemouth.

V_5 can be a Mullard 85A1 or 85A2 or Osram QS83/3, but these are unnecessarily precise for the job, and the Mullard 90C1 or 7475 or Osram ST11 are suitable. The main thing—which should be checked by noting that there is no jerkiness in the meter reading as the input to V_1 is varied steadily through its full range—is that there are no "steps" within the working range of current caused by sudden redistribution of glow. The value of resistance in series has been chosen so that of the total of about 6 mA V_5 takes about 2 mA at zero reading. As the reading increases, V_2 takes more current at the expense of V_5: if too much of the test voltage reaches the grid terminal, the meter current is limited to little more than this 2 mA; after which V_5 goes out and the stabilizer begins to reduce the test voltage. If "+ H.T." is dead-shorted to "GRID," the meter reading may actually be *less* than full-scale: this is a very comforting thought. Risk to V_1 and V_2 is excluded by series grid resistors, and risk to the metal rectifier and the operator by 1 MΩ (R_1) is series with the test voltage. This means that 1 MΩ must be deducted from the reading, but it confers the advantage that there is no definite lower limit to the range of measurement—all that happens is that below about 1 MΩ the accuracy of reading begins to fall off steadily. The anode voltage to V_1 is reduced to 45–50 V by means of a potential divider.

For some purposes a test voltage of 500 may be too high, so it is convenient to be able to switch over to the voltage across V_5. With the high-stability types this is usually between the limits 83–86 V, and the 90C1 86–94, but the 7475 or ST11 may be anything from about 88 to 105, so if one is lucky enough to get one running at 100 it is very convenient for

*** "Stabilized Power Supplies," *Wireless World*, Oct., Nov. and Dec. 1948.

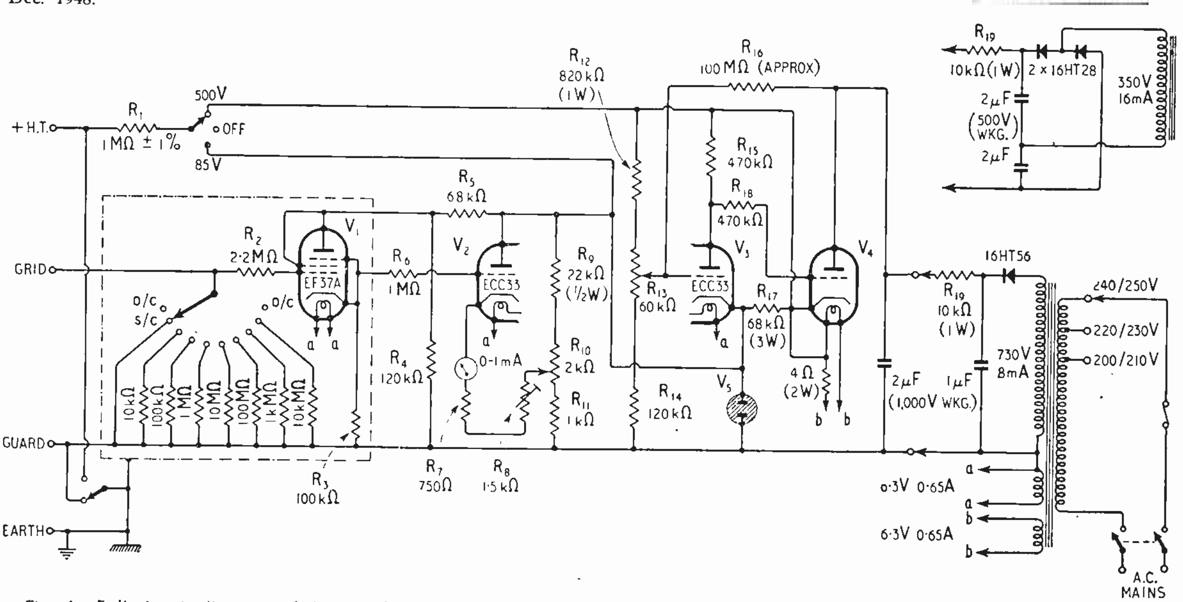


Fig. 4. Full circuit diagram of the megohmmeter. An old-type triode, as explained in the text, may be the most suitable for V_4.

calculation. The possible error due to drop across R_s is of course greater than with 500 V, but for most purposes still tolerable (and in any case can be corrected). A considerable discrepancy between the values obtained for R_x with the different test voltages is not necessarily a cause for despondency; it is quite usual for the resistance of semi-conductors to vary with voltage, contrary to Ohm's Law.

When checking the circuit operation it is advisable to begin with the power unit and stabilizer, temporarily substituting a 25-kΩ resistor for the valve-voltmeter portion. Using a high-resistance voltmeter direct to cathode of V_4, check that the test h.t. can be set by R_{13} to 500 V, with some margin for adjustment. Next, reduce the mains voltage from normal by 10 % and see that the h.t. remains practically constant. Very close stabilization can be obtained by adjusting R_{16}, which may be made by pencilling across between two terminals on a small strip of bakelite until the best results are obtained—a technique familiar to early practitioners in radio. If meanwhile the system behaves in a manner that appears to contradict basic electrical principles the explanation is likely to be spurious oscillation, but with common-sense layout and R_{18} this ought not to occur.

The valve voltmeter should next be restored in place of the temporary load resistor, and R_8 and R_{10} adjusted alternately until with the "GRID" terminal at zero volts relative to "GUARD" the meter reads 0.1 mA and with +5 V it reads 1.0 mA. Fig. 5 shows two alternative methods for calibrating the meter in volts; in the second of these the 500 V and the 1 MΩ in series (R_1) must be reliable and the 0–10 kΩ is a decade box or the equivalent, and of course the range switch must be set to open-circuit. If there is room on the meter dial a resistance scale can be added, and the range switch marked with the factors by which the scale readings must be multiplied. It is wise to have a reminder on the panel that 1 MΩ must be deducted from the reading, if it is appreciable.

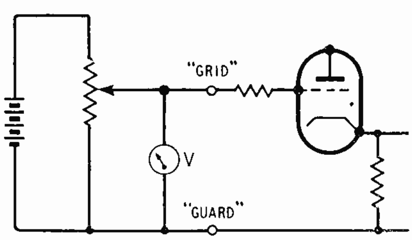
To guard against at least the less extreme onslaughts of load shedding and other occasions of low mains voltage, sufficient rectified voltage is provided to stand a 10 % reduction. In the original set-up, in which an EBC33 was used for V_4, it was found that 10 % reduction in voltage from the h.t. winding alone had negligible effect; 10 % reduction in heater voltages alone reduced the "zero" deflection of the meter slightly, and when this was adjusted by R_{10} the calibration was correct; but 10 % reduction in both caused the stabilization to fail and the calibration to be upset. This situation was overcome by slightly over-running the heater of V_4 at normal mains voltage, but it was rightly judged that if a valve with a more substantial heater was used it would not arise at all, and an old Tungsram HL4+ has proved entirely satisfactory. Low mains voltage is indicated by displacement of the meter zero, and when this is adjusted the calibration is practically correct.

At this stage it is a good idea to check the maximum possible meter overload by temporarily substituting a higher-range milliameter and increasing the input voltage indefinitely.

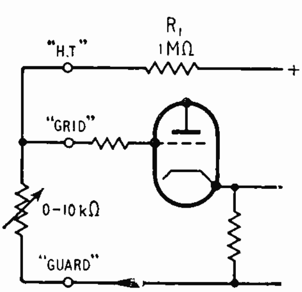
Lastly the input circuit. Obviously special care must be taken to keep the leakage resistance from the grid lead of V_1 large compared with the highest standard resistance. The only places (apart from the valve itself) where there need be any leakage at all are the input terminal and the range switch. The original instrument failed on the top two ranges, and this was traced to a ceramic stand-off terminal that looked impressive but was found to be too conductive. At that juncture Belling & Lee came to the rescue with two new types of terminal specially made for this kind of job; the smaller, with a resistance of 3.6 million megohms, is quite good enough, and there is a larger one with 20 million megohms. The switch is more difficult; but an ordinary ceramic type was found to have a resistance from moving contact and one fixed contact to all other contacts and metal parts of about 180 kMΩ, and this was considered just about tolerable in relation to the highest R_s—10 kMΩ ± 20 %.

To check that the error due to grid current and switch leakage is small enough, the input voltage calibration process (Fig. 5) should be repeated with the highest standard resistance inserted in *series* with the grid as in Fig. 1. This test is equivalent to the unpractical one of checking the calibration by means of an accurately known 0-10 MMΩ variable resistance between "+H.T." and "GRID" terminals, with R_s (max.) in its normal position (see Appendix). This is so, even although the valve is a non-ohmic resistance. First of all the test should be done with the range switch disconnected from the grid, so as to confine attention to the valve. R_s is first shorted by a clip lead, and the meter zero set with zero input. If R_s is 10 kMΩ the zero is likely to shift slightly when it is unshorted. If the shift is more than slight, the excess may be due to stray field. V_1 and its grid lead should always be screened. The screening having been checked, any remaining zero shift is presumed to be due to grid current, and if the valve is reasonably good should certainly be less than 0.3 V. The magnitude of the shift is not necessarily a measure of the error it imposes on readings, for, as already explained, the grid current is usually relatively constant over the range of input voltage, and when the zero has been reset the error should be quite small. If not, try another valve.

Next, connect the switch and set it to the highest range; the resistor for that range will not be present, of course, for it has been placed in series with the



(a)



(b)

Fig. 5. Two alternative methods of calibrating the megohmmeter.

calibrating voltage, and the only effect of connecting the switch is to shunt its leakage resistance across the valve input (Fig. 6). Repeat the previous test, noting the effect on the calibration of unshorting R_s. It may well be that both zero shift and calibration error are less than before, because of the positive leakage resistance offsetting the negative valve input resistance. If however the error at first is distressingly large there is no need to lose heart. Leave the instrument on for about half an hour, or longer in damp weather, preferably in its box so as to raise the temperature throughout, and the story may be quite different. (Whenever the instrument is used on its upper ranges, and especially after it has been out of use for some time and has not been kept in a dry warm place, it is essential to have it on for perhaps an hour or so beforehand). If after all precautions the

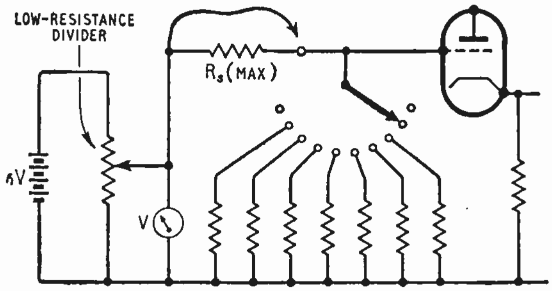


Fig. 6. Adaptation of the Fig. 1 method, for measuring the influence of grid current and switch and " GRID " terminal leakage on any range, especially the highest. Note that the appropriate range resistor is removed from its position in the switch and placed in series.

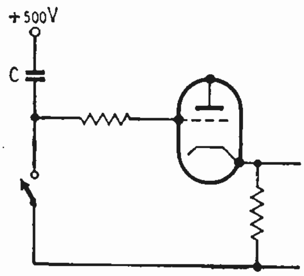


Fig. 7. Alternative method of measuring input resistance and checking calibration.

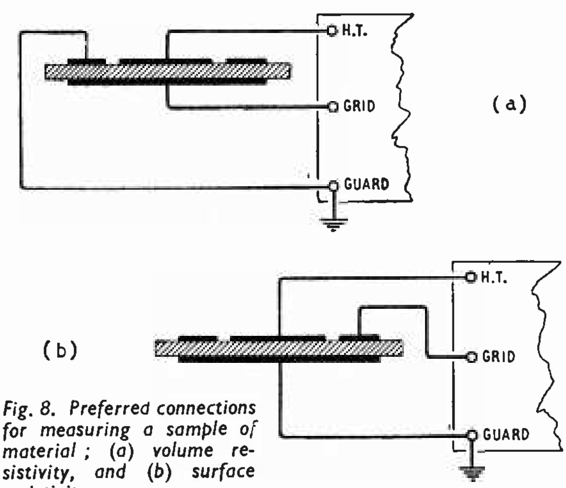


Fig. 8. Preferred connections for measuring a sample of material; (a) volume resistivity, and (b) surface resistivity.

leakage error on the top range when tested as just described much exceeds 10% it may be necessary to clean the switch with methylated spirit.

The method used to measure the switch leakage resistance may be of interest, as it affords an additional means of checking the megohmmeter calibration on the upper ranges. Provided that a capacitor with really high leakage resistance can be found, it is extremely simple. The capacitor is connected as shown in Fig. 7, the grid being short-circuited for obvious reasons. When the short circuit is removed the capacitor discharges through its own leakage and the grid potential slowly rises. There is no other leakage except that due to the valve, which should previously have been found to be satisfactory. The rise in voltage should be practically linear with time and quite slow if the capacitor is a good one. Since a charge often takes some while to " soak in," the test should be repeated until consistent results are obtained. A 4,000-V 0.01-μF capacitor was found to discharge at 15 seconds per volt; and since this initial discharge rate, if maintained, would completely discharge it in CR seconds, R in this case is indicated as 750 kMΩ. With the appropriate switch leakage paths connected across the capacitor the rate quickened to 2.9 secs per volt, indicating 145 kMΩ for the combination, and therefore 180 kMΩ for the switch.

In measuring very high resistances the question of guarding usually arises, as explained in the earlier article. It will be noticed that the instrument as a whole is insulated from earth, so that either positive (+H.T.) or negative (GUARD) terminal can be earthed. If the resistance to be measured (R_x) has one terminal earthed, then that terminal should be connected to " +H.T." and it must not be forgotten that " GUARD " is 500 V below earth. Leakage resistance between the negative side of the instrument and earth, together with any leakage between the earthed end of R_x and " GUARD " comes across the h.t. supply, and unless excessive should be harmless. Leakage between the other end of R_x and " GUARD " comes across R_s, and care should be taken to see that its resistance is large compared with the R_s in use. If neither end of R_x is earthed, " GUARD " should be earthed, and the end of R_x having the higher leakage resistance to this point should be connected to " GRID," in the hope that it will be large compared with R_s and that the leakage resistance from the other end to earth will not be so low as to cause trouble when connected across the h.t. As an example, Fig. 8(a) shows how to connect a sample of insulating material for measuring volume resistivity. Compared with the connections shown in the earlier article, the " +H.T. " and " GRID " connections have been interchanged, because in exceptional cases in which surface resistance is relatively low the resistance of the short path between upper electrode and guard ring may be low enough to shunt the appropriate R_s appreciably and cause a misleadingly high volume resistivity to be indicated. The surface resistivity connections shown in Fig. 8(b) are the same as previously; as mentioned then, this measurement is of little value unless it is possible to control ambient humidity.

The following British Standards specify in detail the procedure for tests of this nature, except that a sensitive galvanometer is shown in place of this valve instrument:

BS488: 1948 *Moulded Insulating Materials for General Electrical Purposes.*

BS771 : 1948 *Synthetic Resin (Phenolic) Moulding Materials.*

BS903 : 1950 *Methods of Testing Vulcanized Rubber.*

A standard practice is to take the reading after the h.t. has been applied for one minute. It need hardly be mentioned that until the h.t. has been switched on, the range switch should be at the short circuit position to which position it should be returned after taking the reading. On the upper ranges the instrument is very sensitive to small changes in capacitance to grid, and one's hands should be kept well away while taking a reading.

APPENDIX

Validity of method shown in Fig. 6 for measuring megohmmeter error due to input current.

In Fig. 9(a), V_t is the h.t. voltage, normally 500; V_1 is the input voltage that would exist if leakage and grid current were nil; V_2 is the actual input voltage, the non-linear input resistance being denoted by R_i.

Then $V_1 = V_tR_s/(R_x+R_s)$; but since in the instrument described, with $V_t = 500$, R_s is never more than 1% of R_x it can be neglected in comparison, and $V_1 \simeq V_tR_s/R_x$. On the same basis,

$$V_2 \simeq V_t \frac{R_sR_i}{R_x(R_s+R_i)}$$

To set up the voltage V_1 at the input, using the circuit Fig. 9(b)—which is essentially the same as Fig. 6—with

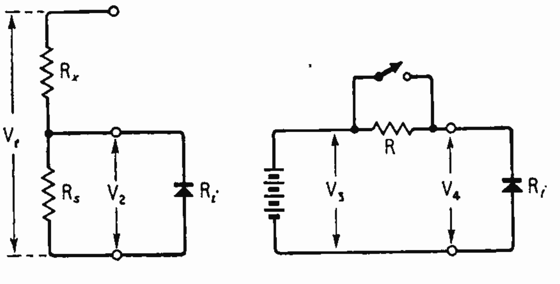


Fig. 9. Theoretical representation of input conditions, with (a) ohmmeter circuit, and (b) calibration circuit (Fig. 6).

the switch closed, V_3 must be made equal to V_1, and if this is taken as V_tR_s/R_x then

$$V_4 = V_t \frac{R_sR_i}{R_x(R_s+R_i)}$$

Except for the negligible difference already mentioned, this is the same as V_2, and therefore the value of R_i—even if considerably non-linear—is the same in both cases, and the Fig. 6 calibration circuit correctly simulates the effect of leakage and grid current in the ohmmeter circuit, but without actually having to provide a known very high-valued resistance R_x.

If the instrument zero is reset on any range that has a perceptible zero error due to R_i, the effective error at any scale reading is the *difference* between the error measured at that reading and the error measured at zero.

SWISS RADIO SHOW

International Exhibition of Broadcast Receivers and Sound Reproducing Equipment

By G. H. RUSSELL, Assoc. Brit.I.R.E.*

THE twenty-fifth Swiss radio exhibition was held in the Kongresshaus Building, overlooking the lake, in the city of Zürich, from August 29th until September 5th. This year, the exhibition coincided with the commencement of regular transmissions from the first television transmitter in Switzerland. This is situated on high ground at Uetliberg, a few miles from Zürich. The transmissions are broadcast on European channel 3, using the C.C.I.R. standard of 625 lines, with a power of 5 kW.

As Switzerland manufactures only a small proportion of her electronic needs, a great deal has to be imported from abroad. The exhibition, therefore, tends to be of a far more international character than its equivalents elsewhere. Countries represented were Austria, Denmark, Germany, Great Britain and the United States of America, but the majority of the exhibits were of German origin.

Apart from radio and television sets, tape-recorders, amplifiers, measuring instruments, components, valves, aerials and gramophone records were displayed in abundant variety. Altogether, there were over fifty stands, many of them displaying goods from several manufacturers.

Television.—The main focus of interest was, quite naturally, on television. The majority of the receivers shown were tuneable over bands 1 and 3. All receivers were of the direct-viewing type, and tubes varied from 14 to 27 inches. British firms represented were Bush, Ferguson and Pye. Amongst the American exhibits were table and floor models with 21-in tubes by RCA, and a 27-in console model by Philco. From Germany there were 14-in, 17-in and 21-in receivers in great variety. One German "prestige" model contained a 21-in television receiver, all-wave radio, three-speed gramophone, tape-recorder, gramophone-record storage space and cocktail cabinet, all in one unit of truly massive proportions.

There did not appear to be anything revolutionary in the circuitry of these receivers. Some sets used continuous tuning, but the majority were switch tuned. Intercarrier sound was a very popular feature, but flywheel sync, on the other hand, was only used by a few of the manufacturers.

Sound Broadcasting.—Switzerland, being situated

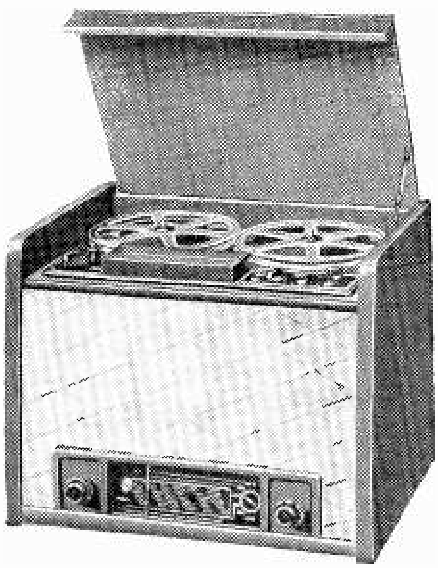
* Bush Radio, Limited.

in the centre of Europe and surrounded by large numbers of high-power stations, must of necessity use broadcast receivers which are highly selective. As there is only one station for each language group within Switzerland, a great deal of foreign listening is indulged in, which makes the selectivity of a receiver of even more importance than it might otherwise be.

One interesting method of coping with this selectivity problem is the "ferrite aerial," one example of which was shown by the Swiss firm of Sondyna. It consists of two lengths of Ferroxcube rod, on which are wound the medium- and long-wave aerial coils. These are screened in all directions but two. The whole unit is mounted well above the chassis on a rotating shaft, which is controlled by means of an external knob. Indication of orientation is given by a rotating device on the dial. Discrimination ratios of the order of 30 db and over are claimed for this aerial, not only against "off-beam" signals, but also against local electrical interference. It is further claimed that the directional properties of this aerial are far greater than can be obtained with a frame.

Because of the public desire for foreign listening, and because of propagation difficulties in such a mountainous country, wire broadcasting is extensively used. Until recently, this has been of the audio-frequency variety, but radio-frequency wire broadcasting is now coming increasingly into use. This provides at least three foreign stations, as well as two of the home programmes; the quality of reproduction is excellent. A channel spacing of 33 kc/s is used. A number of receivers were shown which make provision for the reception of these programmes, the bandwidth being automatically adjusted to take advantage of the improved frequency response.

The fact that one of the German f.m. stations is receivable in the German-speaking area of Switzerland has made the public there very v.h.f.-conscious. As nearly all German receivers incorporate a v.h.f. band as a matter of course, and as the medium and long wave selectivity of these receivers is adequate for Swiss needs, German radio tended to dominate the exhibition. A popular circuit line-up is: self-oscillating mixer, two i.f. amplifiers and ratio-detector. One Swiss firm showed an f.m. converter housed in a small wooden cabinet, the appearance being similar to that of an American midget receiver of pre-war days. Sondyna provide a v.h.f. adapter as an optional facility for their receivers. Permeability tuning is used, and this is operated by means of an eccentric drum attached to the receiver tuning spindle. The unit is built on a flat chassis, measuring about 4½in by 3½in, and is constructed so as to fit above the receiver tuning condenser. The valve line-up is: 6BK7, cascode r.f. stage; 6J6, mixer and oscillator; two 6BH6 i.f. amplifiers and 6AL5 ratio detector. It is claimed that full limiting takes place with an input of 30 μV. The ratio detector seems to have become a standard part of these f.m. receivers, and, with it, an intermediate frequency of 10.7 Mc/s.

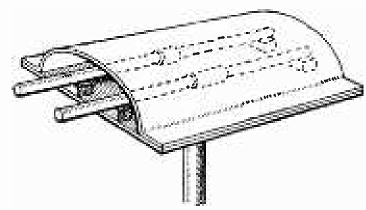


Three-band radio receiver, provision for receiving wire-distributed programmes and a tape recorder are combined in this Swiss domestic sound unit, made by Revox and costing about £130.

Radio-gramophones were all provided with two or three-speed motors, and crystal pickups were universally employed.

Tape Recorders.—A great variety of tape recorders were displayed, including the British Ferrograph model. The Swiss firm of Revox showed their recorder housed in what can best be described as, a table radiogram cabinet, complete with radio and "wired wireless" receivers. Another Swiss manufacturer, Perfectone, demonstrated recorders which included the following features: twin-track recording with automatic track-change-over at the end of the reel, providing two hours continuous playing time, automatic stop at the end of the reel; automatic stop in the event of tape breakage; and instantaneous track-change-over at any point.

Test Gear and Components.—Among the test instruments shown were a wide selection from Advance Components and some of the Marconi Instruments range. American and German instruments were strongly represented. One of the General Radio exhibits was a very compact absorption wavemeter covering the range 250 to 1,200 Mc/s without switching. From the Danish company Radiometer was an f.m./a.m. standard signal generator with a frequency



Ferrite-rod directional aerial for two-band reception.

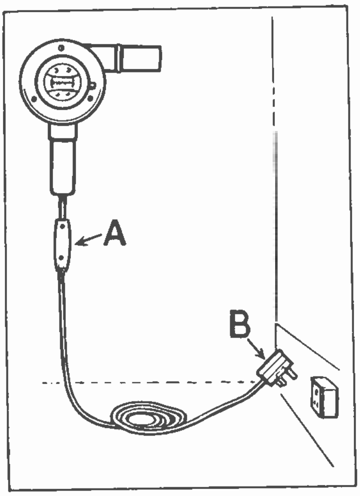
coverage of 54 to 216 Mc/s, with variable deviation from 0 to 300 kc/s. A piston attenuator is used and the output voltage reading is claimed to be 10% ± 1 μV. Frequency calibration is claimed to be within 0.5% of the dial reading. An additional instrument which converts the above signal generator to the range 100 kc/s to 55 Mc/s is available. These two instruments together, therefore, provide a continuous f.m./a.m. signal source ranging from 100 kc/s to 216 Mc/s.

In the components field, British products were reasonably well represented, but as far as could be ascertained, all aerials were of German manufacture. They were invariably of the 300-ohm folded dipole type, and some very imposing arrays were shown, such as a triple aerial system covering bands 1, 2 and 3, complete with reflectors and directors.

THE "BELLING-LEE" PAGE

Providing technical information, service and advice in relation to our products and the suppression of electrical interference

Split Suppression for T.V. Interference



Split suppression is the name given to a technique which is coming into more general use with the advent of TV flex lead suppressors.

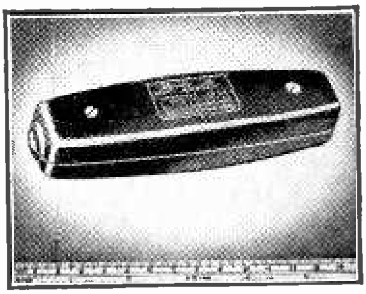
It implies suppression in two stages; TV suppression "A" at one point in the appliance, and broadcast frequency suppression "B" at another.

It is well known that a suppressor must be fitted near the appliance to be effective; this is particularly important at TV frequencies, and if for any reason a TV suppressor has to be fitted in a flex lead, it must be within a few inches of the appliance. See "A." At broadcast frequencies some concessions to this can often be made, and provided that the flex is not too long, a broadcast frequency suppressor will work well at the mains outlet socket "B," possibly forming an integral part of the socket or plug. (There is much to be said for the latter arrangement, since this means that the appliance is suppressed when plugged into any socket.)

TV suppressors are inherently smaller than broadcast frequency suppressors, and "Split Suppression" takes advantage of this by providing a very compact TV suppressor "A" in the flex lead near the appliance, together with a suppressed mains plug "B" to take care of the long and medium wavebands. This is essentially an arrangement for the sake of convenience, and is of obvious value for appliances normally held in the hand, where a bulky suppressor would be a nuisance.

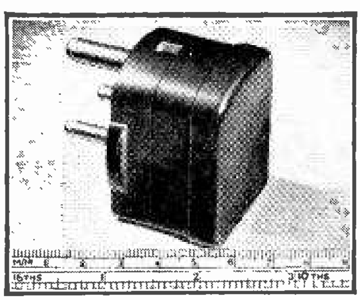
"Split Suppression" is therefore recommended for hairdryers, electric razors, electric drills, etc., with leads not greater than 6 feet. It is not suitable for vacuum cleaners and other appliances with long trailing flexes, but here a rather larger all-wave suppressor can be fixed to or near the appliance without causing inconvenience.

Electric sewing machines can be dealt with by either method.



Flex Lead Suppressor

L.799 is an Inductor and Capacitor suppressor indicated at "A" in sketch (see first column). The inductors are wound for 2 amp. To be effective at TV frequencies it must be fitted not further than 6 inches from the connectors of **the motor in the appliance.**



Plug Point Suppressor

L.1308 is the capacitor filter indicated at "B" in sketch. The capacitors are built into a 3 pin 5 amp. plug. Whilst the plug by itself provides ample suppression in most cases, on long and medium wavebands, it is only effective at TV frequencies when used in conjunction with L.799.

RADIO SHOW

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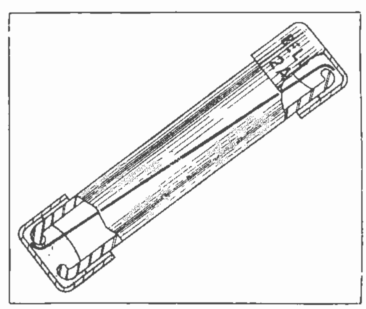
1. Fuse markings on caps are not lost.
2. Even extreme vibration cannot harm the element which is secured against breakage.
3. Hermetic sealing of the element against moisture and corrosion, prevents "perspiration" and sweating of the fuse.
4. Protection against rapid and extreme temperature changes—heat to cold and vice versa.
5. No external solder blobs on end caps—resulting in better end contact.
6. Strain relieved hard glass tube gives much greater strength and resistance to fracture on high current rupture.



7. More accurate dimensions and alignment and higher finish.
8. Element straight and more visible.

Written 30th September, 1953.

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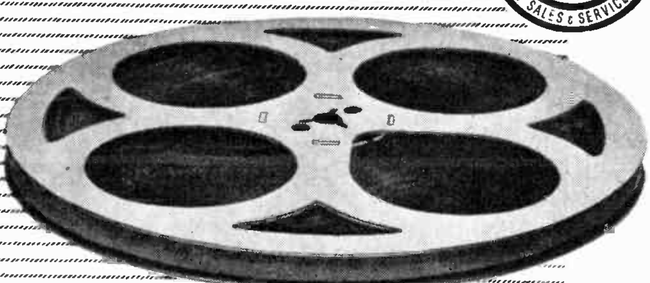

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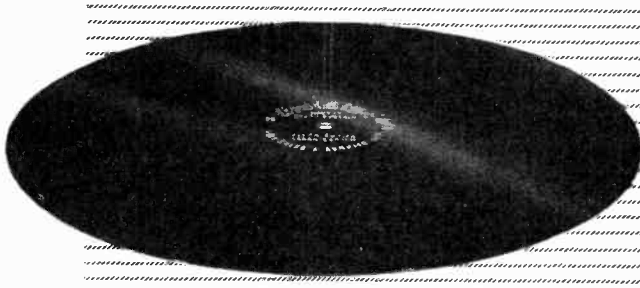

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Colour Television for Britain

Will a Compatible System be Too Difficult and Too Dear for Us?

THE Federal Communications Commission of the U.S.A. is now in the process of considering the proposed standards for colour television submitted to it earlier in the year by the National Television System Committee, a body representing most of the well-known American radio manufacturers. These standards are based on a system of compatible colour television (described on the following page) which has been devised more or less as a counterblast to the old non-compatible C.B.S. frame-sequential system. If the standards are accepted—and it seems fairly certain that they will be—it follows that this system will form the basis of design for all colour transmitting and receiving equipment in America.

At such an important point in the history of American development it is appropriate that some comment should come from this country about our own position. So far, the Television Advisory Committee has recommended that any future British system should be a compatible one. If this proposal is accepted by the Government it is probable that we shall adopt something similar to the N.T.S.C. system. There are, however, a good many problems that would have to be solved before such a system could be made suitable for use in Britain.

Critical Timing

Some of the limitations of the N.T.S.C. system that would make things difficult for us were discussed recently by F. C. McLean, Deputy Chief Engineer of the B.B.C., at a British Association meeting in Liverpool.* To begin with he placed a good deal of emphasis on the critical timing and phase relationships of the various components of the signal. It would be necessary, for example, to lock together the colour sub-carrier frequency, the line and frame frequency and the timing of any colour synchronizing signal. This would mean that the present practice of tying the line frequency to the mains frequency would have to be abandoned. From the transmitting point of view this would cause very little difficulty, but it might give trouble in some existing receivers which would be required to take a monochrome signal from the colour transmissions.

Referring to the distribution of the signal to the various transmitters, he pointed out that a system like the N.T.S.C.'s implies that "a very close tolerance must be maintained on the timing of the various carriers and pulses, and hence all parts of the transmission system must have a very small distortion in terms of amplitude and phase delay over the whole of the video band." Similarly the phase and amplitude distortion introduced by the transmitters themselves would have to be made negligible. All this would result in increased difficulty and cost.

Mr. McLean also thought that a simultaneous sub-carrier system might affect the range of transmitting stations by reducing the useful service areas within which satisfactory reception could be obtained. This limitation might be caused by differential fading or attenuation of the various components of the picture, and at distances of about 50 miles the colour information might be seriously distorted. To cover a given area would, therefore, require more transmitters and hence more channels. This could prove a serious matter for the establishment of a nation-wide colour service.

As for the question of our narrower channel widths in this country, he said it still remains to be decided whether all the colour information can be transmitted within the limitations of a 5-Mc/s channel, or whether such information will have to be sent outside in another channel.

On the subject of receivers, Mr. McLean said that there are likely to be some problems of even greater difficulty than those met by the N.T.S.C. in America. He pointed out, for example, that in this country the sound channel is amplitude modulated, so that separation of the colour sub-carrier might be more difficult than in the U.S.A. where the sound carrier is frequency modulated. Discussing the more general aspects, he said that a colour television receiver requires much greater stability of circuits, components and receiving conditions. We still do not know what effect any variations of these will have on faithful colour reproduction, since all receiving tests so far have been carried out under laboratory or restricted field-test conditions. Colour receivers would cost a good deal more than our present ones and their greater complexity would probably put up the servicing costs as well.

Interference Problems

One other problem which Mr. McLean did not mention but which has troubled a number of engineers is the possibility of the colour signal producing an interference pattern on the black-and-white picture. Although the N.T.S.C. system employs various tricks to reduce this effect it seems that they are not completely effective. It is felt, too, that the process of interlacing the sidebands of the monochrome and colour signals is not entirely foolproof because in practice there are sometimes large instantaneous peaks of energy occurring at frequencies outside the normal distributions and these can cause interference between the two signals.

These, no doubt, are some of the technical difficulties which Sir Ian Jacob, Director-General of the B.B.C., had in mind when he said that "neither here nor in America is there yet a system which has been developed to the point at which it can be confidently adopted."

* "The Application of Colour Television to Broadcasting", a paper read before Section G (Engineering) of the British Association.

American

Principles of the N.T.S.C.

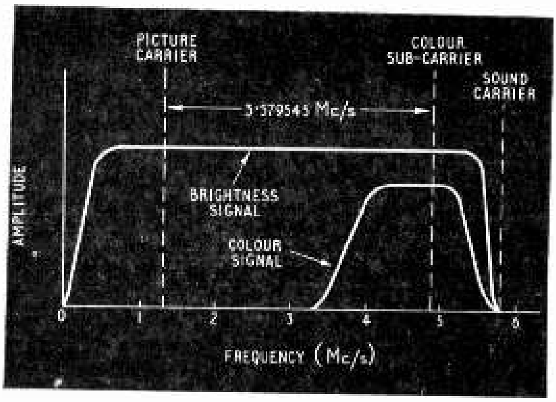
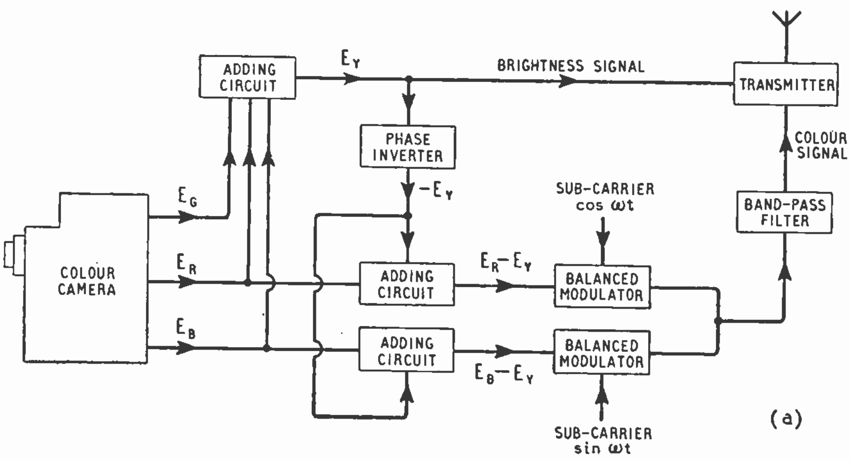


Fig. 1. Frequency characteristic of the N.T.S.C. colour transmission in its 6-Mc/s channel. The vestigial sideband system is used for both the picture carrier and the colour sub-carrier.

WHEN the National Television System Committee first set about the task of devising a colour television system for the United States they were faced with two main technical requirements. The first was that the system should be compatible, that is, the pictures should be receivable in black and white on existing receivers without any degradation from normal quality. The second was that the frequency band of the transmissions should be kept within the present American channel width of 6 Mc/s—in other words, all the vision information would have to be transmitted within a band of about 5 Mc/s. The system which has now been evolved satisfies first of all the compatibility requirement by taking the brightness information of the colour picture and transmitting it as a black and white picture which can be reproduced on existing receivers. The bandwidth requirement is satisfied by transmitting the colour information on a sub-carrier, of approximately 3.58 Mc/s, in such a way that the signal is kept within the normal vision band and yet does not interfere with the black and white picture. This is done by a process known as frequency interlacing. Fig. 1 shows the complete frequency characteristic of the transmission. Note that the vestigial sideband system is used and that the colour signal only occupies just over 1 Mc/s of the whole channel.

This idea of transmitting the picture in the form of two sets of information, brightness and colour, seems rather strange when one thinks of the classical method, evolved from colour photography, of transmitting it in terms of three colour components, usually the primary colours, red, green and blue. The reason for it is, of course, that a separate brightness component is needed to provide the normal black and white picture. It would be possible, of course, to transmit this brightness component in addition to the three colour components, but that would be very wasteful of bandwidth because the colour components would already contain the brightness information and it would be transmitted twice. In the N.T.S.C. system this duplication is avoided by removing the brightness information from the three colour components. The remaining colour information on the sub-carrier then consists of hue (e.g. red, brown, yellow, purple) and saturation (i.e. the extent by which the hue is pure and not diluted by white light).

This method of specifying a colour picture in terms of brightness, hue and saturation instead of in red, green and blue components is rather unfamiliar, but the relationships of the three quantities can be illustrated quite well graphically as in Fig. 2, using the well-known colour triangle. At the corners of the triangle are the three primary colours, while in between are the secondary colours produced by mixing them additively. In the middle, where all the colours are mixed, is pure white. With this arrangement two of the quantities can be represented by a vector rotating about the centre of the triangle. The angle of the vector specifies hue, while its length (or the distance away from white) gives saturation. The third quantity, brightness, can be represented by another vector perpendicular to the plane of the paper and passing through the centre of the triangle. Along the length of this vector the white in the centre gradually changes through grey to black, or zero brightness. Thus, while the picture is being transmitted the colour vector can be imagined as rotating to specify the hue and lengthening and shortening to specify the saturation. (This is, in fact, the way in which the actual electrical vector of the colour signal specifies the information—the hue modulates the phase angle of the sub-carrier and the saturation its amplitude.) At the same time, the perpendicular vector (not shown) can be imagined as lengthening and



Colour Television

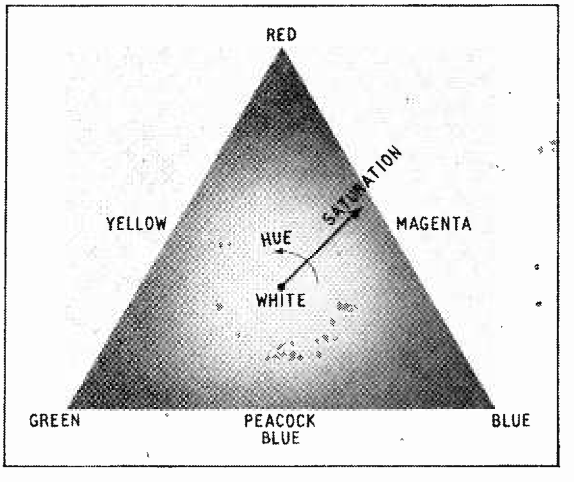
Simultaneous Compatible System

shortening according to the brightness information, and in this way it represents the normal amplitude modulation of the carrier. When there is no colour in the picture at all the rotating vector and the colour signal disappear completely.

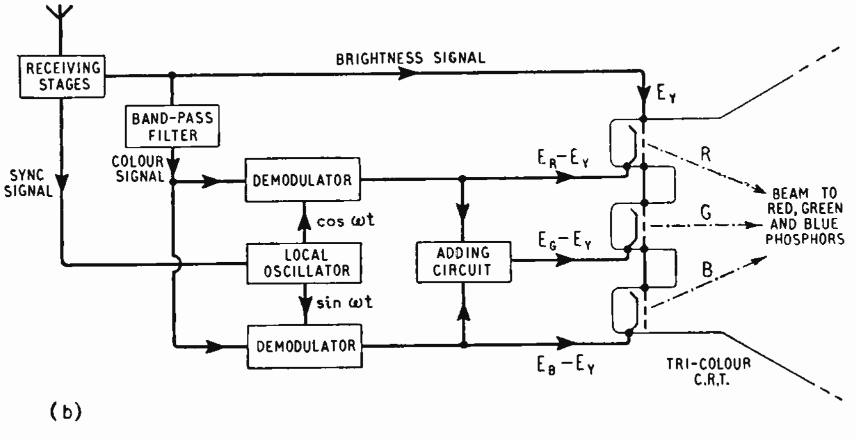
As well as subtracting the brightness information from the three colour components it is possible to make a further saving in colour-signal bandwidth by removing one of the colour components entirely. The reason for this is that all three components are already being transmitted in the form of white light by the brightness signal, so that if only two colour components are transmitted by the sub-carrier they can be subtracted from the brightness signal at the receiving end to recover the third one. Actually it is the green component that is removed and recovered in this way. Thus in Fig. 2 one can imagine the rotating colour vector as being restricted in movement to the right-hand side of the triangle and not having to go through the green corner at all.

Yet another reduction in the amount of colour information to be transmitted is made by taking advantage of certain characteristics of human vision. It is a well-known fact that the eye is insensitive to fine detail in colour and can only see it in black-and-white form. Obviously, then, there is no point in transmitting this fine detail on the colour signal as long as it is carried by the brightness signal. Thus the information-content of the colour signal can be very much smaller than that of the brightness signal and consequently its frequency band can be limited to something quite narrow—just over 1 Mc/s, in fact. This characteristic of human colour vision is, of course, a gradual thing. With slightly larger detail, for example, the eye still cannot distinguish between blue and yellow—they both appear grey—or between brown and crimson or blue and green, but it can between red and green. In the N.T.S.C. system, therefore, the bandwidth requirements of the transmitted colour components are graded accordingly. Those which can be distinguished in medium detail are given the full colour bandwidth of just over 1 Mc/s while those which can only be seen in broad areas are restricted to about 500 kc/s.

The broad functioning of the system can now be followed from the simplified block diagram Fig. 3. At the transmitting end (a) the colour camera analyses the picture and produces three signals representing the red, green and blue colour components, E_R E_G and E_B. These components are recombined in an adding circuit to produce the brightness signal, E_Y, or black-and-white picture, which is sent straight to the transmitter and radiated in the normal bandwidth. The red and blue components are also fed to two circuits where they are added to the signal $-E_Y$ produced by a phase inverter—in other words the redundant brightness component is subtracted from them, as explained above. (The green component is simply ignored as that is also redundant for reasons stated above.) The two resultant signals, E_R-E_Y and E_B-E_Y, now contain all the essential hue and saturation information that has to be modulated on the colour sub-carrier. As mentioned above, the hue information is conveyed by phase modulation and the saturation



Above: Fig. 2. Colour triangle with rotating vector representing the two quantities hue anr saturation. A second vectod representing brightness can be imagined as perpendicular to the plane of the paper and passing through the centre of the triangle.



Left: Fig. 3. Simplified block diagram of the system, with the transmitter at (a) and the receiver at (b). Note how the brightness signal (black and white picture) is shunted round the colour channel.

information by amplitude modulation. The actual method of doing this is to split the sub-carrier into two components, one leading the other in phase by 90°, and modulate the leading component with the E_R-E_Y signal and the lagging component with the E_B-E_Y signal, as shown by the vector diagram Fig. 4. The two parts are then recombined and the resultant vector in Fig. 4 represents the modulated sub-carrier as finally transmitted.

One can now see exactly how the hue and saturation are represented respectively by the angle (phase modulation) and length (amplitude modulation) of this resultant. The E_R and E_B colour-component signals from the camera vary in amplitude according to the hue of the picture, and as a result the two vectors E_R-E_Y and E_B-E_Y vary in length and produce corresponding changes in the phase angle of the resultant. Thus we have the angle of the electrical vector specifying the hue in much the same way as the rotation of the vector in Fig. 2 specifies it in graphical form. Similarly, the E_Y brightness component in Fig. 4 varies in amplitude according to the saturation of the hue, since it represents the amount of white-light dilution. This causes the lengths of E_R-E_Y and E_B-E_Y to vary and consequently the length of the resultant vector. Again, we have the electrical vector lengthening and shortening to specify saturation in the same way as the Fig. 2 graphical vector.

This process of modulating the two components of the sub-carrier is actually done by balanced modulators (Fig. 3) so that the sub-carrier itself is suppressed. The components are then combined and the complete colour signal is fed through a band-pass filter (giving the characteristic shown in Fig. 1) to the transmitter.

At the receiving end of the system (b) the carrier is demodulated and the whole signal is fed into the brightness channel; it is also applied to a band-pass filter which passes only the band containing the colour signal. The brightness signal then modulates all three grids of a tri-colour cathode-ray tube. In the colour channel the two modulating voltages E_R-E_Y

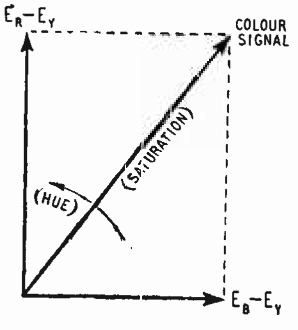


Fig. 4. Vector diagram showing how the two colour-difference signals modulate two components of the colour sub-carrier in quadrature. When these are combined (Fig. 3) the final colour signal is represented by the resultant vector, which carries hue information by phase modulation and saturation information by amplitude modulation.

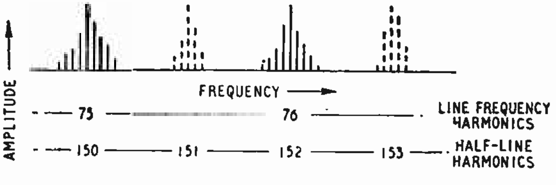


Fig. 5. Illustrating the technique of interlacing the monochrome and colour sidebands. The monochrome sidebands are shown as full lines and the interleaved colour sidebands as broken lines.

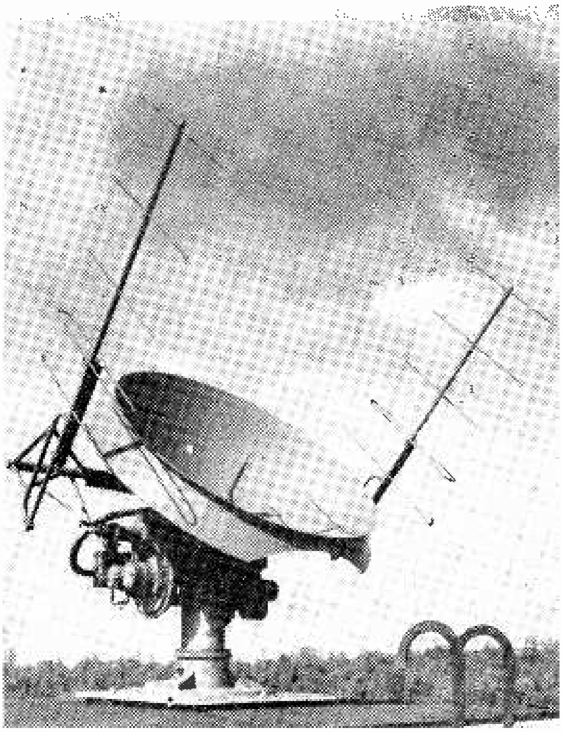
and E_B-E_Y are recovered from the colour signal by a process of synchronous detection. This involves heterodyning the incoming signal with two sine waves, each of which has the same frequency and phase as the desired component. Thus, the local oscillator producing these sine waves must be locked in phase to the colour sub-carrier, and for this purpose a synchronizing signal consisting of several cycles of sub-carrier frequency is transmitted during the back-porch period following each line sync pulse.

From the two colour-difference signals thus recovered the third one, E_G-E_Y, is derived by adding suitable fractions of them together. The three are then applied in a negative sense to the three cathodes of the tri-colour c.r. tube, and the E_Y brightness components that were subtracted at the transmitter are put back by the E_Y signal applied to the grids. In other words, the $-E_Y$ voltages at the cathodes become $+E_Y$ as a result of being applied in a negative direction, and as E_Y is fed to the grids in the same phase the two cancel out. This leaves E_R E_G and E_B, the original three colour-component signals, applied between the grids and cathodes of the tube. Thus, the three electron beams and the three sets of coloured phosphor elements on the screen are modulated according to the three output signals of the colour camera.

An ordinary monochrome receiver tuned to the transmission cannot, of course, do anything with the information on the colour sub-carrier, so it simply responds to the brightness signal and reproduces from this a black-and-white picture in the normal way.

It was mentioned earlier that the colour sub-carrier is transmitted in the same band as the brightness signal (Fig. 1), without interfering with it, by a process known as frequency interlacing. This principle takes advantage of the fact that the sideband frequencies of a television transmission tend to be grouped in clusters around harmonics of the line scan frequency, leaving open spaces in between. The idea, then, is to interleave the sideband clusters of the colour signal between the sideband clusters of the brightness signal, so that neither set interferes with the other, although they are all within the same band. This is done in the N.T.S.C. system by arranging the colour sub-carrier to lie exactly half way between two harmonics of the line frequency—in other words by making it an odd multiple of half the line frequency. The interlacing process then works out as shown in Fig. 5 at line and half-line frequency harmonics.

Although the colour signal does not interfere directly with the brightness signal it will nevertheless get into the vision channel of an ordinary receiver, so that one might expect it to appear as an interference pattern on the black-and-white picture. Actually it does not. The reason is that the intensity modulation of the c.r. tube beam by the colour signal reverses in phase along each line in successive picture periods—blacks become whites and whites become blacks. So, whereas the light modulation produced by the brightness signal is summated in time by the storage effect of the screen and the viewer's persistence of vision in the normal way, that produced by the colour signal tends to cancel out. In practice the cancellation is not complete because the light storage is not long enough. However, the visibility of the interference is kept to a minimum by making the colour sub-carrier frequency as high as possible (see Fig. 1), so that the pattern produced on the screen is a very fine one.



Radar Wind Measurement

New Meteorological Station Using the "Radar Sonde"

WHILE the main purpose of the balloon-borne radio sonde is to transmit meteorological data to the ground, it is also used nowadays for giving information on the speed and direction of the winds which carry it along. Hitherto the system has been to equip the sonde with a reflector and follow it about with a radar set on the ground. Changes in its range, bearing and elevation are then used to compute the required wind information. Unfortunately, this primary radar system is restricted in range to about 40 miles, so the latest step has been to use secondary radar, with a transponder instead of a reflector on the balloon. This increases the range to about 100 miles.

The original secondary radar system, or "radar sonde," was devised some years ago by T.R.E.* Now, an engineered version of it has been developed by Mullard and installed at a new meteorological station near Crawley in Sussex. A feature of this equipment is that it is completely automatic in operation. The radar aerial follows the course of the sonde automatically and gives range, bearing and elevation information from which the wind information is continuously com-

* "The Radar Sonde," *Wireless World*, April, 1951, p.155.

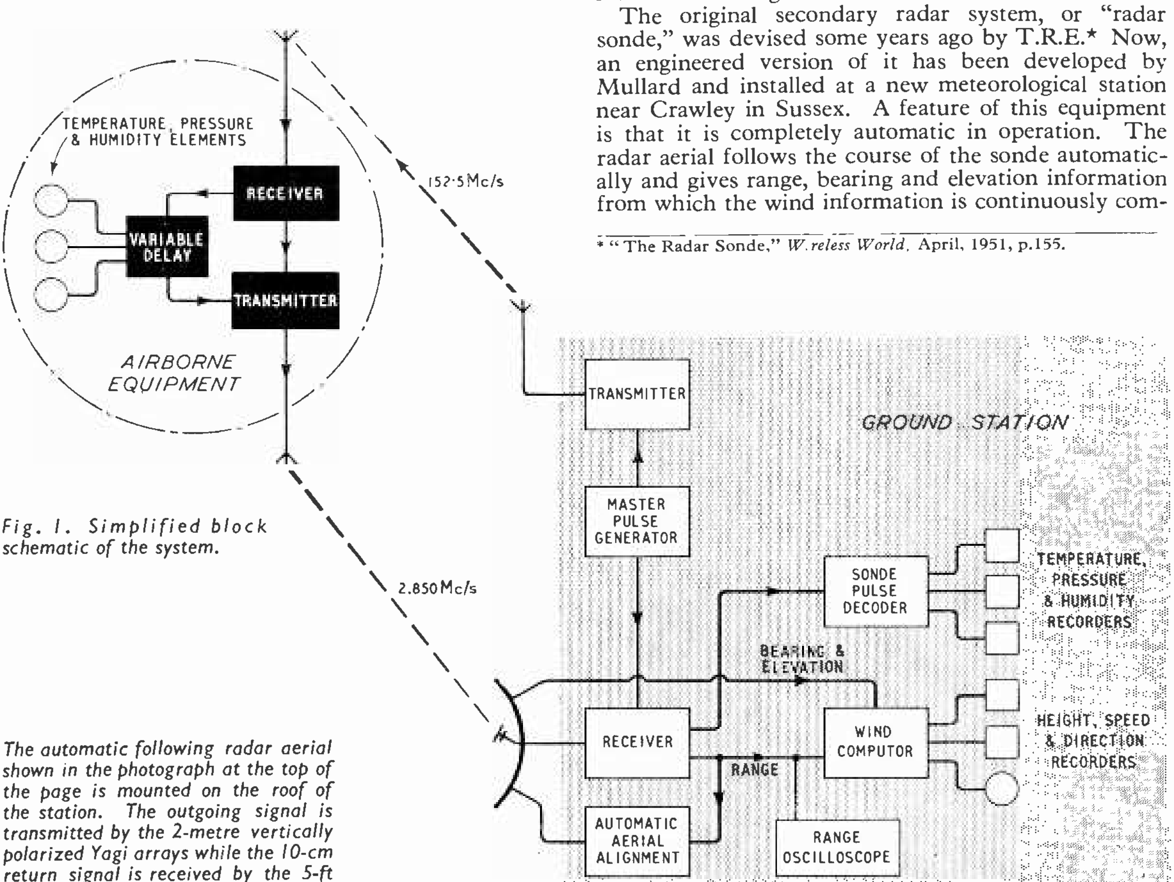
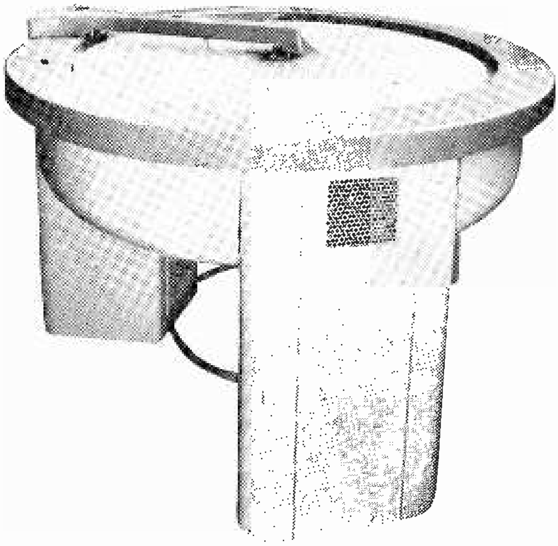
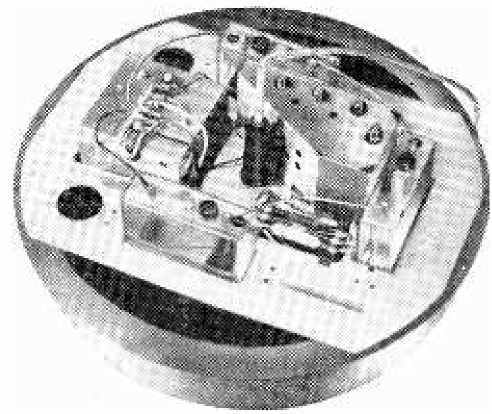


Fig. 1. Simplified block schematic of the system.

The automatic following radar aerial shown in the photograph at the top of the page is mounted on the roof of the station. The outgoing signal is transmitted by the 2-metre vertically polarized Yagi arrays while the 10-cm return signal is received by the 5-ft diameter paraboloid.



This unit houses the wind computor and carries the 4-ft diameter rotating polar chart which records the wind direction. A pen slowly traversing from the outside to the inside of the chart represents the time the sonde is in flight, while rotational movements of the chart represent changes in the wind direction with respect to the initial direction at launching.



An airborne unit with its cover removed. The miniaturized equipment is mounted in a light thermally insulating container and is suspended from the balloon by the quarter-wave receiving aerial. The transmitting aerial projects from the bottom. Power is supplied by 6.5-V batteries and h.t. is obtained by means of a vibrator.

puted and recorded. At the same time the straightforward telemetering of other meteorological data is done through the channel provided by the returning radar signals, and the results are presented continuously by pen recorders.

Fig. 1 is a simplified block schematic of the system. Pulses of 2 μsec duration are transmitted at a repetition rate of 404 per second with a peak power of 50 kW on a frequency of 152.5 Mc/s. They are received by the airborne transponder and arranged to trigger its 30-W transmitter, which sends back pulses on 2,850 Mc/s to the receiving paraboloid. The transit time of the pulses gives the range of the sonde and this information is displayed on a cathode ray tube and fed to the wind computor.

The system for keeping the receiving paraboloid continuously trained on the sonde makes use of a dipole which is offset from the axis of the reflector and rotates in such a way that the aerial beam traces out a cone in the sky. If the paraboloid is pointing in a slightly wrong direction and the sonde is to one side of the cone, the received signal fluctuates in strength as the beam swings around, at a frequency corresponding to the rotational speed of the dipole. The fluctuation frequency is then used as an error-signal to correct the alignment of the paraboloid. If the paraboloid is properly aligned and the sonde is exactly in the centre of the cone the signal strength remains constant and no error-signal is produced. From the positioning of the paraboloid the bearing and elevation of the sonde are obtained and the information is fed into the wind computor.

In the computor the speed and direction of the wind is derived from the rates of change of the range, bearing and elevation information. Wind direction is recorded on a polar chart, while speed and height (which is also computed) are registered on standard pen recorders.

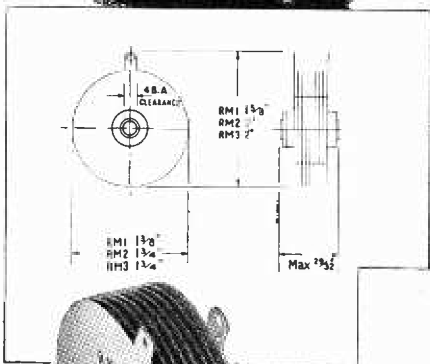
Some of the balloons which are sent up carry just a transponder for wind measurements only, while others have in addition meteorological elements for measuring temperature, pressure and humidity. The system for transmitting these additional measurements on the radar return signal makes use of a second pulse delayed slightly from the main one. The three meteorological elements are selected in sequence by a motor-driven switch and arranged to control the spacing between the two pulses. In the ground equipment the two pulses are used to trigger the front edge and the back edge of a square pulse, so that the duration of this square pulse represents the value of the meteorological measurement. An electronic chronometer then measures the duration of the pulse and gives the answer in the appropriate meteorological terms.

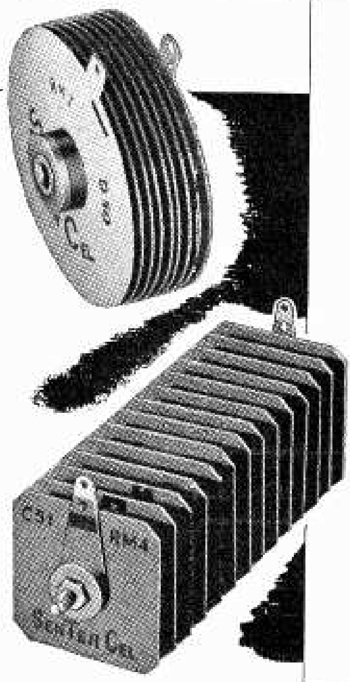
ULTRASONIC DRILL

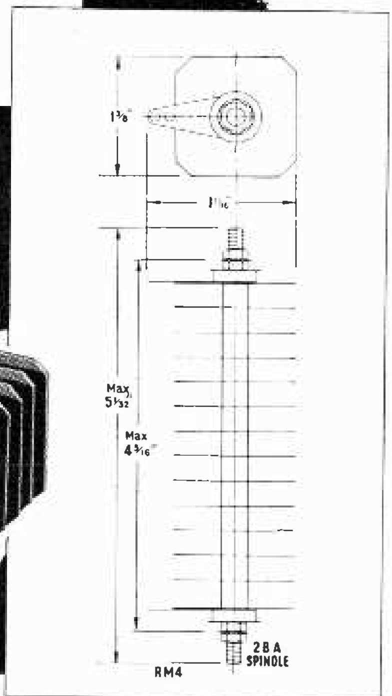
IN this experimental machine, made by Mullard and shown recently at the Institution of Electronics Manchester exhibition, vibrations at about 22 kc/s are generated by a magnetostriction transducer and transmitted to a drilling tip by a tapered metal stub, which acts as a velocity step-up transformer. The box on top contains an amplifier, which forms part of an oscillatory circuit with the magnetostriction device below. Rapid drilling and cutting of most brittle materials is possible when a paste of carbide abrasive is fed to the tip. The use of the machine was demonstrated recently in the television programme "Science Review."

10 advantages of SELENIUM SenTerCel RECTIFIERS miniature selenium rectifiers

REGISTERED TRADE MARK







Compare these outstanding features with those of the rectifiers which at present you are using :—

- Less wiring
- Unlimited instantaneous overload such as the charging current of de-formed electrolytic capacitors.
- Far lower heat dissipation.
- No "warming-up" period.
- No valve-holder.
- Practically indestructible in normal service.
- No limit to size of electrolytic capacitor.
- Saves weight.
- Saves space.
- Low in cost.

Study these **RATINGS**

TYPE	RM0	RM1	RM2	RM3	RM4
Maximum ambient temperature	35°C 55°C	35°C 55°C	35°C 55°C	35°C 55°C	35°C 40°C 55°C
Maximum output current (mean)	30mA 15mA	60mA 30mA	100mA 60mA	120mA 90mA	275mA 250mA 125mA
Maximum input voltage (r.m.s.)	125V	125V	125V	125V	250V
Maximum peak inverse voltage	350V	350V	350V	350V	700V
Max. instantaneous peak current	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
Weight	0.82 oz.	1 oz.	1.4 oz.	2 oz.	4.5 oz.

REGISTERED TRADE MARK
SELENIUM SenTerCel RECTIFIERS

Standard Telephones and Cables Limited

(Registered Office : Connaught House, Aldwych, W.C.2)

RECTIFIER DIVISION: Warwick Road, Boreham Wood, Hertfordshire.
Telephone : Elstree 2401 Telegrams: Sentercel, Borehamwood

LETTERS TO THE EDITOR

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

Ignition Interference in U.S.A.

IN his letter in the October issue, Malcolm S. Morse states that "in the U.S.A. our television sets operate in the midst of millions of motor cars, all unsuppressed, yet never have I seen a case of ignition interference or even heard of anyone troubled by it."

Mr. Morse must have been singularly fortunate in his choice of viewing sites. If he will refer to an American book published this year ("Principles of Television Servicing," by Carter V. Rabinoff and Magdalena E. Wolbrecht: McGraw-Hill) he will find that the authors have quite a bit to say about it on pp. 432-434. Indeed, they say "some years ago an appeal was made to the automobile industry by the F.C.C. to study and if possible develop ways and means of eliminating ignition interference. The industry has been and still is co-operating by extensive research along these lines."

In spite of Mr. Morse's remarks about "poorly designed British sets" the fact remains that it is not possible by any known means to suppress ignition interference at the television set, but it can be done easily and cheaply on the car itself. Certain measures to reduce the interference can be taken in the receiver, it is true, such as by using limiters. In spite of the sets being so "poorly designed," all current British sets include them. They are such a normal fitting that they are taken as a matter of course.

London, N.14. W. T. COCKING.

"Television Interference"

I WAS very interested to read the note on page 320 of your July issue on this subject, as I am one of the "suffering amateurs" operating on the 2-metre band.

Our particular trouble is caused by 2nd harmonics of local oscillators on about 72.5 Mc/s. They sound rough and unstable and some are weakly modulated, probably by a microphonic valve. Similar trouble has been reported by Scottish amateurs.

There are wider issues involved than interference to amateurs, which in all conscience is bad enough already. 72 Mc/s, the fundamental frequency, is used by business radio and certain users are, I understand, already being inconvenienced during TV hours. Our 2-metre band is shared with one of the armed forces, apparently, and whilst their stations are not at present likely to be troubled, an increase in this form of interference might give them cause for complaint. Another problem may arise when new TV channels open up, with the possibility of interference by higher-order harmonics, admittedly weaker but there all the same.

It seems to me that unless something is done now, things will get worse. I realize that TV receiver designers already have a lot to worry about, but in future I think they should give more attention to the "front end," making every effort to reduce unnecessary (and possibly illegal) radiation. This will apply also to converters, of course.

Until now, the v.h.f. bands, both commercial and amateur, have been fairly "clean" and free from the kinds of interference which plague the lower frequencies. Let us keep them that way!

Worthing, Sussex. R. B. FORGE (G3FRG).

Technical Qualifications

AS a holder of the City and Guilds Full Technological Certificate I have followed the correspondence regarding this qualification with a spectator's interest. However, the letter by M. L. Barton in your October issue provokes a reply. It might well have been written by a sworn enemy of the Institute—or a disappointed candidate!

The reference to the mathematics standard is accurate but unfair. Surely Mr. Barton does not think that Inter. B.Sc. maths. would equip one to sit the fourth and fifth year examinations in Telecommunication Principles? Whether specifically examined in mathematics or not, the C. and G. candidate has to reach the standard required to pass these examinations—which, like all advanced electrical papers, are exercises in higher mathematics.

The phrase "telecommunications as understood by Post Office engineers" is just trite nonsense. One imagines "Post Office" electrons rolling down the wire, painted engineer green and stamped G.P.O., while "Barton" electrons saunter along, varicoloured and with a look of independence. The Post Office has done as much work with super frequencies as any other large British organization—and the C. and G. fifth year syllabus is in a large part devoted to the technique of their use.

Mr. Barton finishes his letter with a backward somersault in supporting the Brit.I.R.E., apparently ignorant of the fact that this institution grants the holder of a full technological certificate complete exemption from the technical and maths. sections of its graduateship examination.

If these arguments are the best that can be advanced in criticism of the C. and G. Full Technological Certificate it is no surprise to me that the Ministry by which I am employed (Supply) recognizes the qualification. Might it not be that they, the Admiralty and the B.B.C. are the ones in step?

Farnborough, Hants. P. B. HAYES.

"Meter Overload Protection"

THE mechanical overload tests on microammeters described by J. de Gruchy (September issue) are liable to be misleading unless account is taken of the "transit time" of the meters concerned, a factor which depends not on meter damping alone, but also, in certain cases, on the load in which they are worked.

By transit time is meant the time the pointer takes, with current suddenly applied, to reach any steady reading up the scale, and, for a dead-beat condition, is independent of the magnitude of the deflection.

A normal microammeter of the type mentioned, if used in a high resistance circuit, will have a transit time of about one second. Subjected to a sudden overload of 250 times its full scale current, it will endeavour to maintain its transit time; i.e., the pointer tip will be given an acceleration such as to enable it to reach a point 250 times the scale length in one second. If the scale is 1.5 inches long, the distance it is attempting to travel is 1.5×250 inches per second, an average speed of more than 20 miles an hour!

The kinetic energy released at the top stop, and hence the damage done, will be lessened if the transit time is increased.

The transit time of a microammeter will begin to increase if the resistance of the circuit in which it is worked is taken below ten times its own internal resistance. Maximum transit time, which is considerably more than the open circuit value, occurs, as would be expected, at practically short-circuit conditions.

Therefore, a microammeter used heavily shunted, as, for instance, in a multi-range test set, will withstand more sudden actual meter current overload than one of the same type used in a high resistance circuit.

High Wycombe, Bucks. T. H. FRANCIS.

Lamp Interference

REFERRING to W. B. Mansell's statement in your August issue that gas-filled filament lamps are also responsible for generating interference, I have made a number of enquiries to find support for this view, but so far as I can determine from my friends and colleagues in the interference and lamp manufacturing fields there is every reason to believe that only vacuum lamps are responsible.

It is, however, a fact that, in the past, some few lamps labelled "gas filled" have in fact been vacuum, and have given rise to conflicting reports.

The lamps causing the majority of the trouble are 40-, 60- and 100-watt "rough service" types. The 15- and 25-watt vacuum lamps which are the only sizes normally available to the public are only responsible in rare cases.

Enfield, Middx. A. HALE.

I AM indebted to your correspondents for their helpful comments on the lamp interference problem raised in my letter published in your May issue.

They may be interested to know that the interference in question was ultimately traced to a vacuum lamp in my own home! It was, in fact, a 15-watt domestic type, purchased from a chain store, and was normally kept on all night in the children's bedroom. The interference, however, was not continuous during the time it was in use, but usually occurred some two or three hours after the lamp was switched on.

It appears that the oscillations arose as the result of a fault, since the lamp failed a week or so after the interference was first reported. Furthermore, they were probably mains-borne, because they were being generated inside a metal-clad pre-fab. which would undoubtedly be a big deterrent to direct radiation. The attenuation of incoming signals produced by these houses is sufficient, in this locality at least, to make portable receivers an impracticable proposition without an outdoor aerial.

Weymouth, Dorset. K. ROBINSON.

"*D.C. Restoration in Television*"

W. T. COCKING, in his article in your March issue, analyses the simple case where the resistor of the RC coupling is connected directly in parallel with the diode (his Fig. 6). He makes no mention of more modern arrangements where the resistor is no longer so connected. At the time I anticipated that there would be a further article discussing such circuits. Since none has been forthcoming, and since such an eminent authority as Donald Fink makes no mention of them in the 1952 edition of "Television Engineering," I have made it my business to examine several current receiver designs; in no case has the improved circuitry been applied. I feel therefore that these circuits may not be as widely known as I had imagined, and would like to draw attention to them.

Referring again to Fig. 6 of Mr. Cocking's article, it is apparent that the mean circuit flowing in R_2, the resistor in question, is a function of average picture brightness. This current can therefore vary, as Mr. Cocking points out, between very wide limits and, since the diode mean current must equal this current, the datum to which the sync pulse tips are "restored" will also vary with average picture brightness. This undesirable effect can be eliminated if we can maintain a constant current in the resistor.

One method which partially achieves this result is to connect the remote end of the resistor to a point of which the d.c. potential differs by a margin of several times the signal amplitude from the mean d.c. potential at the coupling. This is illustrated in my Figs. 1(*a*) and 1(*b*) for the two cases of negative-going and positive-going sync pulses. The potential V_A is chosen to give the desired range of signal excursion at the amplifier grid. V_B is a potential differing from V_A by an amount many times the amplitude of signal applied to C, being positive or negative to V_A, as required to cause the diode to conduct. It is obvious that the current in R (and in turn the diode current) is almost entirely dependent on the p.d. V_A-V_B and only to a small degree on the variations in signal applied. This gives a close approximation to the desired condition and much improved restoration results.

Another method of attack is to connect R to a point in the circuit where the same signal excursion exists as that applied to C. The p.d. across R must then be constant, making the current in it constant. The p.d. across R must again be in correct sense to cause the diode to conduct. One simple embodiment of this idea is shown in my Fig. 2(*a*) where R is connected in parallel with C; it can only be used when the p.d. across C is in the correct sense. The sync separator circuit illustrated in Mr. Cocking's article (Fig. 2) can be greatly improved by this method. This is shown in my Fig. 2(*b*), the grid cathode circuit of the valve forming the diode and R_2 and C_1 being connected to a source of signal positive to the cathode (via R_1).

In all these circuits, suitable values of C will be the same as those normally employed in restored coupling (say 0.1 to 0.5μF). R must, however, be very much larger, (10 to 22 megohms), and is chosen to give about the same average current in the diode as obtains in the simple circuit.

I must point out, however, that while these arrangements alleviate one defect of the d.c. restorer, they do not appreciably reduce the other defect discussed by Mr. Cocking—the variation in signal datum which occurs during the frame sync pulse.

Chelmsford, Essex. J. E. NIXON.

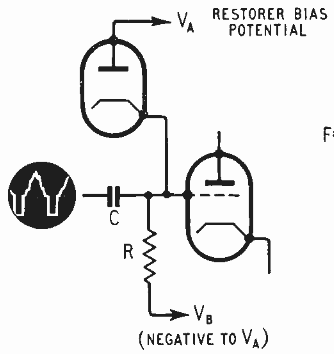


Fig. 1 (a)

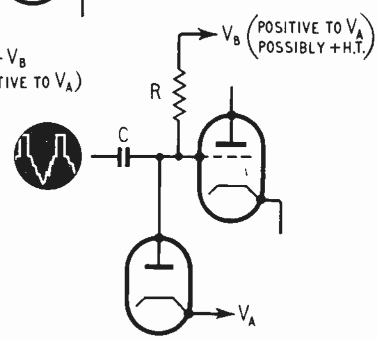


Fig. 1 (b)

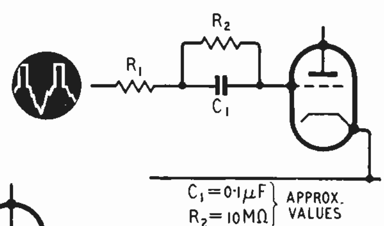


Fig. 2 (b)

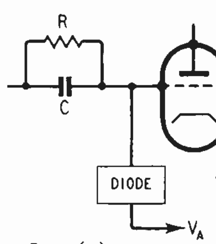
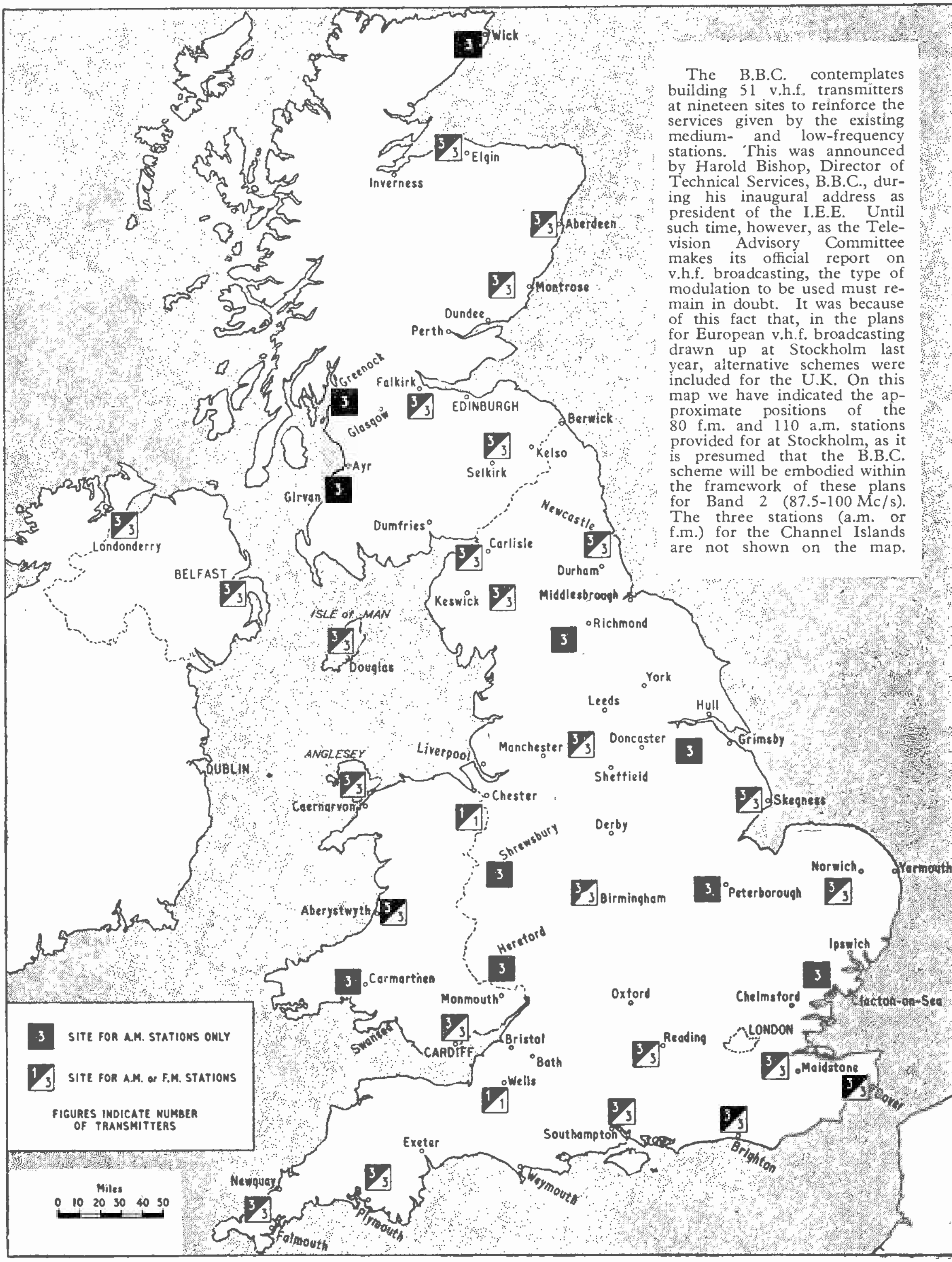


Fig. 2 (a)

V.H.F. Broadcasting: Plans for U.K.

The B.B.C. contemplates building 51 v.h.f. transmitters at nineteen sites to reinforce the services given by the existing medium- and low-frequency stations. This was announced by Harold Bishop, Director of Technical Services, B.B.C., during his inaugural address as president of the I.E.E. Until such time, however, as the Television Advisory Committee makes its official report on v.h.f. broadcasting, the type of modulation to be used must remain in doubt. It was because of this fact that, in the plans for European v.h.f. broadcasting drawn up at Stockholm last year, alternative schemes were included for the U.K. On this map we have indicated the approximate positions of the 80 f.m. and 110 a.m. stations provided for at Stockholm, as it is presumed that the B.B.C. scheme will be embodied within the framework of these plans for Band 2 (87.5-100 Mc/s). The three stations (a.m. or f.m.) for the Channel Islands are not shown on the map.



International Technical Questions

Summary of C.C.I.R. London Meeting

AFTER five weeks' deliberations the 7th Plenary Assembly of the International Radio Consultative Committee (C.C.I.R.) ended on October 7th. The C.C.I.R., which is one of the four permanent bodies of the International Telecommunication Union, is charged with the study of technical radio questions and operating questions of a technical character. To facilitate the study of the questions tabled at each plenary assembly fourteen study groups have been formed and it is the task of these international groups to consider and report on the findings of their national counterparts. A list of the British study groups and their chairmen was given in our September issue (p. 396).

Some 300 representatives from 41 countries participated in the meetings, the findings of which will eventually be published by the C.C.I.R.

During the Assembly's protracted deliberations in London, some three or four hundred documents were considered and a vast number of recommendations approved. At this stage we can do no more than summarize a few of the recommendations which will be submitted to the I.T.U., and some of the study programmes to be undertaken before the next plenary assembly (to be held in Warsaw in 1956).

The approved recommendations of the study group concerned with both sound and vision receivers cover questions of stability, selectivity and sensitivity. In the recommendation regarding receiver stability it is pointed out that in cases where economic considerations prevent the use of effective frequency stabilizing devices attention should be paid to the stability of inductors and capacitors and of the oscillator circuit (including the valve and its power supply). It also recommends the use of temperature compensating components. Tables giving the single-signal and two-signal selectivity characteristics of various classes of receiver (W/T, R/T, domestic broadcast and television) are included in the recommendation that uniform methods of measurement of receiver selectivity be adopted. The same study group has drawn up a programme of investigation into the methods of measuring and expressing the amplitudes of undesired emissions from sound and vision receivers and also of means of suppression. It also calls for a study of the question of the choice of intermediate frequencies.

Three study groups are concerned with propagation—tropospheric, ionospheric and ground wave, respectively. The outstanding subject so far as the ionospheric group was concerned was probably the question of atmospheric radio noise. Study programmes have been agreed upon and one recommendation calls for the setting up of a world network of lightning recorders. It is also proposed to produce a new set of noise curves which can be used internationally in place of the theoretical data at present used.

The 1947 Atlantic City Conference entrusted the C.C.I.R. with the task of studying the establishment of a world-wide standard-frequency and time service. A report on the services provided by the existing stations in Washington, Hawaii, Tokyo, Rugby, Johannesburg and Turin was adopted, together with recommendations for improving the service. The possibility of employing the two-independent-sideband method of transmission for the standard frequency service is to be studied.

Standards for magnetic-tape recording of programmes for international exchange were recommended and approved, although not unanimously. The recommended tape speed is 15 inches per second with alternative speeds of 30 and $7\frac{1}{2}$ in/sec. Single-track recording is recommended and standards are given for tape, spools, frequency response and recording heads. In view of the increasing interest in the interchange of filmed television programmes it has been agreed that an investigation should be undertaken to find out what method or methods should be used for the recording of the accompanying sound for TV programmes intended for international exchange.

Short-wave broadcast receiver manufacturers will soon have to include the 26-Mc/s band in the coverage of their sets if a resolution passed at the meeting is acted upon. This called for the use of this band for long-distance broadcasting because of the very low atmospheric noise intensity in that part of the spectrum.

The vocabulary study group recommended the abolition of all adjectives and superlatives in describing frequency bands and the substitution of numbers as given in the following table, which it is intended should take the place of the table in the Atlantic City Radio Regulations. The lower limit of the frequency range is excluded and the upper limit included in each case. The formula is: Band "N" extends from 0.3×10^N to 3×10^N c/s.

Band Number	Frequency Range	Metric subdivision
4	3 to 30 kc/s	Myriametric waves
5	30 to 300 kc/s	Kilometric waves
6	300 to 3,000 kc/s	Hectometric waves
7	3,000 to 30,000 kc/s	Decametric waves
8	30 to 300 Mc/s	Metric waves
9	300 to 3,000 Mc/s	Decimetric waves
10	3,000 to 30,000 Mc/s	Centimetric waves
11	30,000 to 300,000 Mc/s	Millimetric waves
12	300,000 to 3,000,000 Mc/s	Deci-millimetric waves

To facilitate the preparation by the International Telecommunication Union of an international list of telecommunication terms, definitions and symbols, the C.C.I.R. is to produce a "provisional list of terms and definitions peculiar to the work of the C.C.I.R." which, it is intended, shall serve as a basis for the radio-communications section of the proposed I.T.U. vocabulary.

WORLD OF WIRELESS

International Conferences ✦ Television and Amateur Shows ✦ R.I.C. Awards ✦ R.T.E.B. Exams.

European Broadcasting Conference

A SERIES OF MEETINGS of the European Broadcasting Union is being held at Monte Carlo from November 3rd to 14th. The main meeting is the 1953 General Assembly of the E.B.U., which will be held on the 13th and 14th. This will be preceded, as usual, by meetings of the Technical Committee, Legal Committee, Television Study Group and of the Administrative Council.

The Technical Committee, under its chairman, E. L. E. Pawley of the B.B.C., will review the activities of its various working parties and of the E.B.U. Technical Centre in Brussels for the past year and will fix the programme of work to be undertaken during the following twelve months. The working parties, which are composed of specialists of member organizations, have during the past year been considering indirect-ray propagation on medium-waves, unattended broadcast transmitting stations, the implementation of the Stockholm v.h.f. plans and the standardization of equipment and operational procedure in tape recording. It is possible that the Technical Committee will, in conjunction with the Television Study Group, also review the development of international television exchanges in Europe.

Interference : International Agreement

APPROXIMATELY 60 delegates from 18 countries and various international organizations attended the meeting of the International Special Committee on Radio Interference (C.I.S.P.R.), held in London in the middle of October. The chief aims of the committee are to obtain international agreement on limits which should be imposed on the production of "man-made" interference, methods of measurement and safety considerations involved in the use of suppressors on electrical appliances.

As a result of the meeting, agreement was reached on interference limits in respect of certain classes of electrical equipment. The general adoption of the recommendations made would considerably benefit international trade. At present exporting manufacturers are confronted with a variety of specifications

Among the items referred to national delegations for further study and consideration are: interference limits in the v.h.f. band; interference between receivers (from oscillator and line time-base circuits); interference from high-tension cables and from industrial, scientific and medical r.f. equipment.

TV Show

SOME 40 EXHIBITORS will be participating in the annual exhibition of the Television Society, which will be held from January 7th to 9th in the Electrical Department, King's College, Strand, London, W.C.2. The exhibition is not, of course, concerned only with domestic reception, but will also cover industrial television and television in research.

On the first day, the show will be open from 6.0-9.0 for members and the press only. On the second day it will be open at 12 noon and on the last day at 10.0, and will close on both days at 9.0. Admission will be by ticket obtainable from members of the society or the secretary, 164, Shaftesbury Avenue, London, W.C.2.

Amateur Radio Show

THE SEVENTH Annual Amateur Radio Exhibition, organized by the Radio Society of Great Britain, will be opened at the Royal Hotel, Woburn Place, London, W.C.1, at 12 noon on November 25th by Rene Klein, a founder-member and vice-president of the Society. Mr. Klein, who is now managing director of McMichael Radio, was instrumental in the founding of the Society as the London Wireless Club in 1913.

In addition to the equipment exhibited by manufacturers there will be a wide range of home-constructed gear and a display of amateur television equipment arranged by the British Amateur Television Club.

At the time of going to press the following will be exhibiting: Air Ministry, Avo, Cosmocord, Denco, G.E.C., David Godwin, Grundig, Panda Radio, Philpotts Metalworks, Salford, Siemens, *Short Wave Magazine*, *Telecraft* and *Wireless World*.

The exhibition will be open daily (11-9) until November 28th. Admission 1s.

B.B.C. Tuning Notes

OUR REFERENCE in the September issue (page 409) to the "B.B.C. 1,000-c/s tuning note (not the Third Programme 440 c/s)" was not strictly accurate. There is actually a 1,000-c/s tuning note for the Third Programme. It is radiated for five minutes before the ten-minute 440-c/s note which immediately precedes the opening of the Third Programme.

Incidentally, the degree of accuracy of the radiated audio frequencies has recently been improved and is now ± 5 parts in 10^8.

Writing Prizes

IT WILL be recalled that two years ago the Radio Industry Council launched a scheme to encourage, by the award of premiums, the writing and publication of technical articles to increase the prestige of the British radio industry. Last year five 25-guinea premiums were awarded and two additional £10 awards were made.

The panel of judges, which this year includes Dr. Willis Jackson (late Professor of Electrical Engineering, Imperial College), P. D. Canning, W. M. York, C. E. Strong and Vice-Admiral Dorling, will be meeting shortly to consider articles accepted for publication by journals on sale to the public between January and December this year. They should be submitted to the Secretary of the R.I.C., 59 Russell Square, London, W.C.1, by the author or editor not later than November 30th.

Do You Know?

HOW LONG should the radiator be for a dipole for the reception of the Wrotham v.h.f. transmissions?

Where does one apply for an amateur transmitting licence?

What are the base connections for an X81?

What is the value of a resistor coloured orange all over?

What is the address of the Television Society?

The answers to these and very many other questions can readily be given by the possessor of a 1954 *Wireless World* Diary which includes, in addition to the usual week-at-an-opening diary pages, an 80-page reference section.

The Diary is obtainable from booksellers and newsagents, price 5s 10d (morocco leather) or 4s 1d (rexine), including purchase tax.

Servicing Exam. Results

OF THE 309 ENTRANTS for the Radio Servicing Certificate Exam. in May, 126 (40 per cent) qualified for the certificate—including 30 candidates who passed the practical test only, having been referred last year. A further 87 candidates were successful in the written paper, but were referred in the practical tests. As mentioned last month, the next exam. will be held on May 4th and 6th for the written papers and May 15th for the practical test. The closing date for entries is February 1st.

The percentage of successes in the 1953 Television Servicing Certificate Exam. was higher than in the Radio Exam.—48 per cent. Of the 135 candidates, 64 were successful; including 24 who were referred in the practical test last year. Thirty-six passed in the written papers and may sit again next year for the practical test. The next exam. for the Television Servicing Certificate will be on May 10th and 12th and June 19th, for which the closing date for entries is January 15th.

Particulars and entry forms for both examinations are obtainable from the Radio Trades Examination Board, 9, Bedford Square, London, W.C.1.

PERSONALITIES

Professor F. C. Williams, of Manchester University, has been awarded the ninth Charles Vernon Boys Prize by the Physical Society in recognition of his "invention of the storage system for use in digital electronic computers." The award will be made at the Society's meeting at 5.0 on November 20th in the Lecture Theatre of the Science Museum, London, S.W.7, when Professor Williams will deliver a lecture on "Cathode-ray Tube Storage for Digital Electronic Computers."

Dennis McMullan, M.A., Ph.D., who for the past four years has been undertaking post-graduate research work at the Cambridge Engineering Laboratory, where he developed the scanning electron microscope, is going to Canada as head of the Simulator and Field Equipment Section of the Canadian Armament Research and Development Establishment in Quebec. He graduated from Cambridge in 1944 and went to Bush Radio under the Hankey scheme for the development of Services equipment. Dr. McMullan left Bush in 1946 and, before returning to Cambridge, was for two years with Cinema Television where he worked on high vacuum techniques and for a short while at Sperry Gyroscope designing analogue computors.

H. Walker, O.B.E., A.M.I.E.E., becomes Assistant Superintendent Engineer (Television Studios), B.B.C. He joined the engineering staff of the Corporation in 1931 and transferred to the Television Service in 1936. After war service in the R.A.F. in which he attained the rank of Wing Commander, he returned to the Television Service in 1945 and was appointed assistant engineer-in-charge at Alexandra Palace the following year. In 1950 he became engineer-in-charge of the London station and for the past eighteen months has been head of Technical Operations, Television Studios.

W. D. Richardson has been appointed Assistant Superintendent Engineer (Television Outside Broadcasts), B.B.C. He joined the B.B.C. as a maintenance engineer at Brookmans Park in 1930 and became senior maintenance engineer at Alexandra Palace in 1938. Throughout the war he served in the B.B.C.'s Planning and Installation Department and since 1946 has held various posts in the Television O.B. Department.

Wallace Rubin, B.Sc.(Hons.), Ph.D., who joined Multicore Solders a year ago, has been appointed chief chemist of the Research Laboratories in succession to Dr. P. M. Fisk, who has left after nine years' service with the company.

M. G. Hammett, M.I.E.E., A.M.I.Mech.E.,, who joined Murphy Radio as chief engineer of the Electronics Division at the beginning of September, held a similar position with E. K. Cole's Electronics Division at Malmesbury for some time. He has taken over responsibility for all electronic development and design at Murphy's works at Welwyn and Ruislip.

H. J. Leak, M.Brit.I.R.E., managing director of H. J. Leak & Company, went to the United States to attend the Audio Fair in New York (October 14th-17th) where the company's new products were demonstrated.

H. A. Hartley has gone to the United States to devote himself exclusively to the interests of his American company (H. A. Hartley Co. Inc., of 521, East 162nd Street, New York 51). The sole rights of manufacture and selling in the United States and its possessions are vested in the American company, but for the rest of the world these rights will remain with H. A. Hartley Co., Ltd., 152, Hammersmith Road, London, W.6.

OBITUARY

Allen Longstaff, who was for over 20 years the representative of Amalgamated Wireless (Australasia), Ltd., in London, died in Sydney, N.S.W., on September 19th. It was in 1925 that Mr. Longstaff first came to this country; he was then engaged in experiments being conducted preparatory to the establishment of the Anglo-Australian wireless telephone service. He attended the International Radiotelegraph Conference in Washington as A.W.A.'s representative in 1927 and immediately afterwards was appointed as European Representative of the company. He returned to Australia in 1946.

IN BRIEF

Broadcast Receiving Licences totalling 13,056,689 (including 2,539,103 for television and 196,161 for car radio sets) were current in Great Britain and Northern Ireland at the end of August. The number of television licences increased by 59,649 during the month.

Faraday Lecture.—This year's Faraday Lecture of the I.E.E. will be given by O. W. Humphreys, B.Sc., and will be entitled "Electric Process Heating—An Aid to Productivity." The lecture tour opens at Birmingham Town Hall on November 30th and continues at Leicester on December 3rd, Cardiff (February 1st), London (February 16th), Southampton (February 18th), Manchester (March 23rd), Liverpool (March 25th), Leeds (April 12th), Sheffield (April 14th), Newcastle (May 4th) and Glasgow (May 6th). Admission to the lectures is by ticket and application must be made to the honorary secretary of the I.E.E. Centre concerned, except in the case of London, when application must be made to Savoy Place, London, W.C.2.

Brit.I.R.E. Membership was 4,383 on March 31st—an increase of 365 on the previous year. This was recorded in the annual report given at the meeting on October 21st. In the course of the review of the past year it was stated that a report is being prepared on the use of primary materials in the radio industry. The first part will cover ceramics, constructional metals, magnetic materials and crystals.

Blind Operators.—Donations totalling nearly £540 were received at the Earls Court Radio Show by the United Appeal for the Blind (London) as a result of the demonstration of blind operators assembling components. It will be recalled that the demonstration was provided by Philips who employ about 20 blind operators at their Mitcham Works.

Trans-American Radio.—Radio equipment is being installed in the Sunbeam Alpine car which, with a caravan-trailer, is being driven from Alaska to the Strait of Magellan by a three-man team. The radio installation, which has been supplied by the British Communications Corporation, Ltd., Wembley, includes a 5-watt crystal-control transmitter for c.w. operation in the 20-40-metre amateur band. The operator, Marco McClintock, of Cleveland, Ohio, will use his own call W0DXT. The car will also carry v.h.f. transmitting and receiving equipment supplied by B.C.C.

Sponsored TV?—The organizers of the recent Nottingham Radio and Television Exhibition (the Nottingham Centre of the Radio and Television Retailers' Association) arranged for a series of commercial television programmes to be transmitted on a closed circuit to receivers in the main hall of the exhibition. The majority of the exhibitors at the show were local retailers.

"Old N'Ions."—The annual dinner and reunion of past students of the Northampton Engineering College, Clerkenwell, will be held on November 27th at the Connaught Rooms, Gt. Queen Street, London, W.C.2. Tickets are obtainable from A. F. Thompson, 10, Milborough Crescent, Lee, London, S.E.12.

"Navigation To-day," the exhibition being held at the Science Museum, South Kensington, will remain open until January 17th. It shows the various types of navigational instruments and equipment (including radar and other radio aids) used in navigation in the air, on land and at sea. The museum is open on week-days from 10 to 6 and on Sundays from 2.30 to 6. Admission is free.

C.C.I.R. BANQUET.—Delegates to the London meetings of the International Radio Consultative Committee (C.C.I.R.) were entertained by the Marconi Company at a dinner and dance at the Dorchester Hotel. Dr. Balth. van der Pol, director of the C.C.I.R., is on the right in this view of the head table. Sir George Nelson, chairman of the Marconi group of companies, is on the right of the microphone and H. Faulkner, who was chairman of the plenary assemblies, is next to him.

New Norfolk Transmitter.—As part of its plan to improve the coverage of the Home Service, the B.B.C. is building a new 2-kW transmitter at Hampstead, near Cromer, Norfolk. For technical reasons it will use the same wavelength and radiate the same programme as the Northern Home Service, 434 metres (692 kc/s). Its directional aerial will give a good service in the Sheringham, Cromer, North Walsham and Reepham area without affecting reception of the Moorside Edge transmissions in north-west Norfolk.

R.A.E. Reunion.—The first reunion of those who worked in the Wireless (10) Department of the Royal Aircraft Establishment, Farnborough, between 1922 and 1939, was held at Farnborough on September 25th. Dr. James Robinson, who was the first head of the department after it was moved from Biggin Hill, was the guest of honour. Others present included Air Commodore A. L. Gregory, the first serving R.A.F. Officer to take charge of the department, F. S. Barton (principal director of electronics research and development, M.o.S.) and Dr. J. S. McPetrie, present head of the R.A.E. Radio Department.

Marine I.F.F.—Development models of a device to ensure the identification of ships when seen on a radar p.p.i. are undergoing tests in the United States. The equipment has been devised by a committee of the American Radio Technical Commission for Marine Services to enable a port radar operator to know which of the numerous ships shown on the p.p.i. he is talking to.

Radio-control Equipment fitted in the target model aircraft exhibited by M.L. Aviation at the S.B.A.C. Exhibition (to which we referred on page 464 of our October issue) was made by Beme Electronic and Marine Equipments, Ltd., of Hythe, Hants. It was designed and developed under a M.o.S. contract.

R.A.M.A.C.—The thirteenth conference of the Radio Marine Associated Companies, which is an association of twenty-five marine radio operating companies in nineteen countries, was recently held in the London offices of the British member company—Marconi International Marine Communication. R.A.M.A.C. co-ordinates research and the exchange of technical information on marine radio communication and navigational aids among its members.

Fire !—The incidence of fires caused by television receivers decreased from 6.4 per 10,000 sets in 1947 to 1/10,000 in 1951. The incidence for sound receivers during the same period remained at approximately 1/40,000. These figures are given in "Fire Research, 1952," published by H.M.S.O. for the D.S.I.R., price 3s.

E.I.B.A. Ball.—The annual dinner and ball in aid of the Electrical Industries Benevolent Association will be held at Grosvenor House, Park Lane, London, W.1, on November 13th. Tickets, price 2½ guineas, are obtainable from the Association, 32, Old Burlington Street, London, W.1.

B.I.F.—Plans are already well advanced for the 1954 British Industries Fair, which will be held simultaneously in London and Birmingham from May 3rd-14th.

Non-ferrous Metals being used extensively in the radio industry, we draw readers' attention to the "Metal Industry Handbook and Directory, 1953," which is issued annually to subscribers to the weekly journal *Metal Industry*. A large section of the 456-page Handbook, which is in its 42nd year of publication, is devoted to general properties of metals and alloys, and there are sections covering standards and finishing processes and a directory of producers.

Plastics.—A 44-page booklet listing all the more important plastics materials produced in Great Britain has been prepared by the British Plastics Federation of 47-48, Piccadilly, London, W.1. Each of the 17 classifications of materials listed in the booklet is prefaced by a short note on its uses. The booklet, which is obtainable from the B.P.F. price 2s, also includes lists of manufacturers and trade names.

Association of Plastic Cable Makers has been formed with the objects of promoting and advancing the interests of the industry and the establishment of standards of quality for plastic cables. James, Edwards & Co., 381, Salisbury House, London Wall, London, E.C.2, have been appointed secretaries to the association.

BUSINESS NOTES

"Tape Deck."—In a recent case in the Chancery Division Truvox, Ltd., were the defendants in an action brought against them by Wright and Weaire, Ltd., concerning the use of the trade mark "Tape Deck." Judgment was given for Truvox, on the grounds that the plaintiffs had failed to proceed with their original case. We understand that as a result of these proceedings an application will be made to expunge the term "Tape Deck" from the Register of Trade Marks.

Switzerland has ordered from Marconi's a complete mobile television outside broadcasting unit comprising three image orthicon cameras and associated sound and vision equipment.

E.M.I. are to provide three complete Emitron mobile television microwave links to the Swiss Post Office for O.B. work. Switzerland recently started experimental transmissions from a station on the Uetliberg, near Zurich.

Valve Shrouds.—One of the two machines shown by Heenan and Froude, Ltd., of Worcester, at the recent European Machine Tools Exhibition in Brussels, was a strip-forming machine tooled for the manufacture of valve shrouds.

Hadley Sound Equipments, Ltd., of Smethwick, have advised us that the School Broadcasting Council has approved their new 5-watt amplifier with baffle-mounted loudspeaker as suitable for use in schools. The PR5 amplifier will, therefore, be added to the Council's "List of Approved Apparatus" to which we referred in our May issue.

International Aeradio, Ltd., are to provide and install radio and meteorological equipment at the Fiji Airways base, Nasouri, on the main island. Similar equipment will be installed at the other four airfields, Lambasa, Lautoka, Taveuni and Savu Savu. The company has also been given the contract by the

Government of Iraq for the provision of radio and radar engineering services and the establishment of an electronics training school in Baghdad.

Tanker Radio.—Six new 26,640-ton tankers on order for the Esso Petroleum Company are to be supplied with radio communication equipment and navigational aids by the Marconi International Marine Communication Company.

R.F. Dielectric Heater for the production from glued strips of wood of boards up to 80 × 40 × 2 inches thick has been produced by the General Electric Company and Fielding & Platt, Ltd. R.F. power for this edge-gluing machine, which incorporates a pneumatically operated press, is provided by a G.E.C. 25-kW r.f. generator.

Tannoy in Canada.—To facilitate the distribution and maintenance of Tannoy equipment in North America, Tannoy (Canada), Limited, has been formed with offices in Toronto. F. A. Towler, who was for many years sales manager in London, is the resident executive.

Nera of England, Limited, is the new name adopted by Aren (Radio and Television), Limited, of Jeffries Passage, High Street, Guildford, Surrey. In addition to producing projection television receivers and TV components, the company is manufacturing electronic instruments.

Gillon Electric, Limited, Rockstone Works, Rosemary Lane, Camberley, Surrey (Tel.: Camberley 481), has been formed by G. D. Gilbert and A. L. Leeson (until recently with Allen Components, Ltd.) for the manufacture of radio and television components.

Truvox-Rola-Celestion.—The sale, distribution and service of Rola and Celestion loudspeakers and Truvox p.a. loudspeakers will in future be undertaken by Rola Celestion, Ltd., and not, as hitherto, by Truvox. All enquiries, correspondence, orders and units for service should be addressed to Rola Celestion, Ltd., Thames Ditton, Surrey.

The Sales office of the **Aluminium Wire and Cable Company** is now at 30 Charles II Street, St. James' Square, London, S.W.1. (Tel.: Trafalgar 6441).

Dupley Electronics, Limited, makers of transformers and battery chargers, have moved from Ealing to Athlon Road, Manor Farm Road, Alperton, Wembley, Middlesex (Tel.: Perivale 9126).

Glasgow Branch of W. T. Henley's Telegraph Works Company is now at 149/153, North Street, Glasgow, C.3. (Tel.: Central 1771.)

Aerialite, Ltd., have increased their factory accommodation at Stalybridge, Cheshire, by an extension to the factory giving a further 20,000 square feet of floor space.

MEETINGS

Institution of Electrical Engineers

Discussion on "Safety Precautions in Electronic Apparatus, with Particular Reference to Medical Applications," opened by H. W. Swann and W. Grey Walter, M.A., Sc.D., at 5.30 on November 12th.

Radio Section.—"Some Aspects of the Design of V.H.F. Mobile Radio Systems" by E. P. Fairbairn, B.Sc., at 5.30 on November 11th.

"Loudspeaker Systems—Recent Trends in Design" by Major A. E. Falkus, B.Sc.(Eng.), at 5.30 on November 23rd.

Education Discussion Circle.—Discussion on "What are the Requirements of Electrical Engineering Textbooks?" opened by Instr.-Cdr. D. K. McCleery, M.Sc., at 6.0 on November 9th.

All the above meetings will take place at Savoy Place, London, W.C.2.

Cambridge Radio Group.—Address by J. A. Smale, B.Sc., chairman of the Radio Section, at 6.0 on November 3rd at the Cambridgeshire Technical College, Cambridge.

Mersey and North Wales Centre.—"Radio Telemetering" by J. Walsh, B.Sc., at 6.30 on November 2nd at the Liverpool Royal Institution, Colquitt Street, Liverpool.

"Telemetering for System Operation" by R. H. Dunn, B.Sc., and C. H. Chambers, at 6.30 on November 16th at the Town Hall, Chester.

North-Eastern Radio Group.—"A Method of Designing Transistor Trigger Circuits" by Prof. F. C. Williams, D.Sc., D.Phil., F.R.S., and G. B. Chaplin, M.Sc., at 6.15 on November 16th at King's College, Newcastle-upon-Tyne.

North-Western Radio Group.—"Some Aspects of the Design of V.H.F. Mobile Radio Systems" by E. P. Fairbairn, B.Sc., at 6.30 on November 25th at the Engineers' Club, Albert Square, Manchester.

North Scotland Sub-Centre.—"Electronic Telephone Exchanges" by T. H. Flowers, B.Sc., at 7.30 on November 11th at the Caledonian Hotel, Aberdeen, and at 7.0 on November 12th at the Royal Hotel, Dundee.

South-West Scotland Sub-Centre.—"Electrotechnical Ceramics—a Survey of Compositions, Manufacturing Methods and Properties" by W. G. Robinson, B.Sc.Tech., and E. C. Bloor, B.Sc., at 7.0 on November 4th at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2.

South Midlands Centre.—"Printed and Potted Electronic Circuits" by G. W. A. Dummer, and D. L. Johnston, B.Sc. (Eng.), at 7.15 on November 19th at the Winter Gardens Restaurant, Malvern.

Faraday Lecture "Process Heating" by O. W. Humphreys, B.Sc., at 6.0 on November 30th at the Town Hall, Birmingham.

South Midlands Radio Group.—"Printed and Potted Electronic Circuits" by G. W. A. Dummer and D. L. Johnston, B.Sc.(Eng.), at 6.0 on November 23rd at the James Watt Memorial Institute, Great Charles Street, Birmingham.

Reading District.—"Sound Recording" by G. F. Dutton, Ph.D., B.Sc.(Eng.), at 7.15 on November 30th at the George Hotel, Reading.

London Students' Section.—"Scanning Generators" by Lt. M. J. Wyatt and 2/Lt. P. D. Gibbons at 7.0 on November 10th at the R.E.M.E. Depot, Arborfield, Berks.

"Metallic Resistance at High Frequency" by A. D. Stevens at 7.0 on November 17th at the Public Library, Chelmsford. Essex.

British Institution of Radio Engineers

London Section.—"A High-Definition General-Purpose Radar" by J. W. Jenkins, J. H. Evans, G. A. G. Wallace and D. Chambers, B.Sc. (Cossor), at 6.30 on November 11th at the London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.

Scottish Section.—"Vibration Generators—Their Ancillary Equipment and Application" by H. Moore (Goodmans), at 7.0 on November 5th at the University, Edinburgh.

Merseyside Section.—"Multi-Channel Tuners for Television" by S. L. Fife and W. E. Hosey, B.Sc. (English Electric), at 7.0 on November 5th at the Merseyside and North Wales Electricity Centre, Whitechapel, Liverpool.

North-Eastern Section.—"Principles of Electronic Computing Machines" by Dr. B. V. Bowden (Manchester College of Technology), at 6.0 on November 11th at the Institution of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

West Midlands Section.—"Remote Control Devices and Servomechanisms" by A. E. W. Hibbitt (Muirhead), at 7.15 on November 24th at the Wolverhampton Technical College, Wulfruna Street, Wolverhampton.

Physical Society

"Some Magnetic Measurements—Techniques and Applications" by Prof. W. Sucksmith; and "Cathode Ray Tube Storage for Digital Computers" by Prof. F. C. Williams, D.Sc., D.Phil., F.R.S., at 5.0 on November 20th at the Science Museum, London, S.W.7.

Television Society

Discussion on "Competitive Television" at 7.0 on November 13th.

"Converters for V.H.F. or U.H.F. Television" at 7.0 on November 26th.

Both these meetings will be held at the Cinematograph Exhibitors' Association, 164, Shaftesbury Avenue, London, W.C.2.

Leicester Centre.—"Fly Wheel Synchronizing" by S. E. Gent, B.Sc. (Eng.), (Ferguson Radio), at 7.0 on November 30th at the College of Art and Technology (Room 45), The Newarkes, Leicester.

British Kinematograph Society

Film Production Division.—"Stereophonic Sound Systems" by A. W. Watkins, at 7.15 on November 18th.

Television Division.—"Medium Screen Television" by H. Ibbotson, B.Sc., at 7.15 on November 25th.

Both meetings will take place at the Gaumont-British Theatre, Film House, Wardour Street, London, W.1.

Radio Society of Great Britain

"The Television Society's new TV Station" by H. de L. Banting, D. N. Corfield, D.L.C. (Hons.), and E. A. Dedman, at 6.30 on November 20th at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Institute of Practical Radio Engineers

Midlands Section.—"Television and Radio Suppression in Vehicles" by H. Harrison (Joseph Lucas, Ltd.), at 7.30 on November 2nd at the Crown Hotel, Broad Street, Birmingham.

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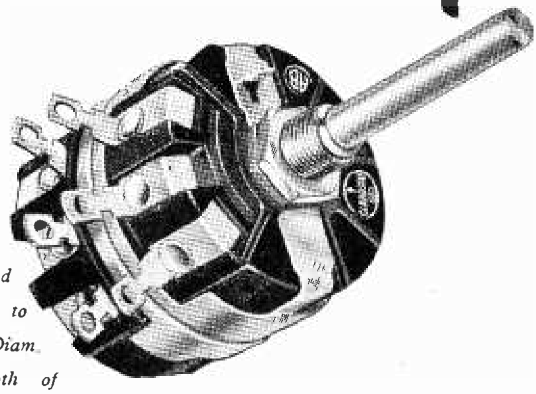

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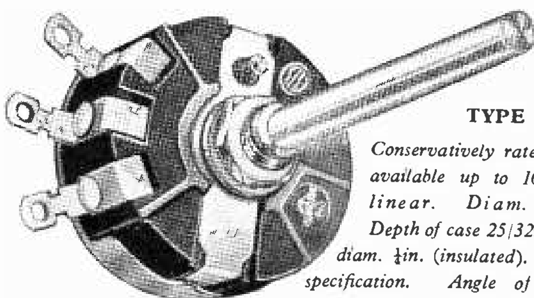

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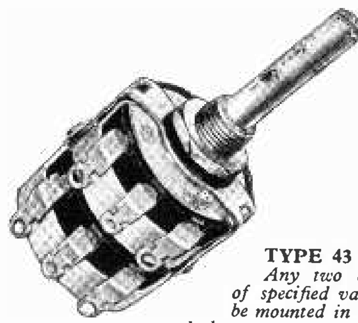

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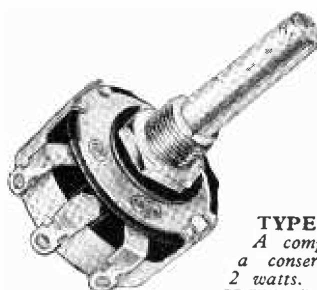

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A compact control with a conservative rating of 2 watts. Available up to 25,000 ohms linear. Diam. 1⅜in. Depth of case 19/32in. Spindle diam. ¼in. (insulated). Length to specification. Angle of rotation, mechanical 300°. Effective 280°.

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SKIN EFFECT

By "CATHODE RAY"

Why High-Frequency Currents Tend to Flow on the Outside of Conductors

IN connection with microwave valves, two months ago, I happened to mention that at such high frequencies it was better to use sheet than wire, because most of the current flowed at the surface—a peculiarity known as skin effect. With such a picturesque name, it could hardly fail to be known. But I wonder if it is *understood*. I suspect that many reasonably knowledgeable technical people regard it as one of the sweet mysteries of r.f. life that are better not inquired into too closely. There is some excuse for this attitude, because the books that do deal with it thoroughly make very heavy mathematical weather of it, full of special Bessel functions, wave propagation, and suchlike. Consequently the simpler treatises tend to laugh it off by hinting that you must be a fool if you can't see that it is in the nature of very high-frequency currents to keep to the surface. The thing is "skin effect," so—well, there you are!

For those who are not honours graduates, but nevertheless have inquiring minds, some of the books strike a happy medium. But the said inquiring minds may perhaps be a little troubled by the fact that several apparently quite different explanations of skin effect exist. There is, however, no cause for alarm; skin effect is one of those things that can be approached by different routes; some people may find one way easier, some another.

Basic Principles

Personally I think the best starting point for any expedition of this kind is with the basic principles of electricity. A bit more thought may be needed to work it out from there, but every time one does it makes those principles clearer in the mind. However, there is no reason against—in fact every reason for—supplementing this approach by views from other positions, which, although established from fundamentals indirectly, may be more familar in practical work. For instance, one way of explaining skin effect is in terms of eddy currents. To anyone who has studied eddy currents and knows all about them, this may be a convenient short cut; but if one's understanding of eddy currents is itself rather shaky it is clearly not a sound proposition.

The simplest conductor to consider is a long straight round-section wire made of a non-magnetic material, say copper, and far enough away from other conductors for their effects to be neglected. When d.c. flows it does so uniformly over the cross-section, so that if the wire were imagined to be divided up into equal thick parallel strands each would be carrying the same current. Since each strand has the same e.m.f. between its ends and the same resistance, it could hardly be otherwise. What calls for some explanation is the fact that with a.c. it *is* otherwise. If the frequency is sufficiently high, the strands around the circumference are found to be carrying nearly all the current, and those in the middle hardly any. Consequently the resistance of the wire as a whole is higher for a.c. than for d.c.

Students of the elementary books that try (regrettably) to make things easier by introducing reactance as a kind of resistance may need to be assured that this increase in resistance is quite apart from the increase in impedance due to the inductance of the wire as a whole. Such an assurance may be especially necessary because inductance does come prominently into my explanation. But not the inductance of the wire *as a whole*. May I emphasize, then, that there is an increase in actual *resistance* of the wire when the current becomes unevenly distributed from any cause whatever, whether by making the current alternate or by substituting Eureka for some of the copper.

Presumably it is obvious that the resistance of a wire is greater if current ceases to flow altogether through some portion of its cross-section, because that is the same thing as making the wire narrower. But anyone who does not find it obvious that *any* departure from uniform distribution of current flow increases the resistance should try calculating the total power dissipated in two parallel resistors when a given total current is shared between them in various proportions. Suppose, for example, that the resistors are each 10 ohms, representing (say) the core and outer parts of a 5-ohm length of wire (Fig. 1) and that the total current is 4 amps. If this is shared equally, each path takes 2 A and the power dissipated in it (I^2R) is $2^2 \times 10 = 40$ watts: total for both path 80 watts. Now suppose one path takes 3 A and the other 1 A. Dissipation in the 3 A path is 90 watts and in the other 10 W; total 100 W. Of course the voltages across the two paths are now unequal (assuming the current is d.c.), which is impossible if the paths are in parallel. But not with a.c. For if the low-current path has more inductance in series with its resistance than the other path, it is quite possible for the voltage across it to be the same as across the other.

But, you may say, surely all strands of a single wire have the same inductance, especially if (as we are supposing) the division of the wire into strands is only imaginary? Even when one takes two separate wires with which to wind a coil, if they are

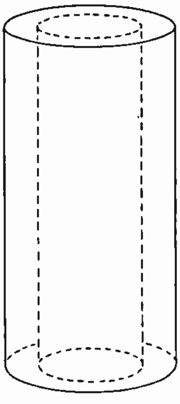


Fig. 1. A short sample (highly magnified) of a long solid wire, divided longitudinally by imaginary boundaries into two "strands," one inside the other, having equal cross-sectional area.

twisted together throughout their length the inductive coupling between them is very nearly 100%; any difference between two longitudinal halves of a single wire must be quite negligible! Regarding the inner and outer parts of the wire as separate strands, with boundaries as in Fig. 1, they obviously have the same length (and, if wound into a coil, the same number of turns), so assuming 100% coupling between them they could be represented electrically as in Fig. 2. At zero frequency the inductance would have no effect, so only the lower part of the diagram would apply, and the e.m.f. to pass 4 A (2 A through each path) would have to be 20 V. Since the wire is supposed to be stretched out straight, its inductance would presumably be quite small, so the d.c. conditions would not be much affected if the e.m.f. alternated at a low frequency, say 50 c/s. Very little more than 20 V would be needed to maintain the total current at 4 A. At high frequencies, however, the back e.m.f. generated by the flux set up by the current would become appreciable compared with 20 V, and a greater generator voltage would be needed to maintain the current. At a sufficiently high frequency, the inductance would become the dominating partner, swamping the resistance. But on the assumption of equal inductance and 100% coupling, the impedances of the two strands would be equal, whatever the frequency, so the currents in them would remain equal.

But now let us see if this representation—which at first sight might seem to be at least a close enough approximation to the truth—is justified. And this is where we get down to the bedrock of basic principles. One of the most important of them is that the magnetomotive force around any loop is proportional to the current enclosed (or linked). In the m.k.s. system it is actually equal to the number of ampere-turns; in the c.g.s. system it is 0.4π times the amp-turns. Our wire, being straight, has only one "turn," so the m.m.f. around any loop embracing it when it is carrying 4 A is (in the m.k.s. system) numerically equal to 4, or, in the c.g.s. system, 5.03. The path of the magnetic field at any point caused by current in a straight wire is a coaxial circle, and its strength is equal to the m.m.f. divided by the circumference of the circle. So just outside the wire, around its surface, the field strength (H) is m.m.f. πD, where D is the diameter of the wire. If D is, say 0.4 cm, H due to 4 A is 4 oersteds. The flux density B is equal to H multiplied by the permeability, μ, and in the c.g.s. system the μ for air is practically 1; so in our example B would be 4 gauss (or lines per sq. cm). In the m.k.s. system it would work out at 0.0004 weber. But for our present purpose numerical values are only of incidental interest, so there is no need to worry about systems of units—they do not affect the basic facts, namely, that the m.m.f. is the same in every concentric path around the wire, because all enclose the same current, and the field strength and flux density are therefore inversely proportional to the diameter, as shown in Fig. 3.

The same principles apply inside the wire itself, but of course we have to allow for the fact that the current enclosed, and therefore the m.m.f., progressively diminishes as the diameter of the path is reduced. The current, uniform distribution being assumed, is proportional to the cross-sectional area, and therefore to the *square* of the diameter. So the field, being proportional to the diameter squared, divided by the diameter, is simply proportional to the diameter and we can complete the field/diameter diagram as in Fig. 4.

The one essential thing to grasp out of all this is that current flowing down the centre of the wire is linked with more flux than current in the outer "skin." The difference is the flux in the wire itself; this flux is proportional to the total current through the wire, but is independent of its gauge. This may seem rather surprising, but if you remember that the maximum flux density (which is at the surface of the metal) is inversely proportional to D, while the area through which it passes is directly proportional to D, you will see that D cancels out when calculating flux = flux density × area.

Now if the current is alternating, the whole of the flux it produces is alternating, and therefore is inducing an e.m.f. in the wire. Other things being equal—frequency and length of wire—the e.m.f. induced is proportional to the peak flux. Since, as Fig. 4 shows, the flux linked with the core of the wire is greater than that linked with the skin, we see that more e.m.f. is induced in the core than in the skin. But the generator e.m.f. applied across all strands of the wire is the same, so after the induced e.m.f.s have been deducted there is less to spare for driving current through the resistance of the core than through the resistance of the skin. Consequently the effect of the unequal flux

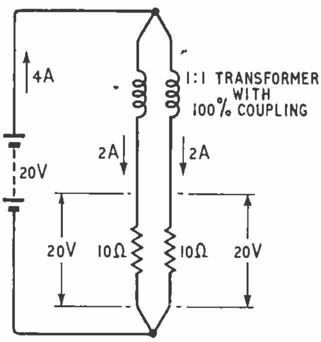
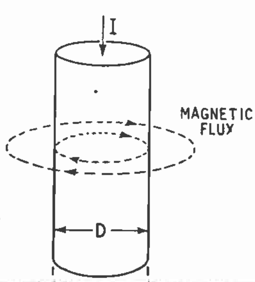


Fig. 2. If the resistance of the wire is taken as 5 ohms, the two "strands" can be represented by two 10-ohm resistances in parallel. Their inductances are also in parallel and very closely coupled; on the assumption that they are equal they are shown as making up a 1 : 1 transformer. At zero frequency the inductance has no effect, and an e.m.f. of 20 volts is sufficient to maintain a current of 4 amps, divided equally between the strands.



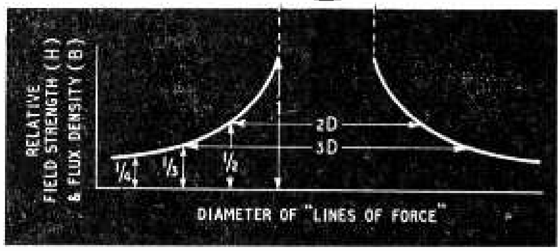


Fig. 3. The density of magnetic flux paths ("lines of force"), two of which are shown around the wire, falls off inversely as their length (which is proportional to their diameter) as shown in the lower part of the diagram. D is the diameter of the wire.

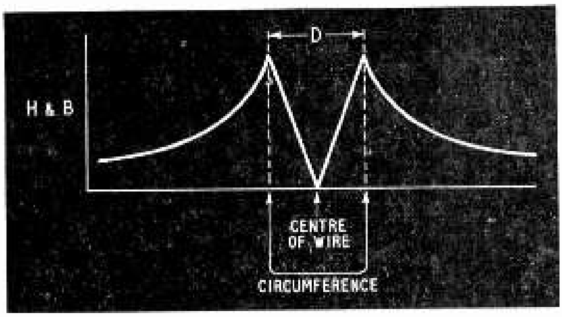


Fig. 4. To the field and flux density diagram for the field outside the wire is here added the portion applying to the field inside the wire, assuming the current is uniformly distributed. This diagram takes no account of the sign (direction) of the field.

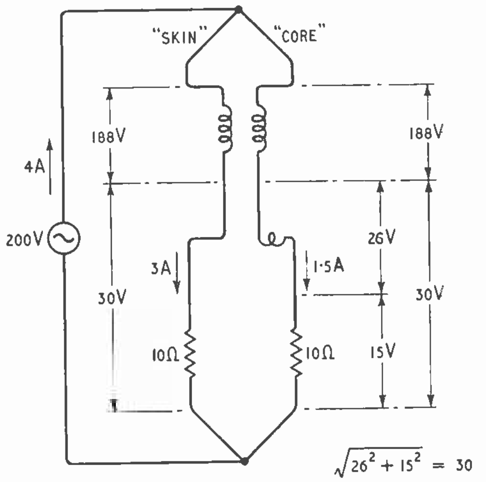


Fig. 5. This is Fig. 2 modified to apply to a frequency high enough for the reactance of the wire to be greater than its resistance. The fact that (as shown in Fig. 4) there is more flux outside the core of the wire, linked with it, than there is outside the skin, causes the core to have a higher inductance, so that less voltage is left to drive current through its resistance, and less current flows through it.

is to divert current from the core to the skin, and the resistance of the wire as a whole is increased.

Using conventional circuit symbols, this state of affairs can be shown as in Fig. 5, where the little extra coil in the "core" path represents the extra inductance corresponding to the flux inside the wire. The important point is that this inductance is not coupled to the "skin" path. Its back e.m.f. constitutes an extra voltage drop in the core path, and to make the situation clearer some figures are given on the diagram. For comparison with Fig. 2 the generator voltage has been raised sufficiently to maintain the total current at 4 A. The voltages across the two "windings" of the transformer *must* be equal and in phase, because the ratio is 1:1 and the coupling 100 per cent, so the voltages across the rest of each path must also be equal. But because of the extra inductance the current in the core path is not only less than the skin current but lags it in phase. In this case the phase difference is nearly 60°, which accounts for the fact that although the current in one branch has gone up by 1 A it has gone down in the other by only 0.5 A. So here is another cause of increased resistance. If you compare Fig. 5 with Fig. 2 you will find that the power dissipated, for the same current, has risen more than 40 per cent, equivalent to a rise in resistance from 5 Ω to more than 7 Ω. Note that a large diversion of current has been caused by a relatively small difference between the inductances of the two paths.

One result of the diversion of current from the core is to modify Fig. 4. The field outside the wire (being determined only by the total current) remains unchanged, but there is less inside. This tends to reduce the excess of voltage induced in the core. The diversion therefore takes place only so far as is necessary to bring about a balance, such as that shown in Fig. 5. But if the frequency is very high indeed, and the resistance of the wire is very low (as it would be if made of heavy gauge copper), practically the whole of the applied voltage is used in overcoming the inductance. In other words, the voltage induced in all strands of the wire must be practically the same. This cannot happen if some strands are linked with more flux than others, so current ceases altogether except at the surface. Then there is no flux inside the wire and all parts of the wire are linked by the same flux, (i.e., the flux outside the wire). And the resistance of the wire is many times greater than it was. The resistances of the various "strands" are still the same as before; it is just that fewer of them are being used. Directly the resistance rises so much as to absorb an appreciable part of the voltage applied to the outermost skin, it makes possible a slightly greater induced voltage in the inner layers, which means that some current, though small, can flow there.

The thicker the gauge of the wire, the lower its d.c. resistance in proportion to its inductance, and the greater the skin effect. This fact sometimes makes unthinking people jump to the conclusion that at very high frequencies a thick wire has a greater resistance than a thin one. Actually, of course, the thick wire has the lower resistance, however far skin effect is developed, for it has more surface. It is true that *in proportion to the amount of metal used* its resistance is greater, because that goes up as the square of the diameter whereas the surface goes up in simple proportion to the diameter. So to obtain the lowest resistance with a given amount of metal it should be in the form of a thin-walled tube. It is also true that a coil wound with thick wire may have a higher r.f. resistance than a coil of the same dimensions wound with thinner wire. But if so it is not because of skin effect but because the lower resistance of the thick wire is being more than offset by greater dielectric losses in the insulation between the turns.

A moment or two ago we saw that skin effect brought about a reduction of magnetic flux inside the wire, the flux outside (for a given current) remaining the same. So the total flux produced by a given current is reduced, or in other words the inductance of the wire is reduced. The inductance of any circuit depends to some extent on frequency: it is greatest at zero frequency, when Fig. 4 holds good; it falls as skin effect comes into play; but there is a limit to the fall, for however high the frequency the circuit cannot lose more than all the flux inside the wire, and that is usually quite a small proportion of the whole. So at very high frequencies the inductance curve levels out again, towards a slightly lower figure than the d.c. value. The more refined formulæ for calculating inductance provide a frequency correction.

We have already seen that skin effect is more pronounced with thick solid wire than with thin, in the sense that a given frequency multiplies its resistance by a larger factor, though it never becomes so high as that of the thin wire. It should also have been clear that wire made of low-resistance metal develops skin effect at a lower frequency than high-resistance metal. Study of Fig. 5c shows that the lower the resistance of the wire—whether because it is thick or because it is made of low-resistance material, or both—the lower the frequency at which its inductance is large compared with its resistance, causing the current to crowd towards the skin in order to reduce the internal flux and thus equalize the inductive voltages in all strands. So a thick copper wire shows skin effect at a comparatively low frequency; a thick resistance wire or a thin copper wire is similarly affected only at a much higher frequency; and a thin resistance wire maintains its resistance within close limits up to a much higher frequency still. Finally, a wire made of iron or other magnetic material, though higher in resistance than copper and therefore less subject to skin effect, has an enormously higher permeability than copper, so the internal flux is multiplied accordingly, and the net skin effect is far greater even than with copper.

Skin effect is therefore increased by the following: conductance per unit length, permeability, and frequency. The exact calculation of the increase in resistance is, as I said, a matter for the brighter mathematicians, and practical people like ourselves fall back on tables or graphs. While it is easy enough to use these to find the increase for an infinitely long straight wire with no other conductors anywhere near, no real circuit answers to that description. Even if one takes a practical view of "infinitely long" (in some circumstances a foot or so may be indistinguishable from infinitely long) there must be a return path somewhere if there is to be any current. However, if this is outside the more intense parts of the wire's magnetic field, it can be disregarded for purposes of calculating skin effect. But most often one is interested in r.f. resistance as it affects coils, transmission lines and other circuits that do not even roughly conform to the above description. Take a coil, for instance. The flux inside the wire forming any of the turns is caused not only by the current in that turn but also by the same current in other turns. So Figs. 3 and 4 do not hold good, and the explanation based on them falls down. But its conclusion does hold good if it is expressed more generally. What we really found was that when the frequency is high enough for the inductance to predominate over resistance in the impedance *the current tends to flow where it makes the inductance least.* In a straight wire, this is at the circumference of the cross-section; in short, the skin.

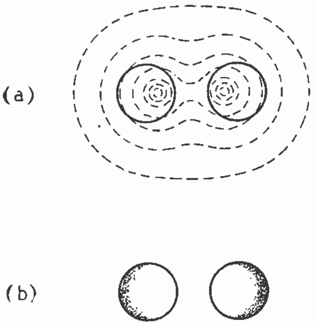


Fig. 6. When two wires carrying the same current are close together, their combined magnetic flux is distributed something like this (a), and the h.f. current consequently tends to flow where shaded (b).

Fig. 6 shows a section through two adjacent wires carrying current in the same direction. Assuming their returns are relatively far away, the flux pattern will be somewhat as shown at (a). The parts of the wire linked with least flux are those farthest apart, so the greatest current density will be through them, as shown by the shading at (b). This modified distribution is sometimes given a separate name, *proximity effect*, but basically it is the same as skin effect. In a single-layer coil, the tendency is for the current to flow along the inside surfaces of the wire. Abacs for calculating r.f. resistance of coils are in *Radio Data Charts.*

Then there is the coaxial line. It is no surprise to learn that current through the inner conductor tends to flow at the outer surface, as in simple skin effect. But it may seem rather contradictory that the current through the outer conductor tends to keep to the *inner* surface. Yet it follows from the same sort of reasoning as we used for the isolated wire. If in Fig. 7 we work from the axis outwards, calculating the m.m.f. due to the zero-frequency current enclosed, and dividing by the length of the field path or "line of force," everything is as before until we reach the inside diameter of the outer conductor. Here we start to enclose a current flowing in the opposite direction, so the net m.m.f. decreases. By the time we reach the outside diameter we are enclosing no net current at all, because the currents in the inner and outer conductors are equal and opposite. So from here outward there is no magnetic field—which of course is one of the advantages of this type of cable. Looking at the possible current paths, we see that a path down the core of the inner conductor, and up the outer skin of the outer, links with all the flux there is, both in the space between the conductors and in the metal, so has maximum inductance. The path of *least* inductance, and therefore most popular with high-frequency current, is along the surfaces enclosing the space between the conductors.

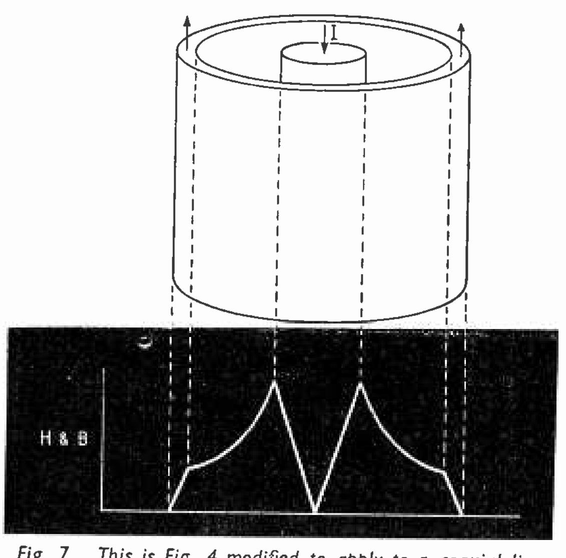
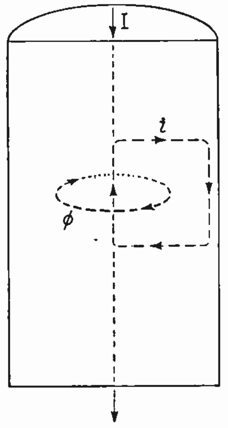


Fig. 7. This is Fig. 4 modified to apply to a coaxial line, where the external field is cancelled out by equal and opposite currents in the two conductors.

The only metal having a lower resistivity than copper is silver, so where low r.f. resistance is worth the extra cost it is customary to silver-plate the surfaces where the current flows. But the resistivity of silver is only about 5 per cent lower, and it has been found* that plated surfaces are microscopically rough,

* "Attenuation and Surface Roughness of Electroplated Waveguides," F. A. Benson, *Proc. I.E.E.*, Part III, July 1953, p. 213.

Fig. 8. *In this wire, shown in section, the alternating flux (represented by the single line of force, ϕ) induces current around paths such as the square one marked. When all such paths are taken into account, the net result is skin effect.*



and the extra distance the current has to go, up and down all these little hills, may more than swallow up the slight advantage.

For the sake of anyone who would like an alternative approach to simple skin effect, Fig. 8 shows a longitudinal section of our piece of wire with current flowing down it. Consider any closed path in a vertical plane inside the metal, such as the square one shown dotted. Provided that it is not exactly in the centre, such a conducting loop as linked with some flux, represented by the single coaxial line of force marked "ϕ". As the current in the wire alternates, so does this flux, which therefore induces an alternating e.m.f. around the loop (and around all others like it), and because the loop conducts a current flows around it. According to Lenz's Law, the direction of current must be such as to oppose its cause; so inside the flux loop it must be opposite to the current that set up the flux, which means that nearer the surface of the wire it must be in the same direction as the current there (which was *not* responsible for the flux). In other words, the current near the axis of the wire is weakened, and the current near the surface is strengthened; in still fewer words —skin effect.

Some time ago, when discussing Energy (January 1952, to be precise) I mentioned that the electrical energy travelling along a resistanceless wire existed solely in the space around, in the form of electric and magnetic fields; it was only in so far as the wire has resistance that energy enters into the wire, there to turn to heat. In saying this I neglected the magnetic field inside the wire, but this was reasonable, for at most it is a small proportion of the whole, and, if a wire really could be devoid of resistance, skin effect would be full developed even at the lowest frequency and there would be no current or flux inside. Supposing now the wire *has* resistance, energy from the fields must enter it from the outside inwards, being dissipated as it goes. One would expect, therefore, the greatest dissipation to be at the surface, and (since energy must travel at a finite speed) the dissipation nearer the axis of the wire to be not only less intense but also delayed in time. This is exactly what we have already found: the current inside the wire being less, the I^2R loss is less than at the surface; and since the inductance is greater it lags in phase.

An interesting point is that when d.c. is switched on, the magnetic field around the circuit has to grow, so there is a transient skin effect as well as a transient inductive effect, and the current in the wire starts flowing in the skin first and spreads to the inner parts later, before finally becoming uniformly distributed.

The "strands" we have spoken about hitherto have been distinguished only by imaginary longitudinal boundaries in the solid wire. What if we were to make up the wire of a number of actual separately insulated strands? This idea would occur at once to anyone who viewed skin effect as a manifestation of eddy currents, as in Fig. 8, because the way to minimize eddy currents in iron cores is to break up the current paths by using insulated stampings. It might seem that the insulation of the strands would in the same way interrupt the eddy currents where they pass horizontally from axis to circumference. But in fact these currents do not exist anyway! The current path marked in Fig. 8 is by no means the only one; there is another above it, and its lower horizontal portion carries current equal and opposite to the upper portion of the first, so cancelling it out. And so on for other paths. The only places where the current can be regarded as flowing at right angles to the axis of the wire is at each end (where there must be a conducting path there if the strands are to be electrically in parallel!).

So stranding alone does not overcome skin effect. The way to do so is to arrange that equal flux links every strand. This can be done by organizing the strands so that each occupies inside and outside positions in the same proportion. Stranded wire so organized is known as litzendraht, or more commonly as litz, and by its use the r.f. resistance of coils of given dimensions can be considerably reduced. But not only is this wire itself much more expensive than solid, it must be handled carefully and connected with great care and trouble, for if there are short-circuits between some of the strands, or every strand is not soundly connected at the ends and unbroken throughout its length, the result falls considerably short of expectation. In fact, a badly made litz coil may be even worse than if the wire were solid. The higher the frequency, the more difficult it is to obtain the benefit of litz, for apart from defects of workmanship the capacitance between strands increasingly nullifies its purpose.

I.E.E. PREMIUMS

THE Kelvin Premium (£25) has been awarded by the I.E.E. to Dr. W. Culshaw (T.R.E.) for his paper on "A Spectrometer for Millimetre Wavelengths" which was read during the Symposium on Insulating Materials.

Many of the Radio Section awards are for papers read at last year's Convention on "The British Contribution to Television." The Duddell Premium (£20) went to D. C. Birkinshaw (B.B.C.) for his paper "Television Programme Origination: the Engineering Technique," and the Ambrose Fleming Premium (£10) to D. A. Wright (G.E.C.) for "A Survey of Present Knowledge of Thermionic Emitters."

Premiums valued at £10 have been awarded to the following for the papers quoted: H. Cafferata, C. Gillam and J. F. Ramsay (Marconi's), "Television Transmitting Aerials"; E. McP. Leyton, E. A. Nind and W. S. Percival (E.M.I.), "Low-Level Modulation Vision Transmitters, with special reference to the Kirk o'Shotts and Wenvoe Stations"; Prof. F. C. Williams and G. B. B. Chaplin (Manchester University), "A Method of Designing Transistor Trigger Circuits."

The following received £5 premiums: G. R. M. Garratt (Science Museum) and A. H. Mumford (Post Office), "The History of Television"; Dr. B. G. Pressey, G. E. Ashwell and C. S. Fowler (D.S.I.R.), "The Measurement of the Phase Velocity of Ground-Wave Propagation at Low Frequencies over a Land Path"; P. A. T. Bevan (B.B.C.), "Television Broadcasting Stations"; W. R. Piggott (D.S.I.R.), "The Reflection and Absorption of Radio Waves in the Ionosphere"; H. E. Holman and W. P. Lucas (E.M.I.), "A Continuous-Motion System for Televising Motion-Picture Films"; Dr. E. C. Cherry (Imperial College) and G. G. Gouriet (B.B.C.), "Some Possibilities for the Compression of Television Signals by Recoding"; Dr. A. J. Biggs (G.E.C.) and E. O. Holland (Pye), "The British Television Receiver"; L. C. Jesty (Marconi's), "Television as a Communication Problem"; Prof. H. E. M. Barlow, Dr. A. L. Cullen and A. E. Karbowiak (University College, London), "Surface Waves" and "An Investigation of the Characteristics of Cylindrical Surface Waves."

The premiums were awarded at the opening meeting of the session on October 8th.

BRIT.I.R.E. AWARDS

THE premier award of the British Institution of Radio Engineers—the Clerk Maxwell Premium (20 guineas)—has been given to Dr. Charles Süsskind of the Microwave Laboratory at Stanford University for his paper "Obstacle-Type Artificial Dielectrics for Microwaves."

I. A. Harris (M.o.S.) has received the Heinrich Hertz Premium (20 guineas) for his paper "A Systematic Method of Linear Small-Signal V.H.F. Analysis for Valve Circuits." The Louis Sterling Premium (15 guineas) was made to Dr. R. T. Theile and H. A. McGhee (Pye) for their paper "The Application of Negative Feedback to Flying Spot Scanners." The award for the most outstanding contribution on aids to aircraft safety—the Brabazon Premium (15 guineas)—went to P. L. Stride (E. K. Cole) for his paper "Search Radar for Civil Aircraft."

The first award of the A. F. Bulgin Premium (15 guineas)—for a paper from a member of the Armed Services—was made to Lt.-Col. J. P. A. Martindale (formerly of the Royal Military College of Science) for his paper "Lens Aerials at Centrimetric Wavelengths." V. J. Cooper (Marconi's) received the Marconi Premium (10 guineas) for the paper "New Amplifier Techniques." The Leslie McMichael Premium (10 guineas) went to J. A. Hutton (Murphy) for his paper "The Focusing of Cathode Ray Tubes for Television Receivers." The Dr. Norman Partridge Memorial Award (5 guineas) was made to K. R. McLachlan and R. Yorke (University of Southampton) for their paper "Objective Testing of Pick-ups and Loudspeakers."

The awards were made at the annual general meeting on October 21st.

TECHNICAL TRAINING

THE central feature of the Technical Training Display at the Show, provided by a number of colleges under the ægis of the Radio Industry Council, was a map indicating the types of training available at educational establishments throughout the British Isles. This information, which was provided by the Ministry of Education, is tabulated below. The initials against the name of the town or the college indicate the type of training provided: A, telecommunications engineering; B, servicing; C, Higher National Certificate with electronics or telecommunications; D, B.Sc. degree with electronics or telecommunications; and E, Higher N.C. in applied physics.

Angus
Dundee (A, B, C)
Bedfordshire
Bedford (A)
Luton (C)
Berkshire
Maidenhead (B)
Newbury (A)
Reading (A)
Buckinghamshire
Bletchley (A)
High Wycombe (A)
Slough (A)
Wolverton (A)
Caernarvonshire
Bangor (A)
Cambridgeshire
Cambridge (B, C)
Cheshire
Chester (A)
Crewe (A, B)
Stockport (A, B, C)
Cornwall
Camborne (A, B)
Falmouth (B)
Cumberland
Carlisle (A, B)
Whitehaven (A)
Denbighshire
Wrexham (A, B, C, D)
Derbyshire
Chesterfield (A)
Derby (A, B)
Devon
Barnstaple (A)
Exeter (A, B, D)
Plymouth (A, B, C)
Torquay (A, B)
Dorset
Weymouth (A, C)
Durham
Darlington (A)
South Shields (A, B)
Stockton (B)
Sunderland (D, E)
West Hartlepool (A, B)
Essex
Chelmsford (C, D)
Dagenham (A, B, C)
East Ham (C)
Southend (B, C)
Walthamstow (A, C)
West Ham (A, B)
Fifeshire
Cowdenbeath T.C. (B)
Glamorganshire
Cardiff (A, B, C, D)
Rhondda T.I. (A)
Swansea (A, B, C, D)
Treforest (A, B, E)
Gloucestershire
Bristol (A, B, C, D)
Cheltenham (A, B)
Cinderford (B)
Gloucester (A, B, C)
Stroud (A)
Hampshire
Bournemouth (A, B, C, D)
Portsmouth (A, B, C, D)
Southampton University College (A, B, C, D)
Herefordshire
Hereford (A, B)
Hertfordshire
Hatfield (A, B)
Letchworth (A, B)
Kent
Canterbury (A, B)
Dartford (A, B, C)
Dover (A)
Folkestone (A)
Medway (A, B)
Thanet (A)
Tunbridge Wells (A)
Lanarkshire
Coatbridge T.C. (B)
Glasgow
Stow Eng'g. Col. (A, B)
Allan Glen's (A, B)
Royal T.C. (C, D)
Hamilton (B)
Lancashire
Blackburn (A, B)
Blackpool (A, B)
Bolton (A, B, C)
Bootle (A)
Burnley (B)
Lancaster (A)
Liverpool
College of Technology (A, E)
Old Swan T.I. (A)
Riversdale T.C. (A, B)
Manchester
Col. of Technology (C, D)
Openshaw T.C. (A, B)
Oldham (B)
Preston (A, B, C, D, E)
Salford (A, B, C, D, E)
Southport (A)
Wigan (A, B, C, D)
Leicestershire
Leicester (B)
Loughborough (B, C, D)
Lincolnshire
Lincoln (A, B)
London
Battersea P. (A, C, D)
Deptford (S.E. London T.C.) (A, B, C, E)
Finsbury (Northampton P.) (A, C, D, E)
Islington (Northern P.) (A, B)
Lambeth (Norwood T.C.) (A, B)
Paddington (B)
Poplar (B)
St. Marylebone (Regent St. P.) (A, B, C, D)
Southwark (Borough P.) (A, C)
Woolwich P. (A, C, D)
Middlesex
Acton (A, C, D)
Enfield (B, C)
Hendon (C)
Southall (B, C)
Willesden (A, C)
Midlothian
Edinburgh
Heriot-Watt (A, B, C, D)
Leith T.C. (B)
Monmouthshire
Crumlin (C)
Newport (A)
Norfolk
Gt. Yarmouth (A)
Norwich (A)
Northamptonshire
Peterborough (A)
Northumberland
Newcastle-on-Tyne (A, B, C, D)
Nottinghamshire
Nottingham (A, C)
Oxfordshire
Oxford (A, E)
Renfrewshire
Greenoch Watt Memorial Sch. (A, B)
Paisley T.C. (C, D)
Shropshire
Shrewsbury (A, B)
Somerset
Bath (A, B)
Taunton (A, B)
Staffordshire
Burton-on-Trent (A, B, C)
Stafford (A)
Stoke-on-Trent (A, B)
Walsall (B)
Wolverhampton (A, B, C, D)
Stirlingshire
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Suffolk
Lowestoft (A, B)
Surrey
Croydon (A, B, C)
Richmond (B)
Wimbledon (A, B, C)
Sussex
Brighton (A, B, C, D)
Hastings (B)
Warwickshire
Birmingham (A, B, C, D, E)
Coventry (A, C, D)
Leamington (A)
Rugby (A C, D)
Wiltshire
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Salisbury (A, B)
Swindon (A)
Worcestershire
Gt. Malvern (C)
Kidderminster (A)
Worcester (A)
Yorkshire
Bradford (A, B)
Castleford (Whitwood) (B)
Doncaster (A, B)
Halifax (A)
Huddersfield (A, B, C)
Kingston-upon-Hull (A, B, D)
Leeds (A, B, C, D)
Middlesbrough (A, B)
Rotherham (A, B, C, E)
Scarborough (A)
Sheffield (A, B)
Wakefield (B)
EIRE
Dublin (B)
NORTHERN IRELAND
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Abbreviations: P., Polytechnic; T.C., Technical College; T.I., Technical Institute.

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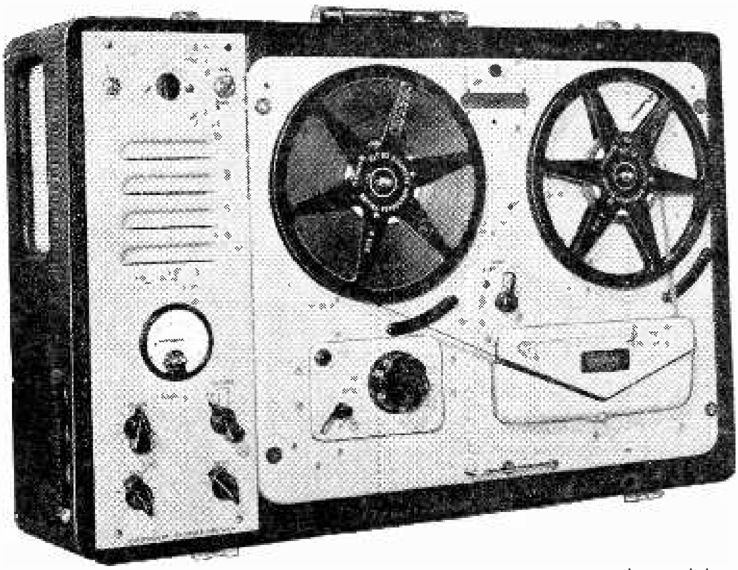

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★ A heavy mu-metal shielded microphone transformer is built in for 15-30 ohms balanced and screened line, and requires only 7 micro-volts approximately to fully load.

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★ A power plug is provided for a radio feeder unit, etc. Variable bass and treble controls are fitted for control of the play back signal.

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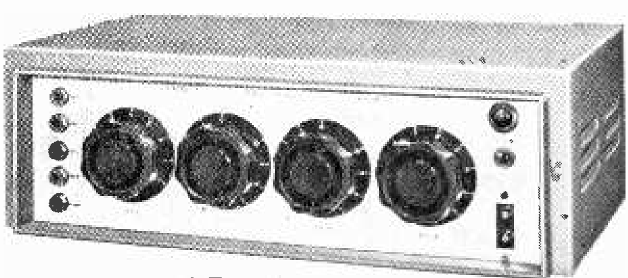

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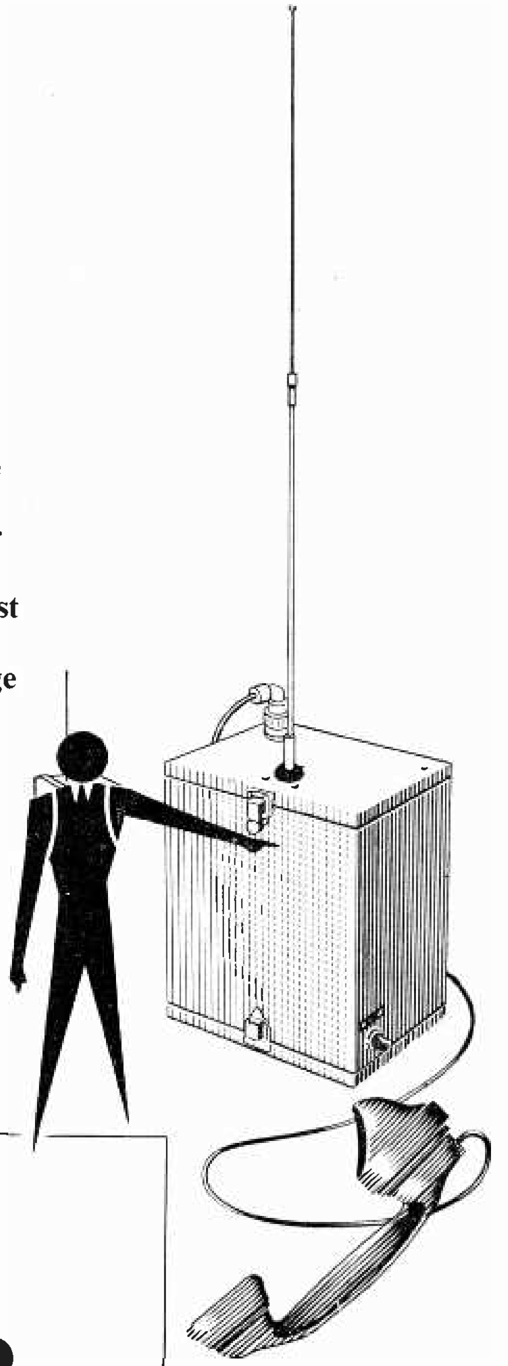


TRANSISTORS

10.—*Analogue, "Field-Effect," and Tetrode Transistors : Junction Photocells*

By THOMAS RODDAM

In the first eight articles of this series the discussion related to the conventional transistors, the ones which are in production in America and elsewhere. Three types have been mentioned, the point type and the two polarities of junction transistor : in essence, as we have seen, these reduce to only two basic types, the point type with a current gain of more than unity and the junction type with a current gain of less than, though very close to, unity. A modified version of the junction transistor, the symmetrical unit, was mentioned in the ninth article. This month I want to describe some of the other members of the transistor family which have been constructed. Which of them will prove important is anyone's guess, but they serve to show the lines along which transistor development is proceeding.

The group of transistors to be described first is the general class of unipolar transistors. The most easily appreciated types of unipolar transistors are the analogue transistors, which are called by this name because they really are very analogous to ordinary triodes. Externally, it is true, the usual junction transistor is quite valve-like, but of course any fairly linear three-element system must be rather like some sort of triode. The analogue transistors are fundamentally like a valve. The description of these transistors follows closely that given by Shockley. To begin with, consider two electrodes in a vacuum —a vacuum capacitor, in fact. Assuming that a battery is connected to the two plates, there will be a potential difference between them, an electric field in the space between the plates, but no charge in the gap, because the emission is negligible. A very similar structure can be realized with semi-conductors by arranging an intrinsic semi-conductor, one which is absolutely pure, with a *p*-region at one end and an *n*-region at the other. Provided that the *n*-region is connected to the positive terminal of the battery and the *p*-region is connected to the negative terminal, very few carriers will enter the intrinsic region in the middle, and there will be a concentration of charge along the two boundaries. Of course, if the polarity is reversed the majority carriers in the two "doped" regions will flow into the middle.

In an ordinary valve the electric field is distributed so that it tends to pull electrons out of the grid and cathode, and to catch them at the anode. This is obvious when the valve is cold, and when the cathode is hot the main change is that electrons come out from the cathode very easily, while the field at the cathode is reduced by space charge.

An analogue transistor can have the structure shown in Fig. 1, in which the "cathode" and "anode" are made of *n*-germanium, the "grid" of *p*-germanium, and the "vacuum" of pure germanium. At the "cathode" the electric field will tend to extract electrons, and these will form a space charge round the "cathode." As the "grid" is negative with respect to "cathode," the electrons will not flow into the "grid," and the "grid wires" will be surrounded by what Shockley calls depletion regions. As the "grid" potential is varied the number of electrons which slip through the gaps between "grid wires" will vary. The behaviour is thus very much the same as in an ordinary valve.

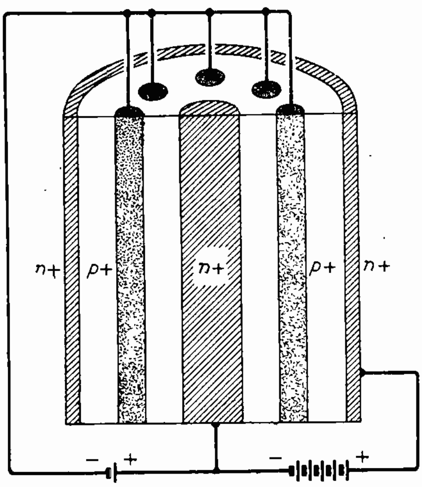


Fig. 1. Transistor analogue of a triode valve. The space between "electrodes" is pure (intrinsic) germanium.

The analogy is not absolutely exact, of course. For one thing, the electrons do not flow in a stream, bouncing together like billiard balls and obeying the law of conservation of momentum. In consequence there may be no "grid" current even if the "grid" is positive with respect to "cathode," so long as the field at the "grid" is electron extracting.

The important distinction between the analogue transistor and the ordinary transistors lies in the fact that there is no emitter in the analogue transistor. In the junction transistor the controlled current and the controlling current both flow in the base region, so that input and output are mixed up together. In the point transistor, both holes and electrons are involved, and the injection of holes at the emitter is an essential feature of the operation. An electron-flow analogue transistor may have a small saturated flow of holes, just as the ordinary valve may have a small current due to ions, but the essential working depends on one kind of current carrier only. For this reason the new kind of transistor is called a unipolar transistor to distinguish it from the bipolar transistor we have met previously.

There is a second variety of unipolar transistor, the field-effect transistor, which differs from the analogue transistor by having unbalanced chemical impurities in the " vacuum " region. But first we must introduce some terminology. It seems obvious that we should follow Shockley,[1] and this is what he says:

" Since the role of emitter is not played in the normal way in the unipolar transistor and since the collector also functions somewhat differently, it appears advantageous to introduce new terminology for the electrodes in the unipolar types. The choice proposed for the electrodes is as follows: *Source* for the electrode from which the carriers enter the region of relatively high electric fields; *drain* for the electrode at which they arrive and out of which they flow; in the analogue transistor the control electrode will be called the *grid* because of its close analogy with vacuum-tube structures. In the field-effect transistor it is proposed to call the control electrode the *gate.* The fact that gate and grid have the same initial letter leads to the use of a common subscript for these two similarly functioning electrodes. The choice of these names has been based partly on an attempt to find names which describe functions and partly on the value of the names from a phonetic and abbreviational point of view. It should be noted that none of the new subscripts are the same as those encountered in bipolar transistors. Furthermore, it may be noted that the names selected are all monosyllabic."

The typical structure of the unipolar field effect transistor is shown in Fig. 2(a). It is a triode, and is constructed from a sandwich of p-material between two layers of n-material, the latter being heavily doped so that it can be described as $n+$ material. The actual " space current " is carried by holes moving from left to right, and the current electrodes are made up of heavily doped p-material ($p+$) shown as 1 and 2. The p-n junctions are biased back, since both 1 and 2 are negative with respect to the earthed $n+$ plates 3. Space charge regions near the n plates are formed, and in these regions there are very few carriers. All the carriers flow through the central channel.

The width of the channel is, of course, a function of the relative bias on the gate electrodes. If 2 is more negative than 1, the bias will be greater near 2 so that the channel will be narrower at the right-hand end than at the left. The approximate theory shows that if this effect is sufficiently pronounced the channel will be closed completely. In more detailed analysis we find there is a point known as the *extrapolated pinch-off point* or *expop.* The distribution of space charge is shown in Fig. (2)b, and the actual shapes and sizes of some experimental units in Fig. 2(c).

Quite obviously the hole current in the channel can be controlled by varying the potential of the gate. Analysis and computation lead to the conclusion that gain can be obtained at frequencies as high as 10 Mc/s in a device which has all the predictability of the junction class of transistors. This is of very great importance, because the point transistors still seem to present considerable difficulty to the manufacturers.

The actual experimental units had mutual conductances up to 0.3 mA/volt and flat responses up to 3 Mc/s. Important among their properties are high input and output impedances. Unfortunately the noise figure is high, and under particular conditions one unit had a noise figure of 68 db. Dacey and Ross[2] state that using 17 ohm-cm germanium it should be possible to get a mutual conductance of 24 mA/V and an upper frequency limit of 140 Mc/s.

Another field controlled device is the junction " fieldistor " described by Stuetzer.[3] This is shown schematically in Fig. 3. The p-n junction is biased in the non-conducting direction and a control electrode is mounted very close o the surface. As a biasing potential is applied to the control electrode, there is a surface effect at the germanium junction, and the back resistance varies. In this form the mutual conductance is only a few microamps per volt.

By adding a liquid of high polar moment in the

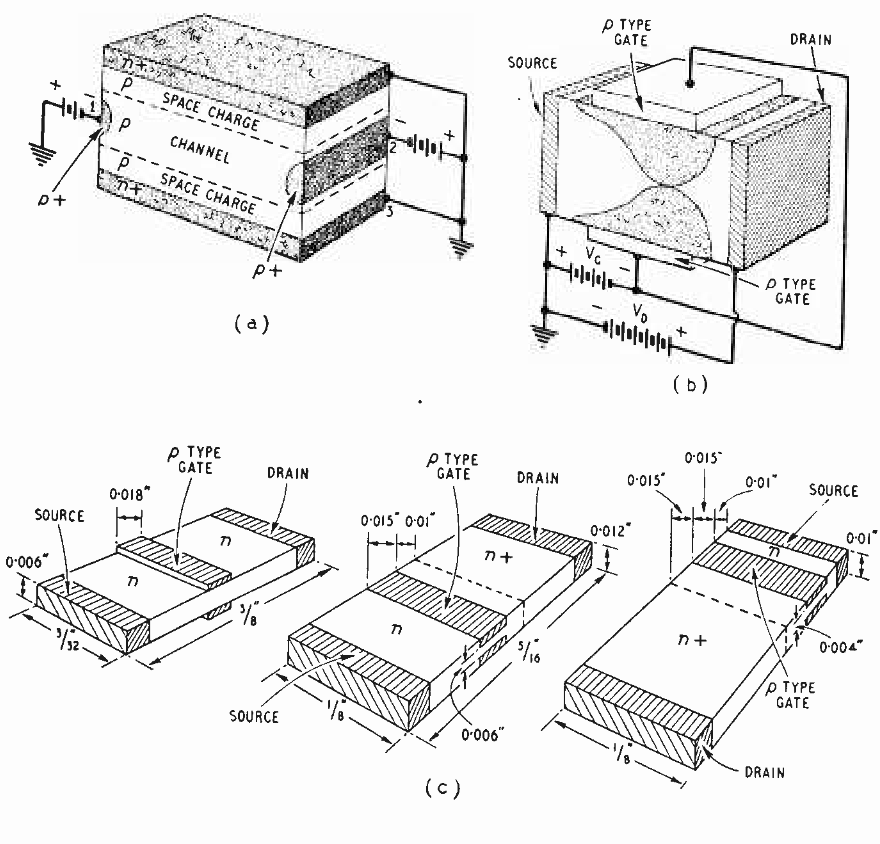


Fig. 2. (a) Structure of a unipolar field-effect transistor triode. (b) Distribution of space charge. (c) Dimensions of some experimental field-effect transistors.

[1] *Proc. I.R.E.*, Vol. 40, p. 1313, Nov. 1952.

[2] *Proc. I.R.E.*, Vol. 41, p. 970, August 1953.

[3] *Proc. I.R.E.*, Vol. 40, p. 1377, Nov. 1952.

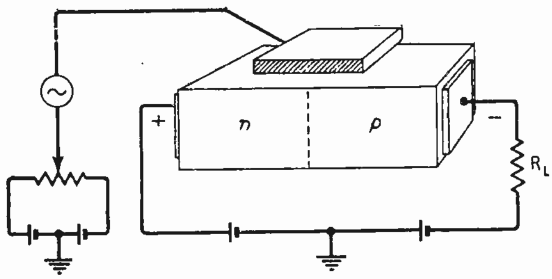
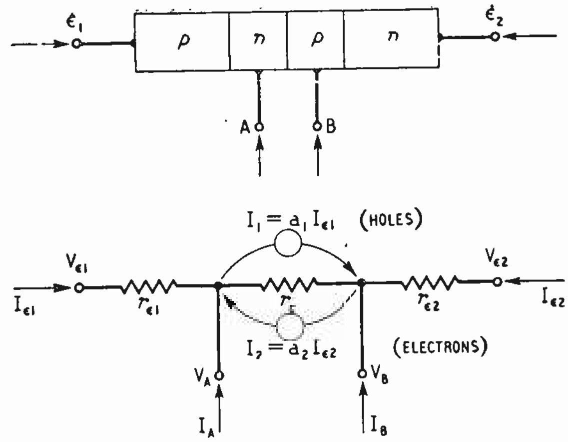


Fig. 3. In the "fieldistor" a liquid polar dielectric between control electrode and junction increases mutual conductance.



Right: Fig. 4. p-n-p-n junction transistor and its equivalent circuit.

space between electrode and germanium the device is completely transformed. The mutual conductance changes sign and becomes fairly large, the output impedance drops, and the frequency response, which without the liquid extends up to some hundreds of kilocycles per second, starts to droop at audio frequencies. A mutual conductance of some milliamps per volt, already well down at 1000 c/s, can be produced.

This device seems to be one which has not much future. A study of its mode of action shows that it is a surface device, not a volume device, and it has one value. It shows why we must be careful in choosing the material if we want to embed a diode in wax. Polar waxes would be fatal.

The next type to be considered is the *p-n-p-n* junction transistor. Schematically this is shown in Fig. 4, and according to the early terminology this is a *p-n-p* transistor with a "hook" collector on the right. The effect of the hook collector is to increase the current gain, and as a result values of α of the order of 50 can be obtained. As we have seen earlier, in an ordinary junction transistor the value of α does not exceed unity.

The mechanism of operation of this type of transistor is, perhaps, too complicated for this series. It is, however, possible to carry out experiments connected with this type of transistor, since it can be simulated by connecting an *n-p-n* transistor and a *p-n-p* transistor together in the way shown in Fig. 5. Notice that the terminal on the right is marked ϵ_2 and is an emitter, not a collector. Used as an earthed-base hook collector transistor B is left disconnected and the equivalent circuit takes the form shown in Fig. 6. The value of α can be reduced by connecting a resistance between B and ϵ_2. In an even more complicated arrangement a diode is connected here, and by building out $r_{\epsilon 2}$ with 22 ohms and using a *p-n*-diode between B and ϵ_2 an almost constant value of α over a range of 0.01 to 1.0 mA of $I_{\epsilon 1}$ has been obtained. The α was just under 3.

These *p-n-p-n* transistors are likely to be very hard to produce. It is anyone's guess whether other forms will be found to do the job before the production difficulties are solved.

A four-electrode junction transistor of another kind is the one described by Wallace, Schimpf and Dickten.[4] This is a normal *n-p-n* transistor with an additional

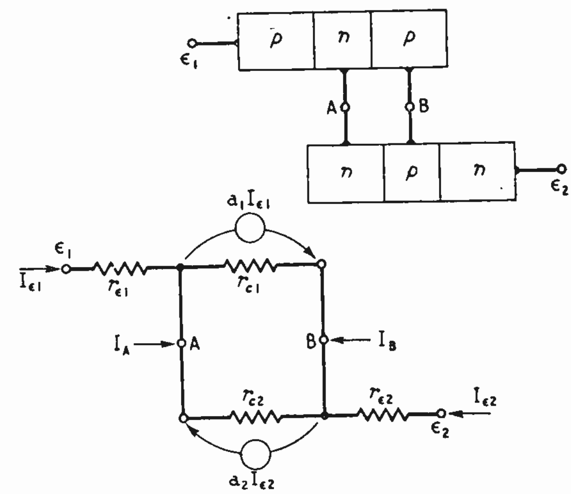


Fig. 5. Combination of p-n-p *and* n-p-n *junction transistors.*

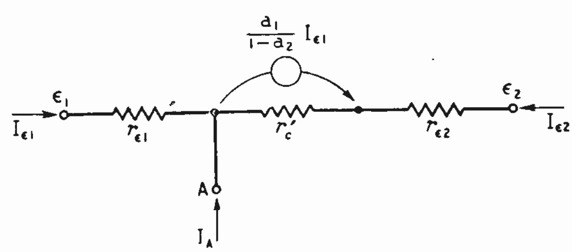


Fig. 6. Equivalent circuit of a "hook" collector transistor.

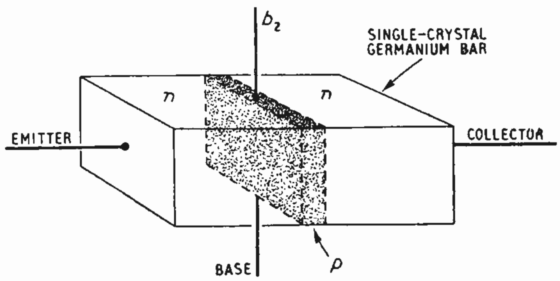


Fig. 7. Tetrode transistor with fourth connection b_2.

[4] *Proc. I.R.E.* Vol. 40, p. 1395, Nov 1952.

connection made to the p-layer. The advantage of this type is its excellent high-frequency response. Even the first few experimental models oscillated at frequencies up to 130 Mc/s. A video amplifier with a gain of 22 db up to 5 Mc/s and a 15 db amplifier with a 9-Mc/s bandwidth centred on 32 Mc/s are examples of its first use. The structure of this tetrode is shown in Fig. 7. The actual thickness of the p-layer is rather thinner than in the ordinary n-p-n transistors: this helps to keep the cut-off frequency of α high. Another factor favouring high-frequency performance is the use of a smaller collector area, and in the units described this was only about 10^{-4} sq in.

The fourth electrode, b_2, is fed with a bias current which corresponds to a negative potential at b_2 of about − 6 volts. As the emitter is at about − 0.1 volt with respect to base, the top of the emitter junction is biased negatively and does not emit electrons into the p layer. Only near the base electrode will there be any emission: excluding all other currents the bottom 1/60th will have a p-layer positive with respect to the n-layer of the emitter contact. This could be achieved equally by cutting away the top 59/60ths of the bar, but this would actually mean making a bar only 1/6000 inch thick. With this very low effective thickness the base resistance will clearly be very low, and measurements show that a very practical value of I_b, − 2 mA, results in a reduction of base resistance to 40 ohms from an initial value of 1100 ohms for $I_{b2} = 0$.

Unfortunately, at the same time as r_b is reduced, α is reduced, and in one example given α falls from 0.99 to 0.75. The frequency characteristic of α tends to flatten out a little, although the roll-off point is much the same. For these junction tetrodes α is about 3 db down at 15–20 Mc/s.

It is shown by Wallace, Schimpf and Dickten that the gain of an earthed-base transistor amplifier will be 3 db down at a frequency given by

$$\frac{f}{fc\alpha} = 1 - \frac{\alpha_0 r_b}{r_e + r_b + R_G}$$

where $fc\alpha$ is the frequency of cut-off of α and R_G is the internal resistance of the input generator.

When $r_b = 0$ the response is 3 db down at $fc\alpha$, which in this case is 15–20 Mc/s. For an example discussed in their paper, the gain with the fourth electrode inoperative is 3 db down at $f = 0.055\,fc\alpha$, or about 1 Mc/s, while with the bias current flowing into the fourth electrode the gain is 3 db down at $f = 0.603fc\alpha$. This is up in the region of 10–12 Mc/s. Gains of the order of 20 db are obtained under these conditions: a gain of 20 db, flat up to 10 Mc/s, with resistive terminations is a very useful thing for any video amplifier designer.

The television designer is interested in getting his gain in bandpass amplifiers. A circuit using the junction tetrode is shown in Fig. 8: this gives 15 db gain over a 9-Mc/s band centred at 32 Mc/s, and the response curve is shown on the right-hand side of Fig. 9. The other two curves are the responses of amplifiers of the same basic type, but designed for narrower bandwidths and lower frequencies.

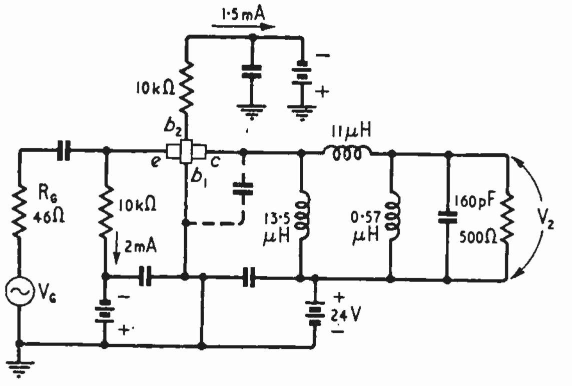


Fig. 8. Typical bandpass amplifier stage using the transistor tetrode.

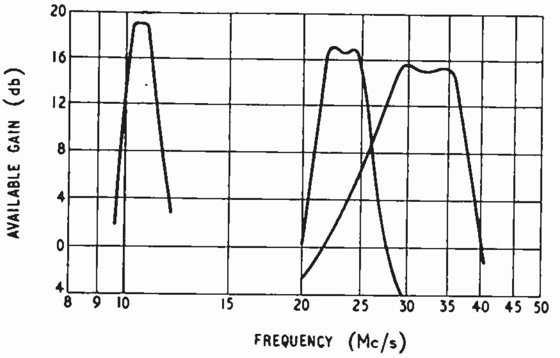


Fig. 9. Response curves of tetrode transistor amplifiers.

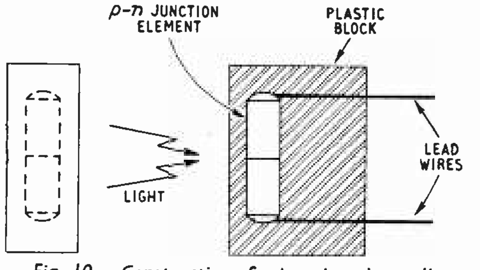
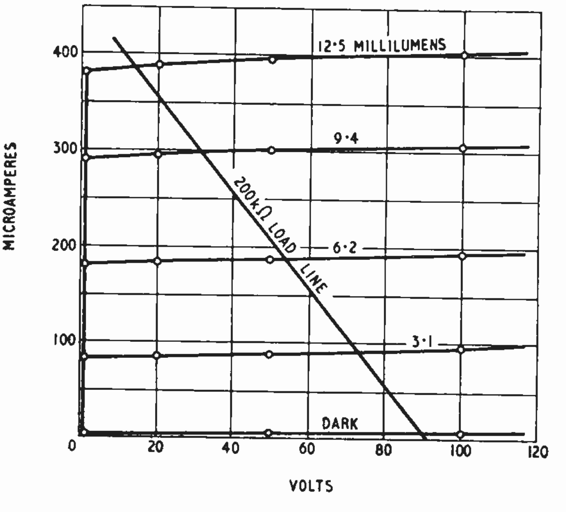


Fig. 10. Construction of a junction photocell.

Below: Fig. 11. Characteristics of the M-1740 junction photocell (average of ten).



In an oscillator, one transistor of this type gave an output of 0.25 mW at 100 Mc/s.

Another tetrode, quite different from this modified junction triode, is the new Sylvania point-contact tetrode; type 3N21. This is a point-type transistor with twin emitters and a single collector, the purpose of which has not been revealed. A transistor of this kind was made experimentally elsewhere some years ago, and could be used as a push-pull detector with gain, analogous to two triodes with the grids connected in push-pull and the anodes connected in parallel. Sylvania are promising a pentode, which will be provided with three emitters, and a common collector.

The general family of transistors must, I think, be considered to include the junction diodes, of which the *p-n* junction photocell is certainly entitled to be called a transistor. Fig. 10 shows diagrammatically the form of the Bell, M-1740 junction photocell, while Fig. 11 shows its characteristics. The photocell can be regarded as the base and collector of an *n-p-n* transistor, and it is connected with the *n*-electrode, the collector, positive with respect to the *p*-electrode, the base. When a light shines on the junction, hole-electron pairs are generated and these produce the "transistor conduction" effect at the rectifying barrier. This type of photocell is, of course, very small, and its other advantages are low dark current at room temperature, high speed of response, high sensitivity and low noise. At the recent Radio Exhibition a photo-transistor (Type P50A, made by Standard Telephones) was shown operating an ordinary P.O.3000 type relay. The maximum operating current of this particular type of cell was 2.5 mA and the maximum operating frequency 50 kc/s.

The junction technique has also been applied to power rectifiers, and two types are now appearing in this country. The great feature of these rectifiers is that the drop in the forward direction is very small, about 0.5–0.7 volt, although they will give an output current of up to 500 mA at up to 100 volts. The home-produced variety has not yet reached these ratings, but the smaller type, with a maximum input of 100 V RMS and a d.c. output current of 30 mA, weighs only 0.0017 ounce (0.75 gm).

By the time this article appears there may be some more new types of transistor, as well as those I have overlooked.

" A slow sort of country ! " said the Queen. " Now, *here*, you see, it takes all the running *you* can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that ! "

That is just what you would expect, since the transistor is a valve, through the looking glass.

NEW AIRFIELD RADAR EQUIPMENT

A COMPACT, mobile and easily operated surveillance radar giving a medium-range coverage for a small airport or Service airfield has been developed by Decca. Known as the Type 424, it employs much of the circuitry and technique which has been developed for their marine radar equipment and it is claimed that by utilizing some of the existing and well-tried practices a considerable saving is effected in the price of the apparatus. This new radar gear, while giving most of the facilities offered by a full-scale G.C.A. (Ground Controlled Approach) equipment, costs only £5,000.

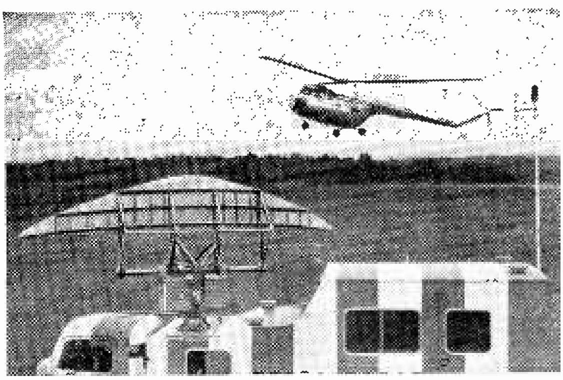
Its initial function is a Service one and it was conceived primarily for speeding up the landing of modern jet fighter aircraft which, owing to the very high fuel consumption, especially at low altitudes, must be brought down on to the airfield with the least possible delay.

Recent experience with the equipment has shown that it has definite applications in civil aviation and a complete set has, in fact, been ordered for use at one of the municipal airports in the north of England.

The Type 424 can be supplied in mobile, static or air-transportable forms, the latter being of particular interest to military air forces. It comprises the following basic units:—

Scanner :—The parabolic cylinder-type scanner measures 14 ft across and gives a beam-width of 0.750 deg in the horizontal plane and 3.80 deg in the vertical. The scanner rotates at 24 r.p.m. and provision is made to tilt it between −2 deg and +20 deg to meet operational requirements.

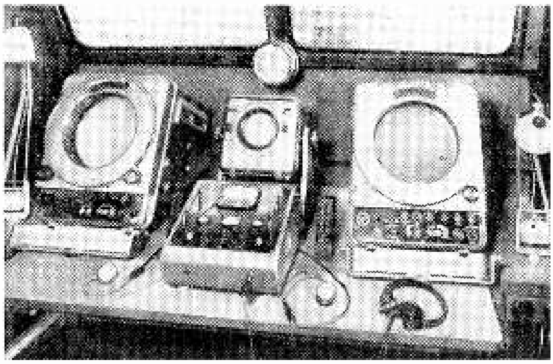
Radio-frequency Head:—Immediately below and rotating with the scanner is a radio-frequency head containing a pulsed magnetron generator giving an r.f. output to the scanner on 9,375 Mc/s (3.2 cm). A peak pulse output of 30 kW is available with two pulse lengths of 0.1 μsec and 0.5 μsec respectively. Contained also in the radar head are the detector and early stages of the receiver.



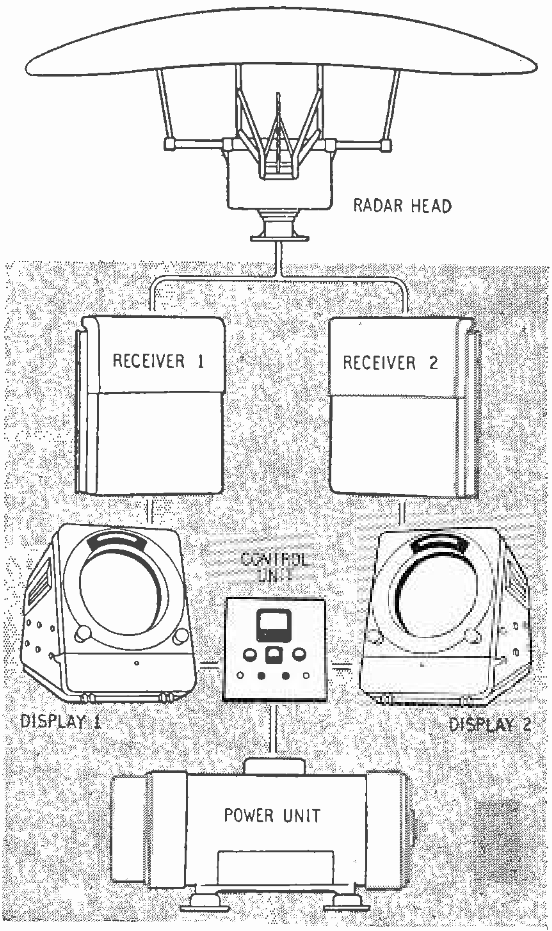
Horn-fed scanner and radar head of the Decca airfield radar forming part of a mobile control unit. A helicopter "talked-down" and about to land is seen in the background.

Receivers:—The output from the radar head is split and fed to two identical and independent receivers and these in turn feed two independent PPI (Plan Position Indicator) display units fitted with 12-in c.r. tubes. For normal operation one display unit would be used for marshalling aircraft from the limit of range of the equipment (20 to 25 miles) into 5 miles or so and the second display unit would take over the actual runway approach and landing control. Instructions to pilots are given over the normal v.h.f. radio-telephone equipment. Two controllers, one handling the approach and marshalling and the other the actual landing, can thus be employed.

Each display unit has range adjustments for coverages of 0.5, 1.0, 2.5, 5.0, 10 and 25 miles radius with the radial scanning trace based on the centre of the tube.



Layout of the controller's position showing two airfield display units, miniature CRDF display, control box and v.h.f. radio telephone control units.



Schematic layout of the various units comprising the Decca airfield radar Type 424.

An illuminated marker line can be projected directly on to the c.r. tube showing the approach path for the airfield runway in use and on this line are projected range markers. This is said to obviate any likelihood of parallax error in positioning an aircraft on the approach line, such as might arise when the runway approach path and other airport features are displayed on the glass screen of the PPI unit.

Control Unit:—This is situated normally between and slightly to the rear of the two display units and carries all the controls including a remote indicator for tilt angle of the scanner.

Additional equipment developed for use with this radar is a miniature CRDF (Cathode Ray Direction Finder) display unit which operates in conjunction with the Standard Telephones v.h.f. D/F equipment and is intended for identifying the aircraft seen on the Decca display units.

Identification is, however, quite possible without this extra aid by adopting the familiar controller's technique of instructing each aircraft it is required to identify to embark on a particular manœuvre, usually an abrupt change in course for a short distance.

Power Supply:—The equipment operates at 80 volts, 1,000 c/s from a rotary converter; consumption is about 4.5 kW.

During the course of a demonstration aircraft were picked up unmistakably at the maximum range of 25 miles, the characteristic bright "hyphen" on the PPI tube being of excellent definition. Its flight path under v.h.f. radio control was clearly followed, the speed of scanning (20 r.p.m.) keeping the response well illuminated right up to the touch-down point.

In bad visibility this radar can quite obviously be used to bring aircraft safely in to the airfield and exactly on to the end of the runway without any additional navigation aids.

INTERNATIONAL STANDARDS

A BRIEF summary of the results achieved by the various technical committees of the International Electrotechnical Commission during the meetings in Yugoslavia in July has been issued by the British Standards Institution. About three hundred delegates, representing seventeen countries, participated; the largest delegation being from the United Kingdom —43 in all.

A document on the procedure for applying basic climatic and mechanical robustness tests to radio components was approved for publication. A colour code for ceramic capacitors and a specification for fixed paper capacitors were passed for circulation to the National Committees for approval. Agreement was also reached regarding a group specification for ceramic capacitors and for carbon resistors which will be used in the drafting of detailed specifications.

The Committee on Insulating Materials has been considering the standardization of methods of test for specific properties, and at the recent meeting it reviewed in detail the tests for tracking, volume and surface resistivity, and heat resistance.

As the result of comments on a specification for valve bases, a number of additions and modifications to the text were made at the meeting and a revised draft will be circulated. The dimensions of subminiature valves were also discussed and a draft specification is to be prepared.

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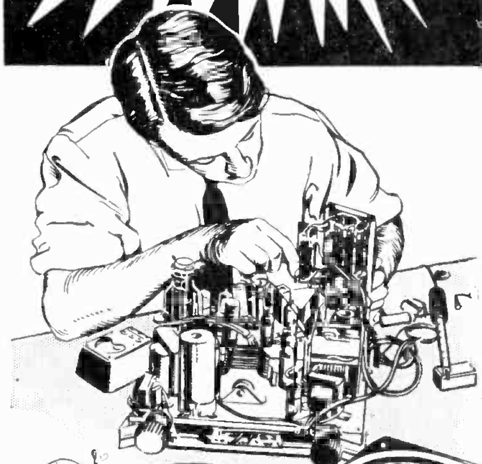

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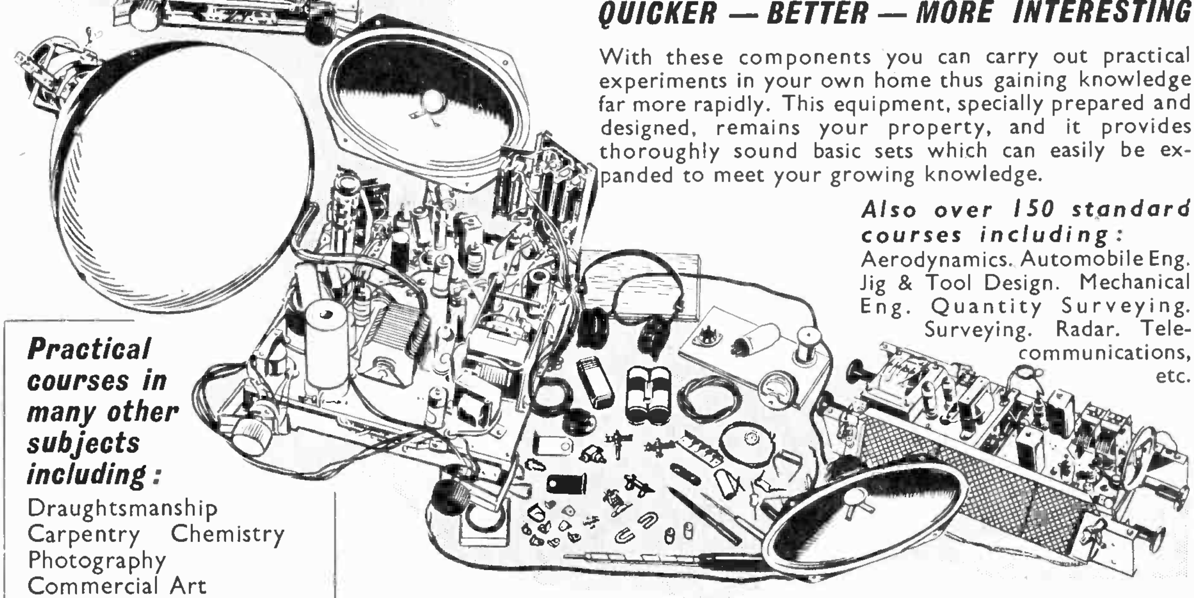

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Neon Tube Measuring Device

Applications as a Microammeter and High-resistance Voltmeter

By H. E. STYLES, B.Sc.

THE neon gas discharge tube has become well established as a device for providing stabilized d.c. voltages, but little attention seems to have been given hitherto to the application of such tubes to the detection and measurement of minute electric currents. In a recent article[1] the author showed how measurement of high resistances may be effected by means of a neon tube shunted with a capacitance, and this application provides a good illustration of the fact that such discharge tubes can be employed for detecting and assessing the magnitude of extremely small currents.

Experience with the instrument described in that article has shown that the circuit of Fig. 1 produces in the telephone receiver a very clearly audible click every five seconds or so. As the mean potential of the capacitance in this circuit approximates to 100 volts, it follows that the average current passed by the resistance must have a magnitude of the order of only 0.01 microampere.

Despite the smallness of this current the device not only renders it readily detectable by ear but does so in a manner which enables quantitative measurements to be made. Furthermore, a current of 0.01 microampere by no means represents the limit of sensitivity obtainable as not only can a lower discharge frequency correspond to a lower mean current but, given a sensitive telephone receiver, the shunt capacitance may be reduced considerably without rendering the discharge pulses inaudible.

It is evident, therefore, that this simple circuit provides an extraordinarily sensitive device for the detection and measurement of electric currents. If, however, the utmost sensitivity is not required, an even simpler circuit may be employed, as, with pulses of sufficient magnitude, a telephone receiver is unnecessary; the flash of the discharge can be clearly seen.

Elimination of the telephone receiver not only represents a simplification, but may be regarded as highly desirable if measurements are being made in very high voltage circuits. It has been found that a CV188 tube shunted with a capacitance of 0.01 μF produces flashes which can be seen with reasonable facility, but for most purposes a shunt capacitance of 0.1 μF is better.

With such a capacitance the neon discharge is sufficiently intense to be easily visible in daylight whilst the capacitance is small enough to permit measurement of currents well below one microampere. For higher currents, of course, a larger value of capacitance may be required.

The mechanism whereby the neon oscillator circuit is able to render minute currents detectable is, of course, quite simple. The circuit merely integrates the more or less steady current flowing through the resistance over an appropriate period of time and subsequently releases the stored energy in precisely regulated pulses of sufficient magnitude to render them evident to the sense of hearing or sight according to the method of detection adopted, the former providing the greater sensitivity.

There are certain limitations to this method of current measurement consequent upon the fact that sufficient electromotive force must be available to raise the potential of the shunt capacitance above the striking potential of the discharge tube. The device is thus restricted to circuits associated with relatively high voltages and resistances, but within these limitations it can prove very useful.

Experimental Investigations.—Experiments to assess the potentialities of a neon oscillator as a current measuring device were made with the circuit of Fig. 2,

[1] "Inexpensive Megohmmeter," *Wireless World*, Oct., 1953, p.484.

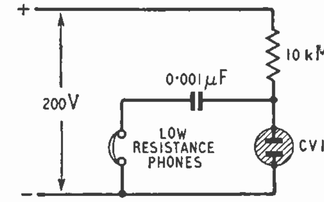
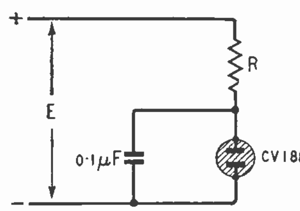
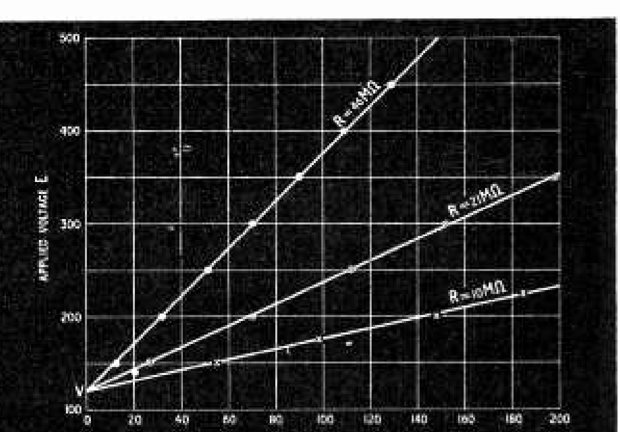


Fig. 1. Circuit giving audible response for current of 0.01 μA.



Left: Fig. 2. Flashing oscillator used for experimental investigations.



Right: Fig. 3. Experimental results with circuit of Fig. 2.

the behaviour of which was observed over a range of applied voltages with various values of resistance R. The observed data are presented graphically in Fig. 3 from which the following conclusions may be drawn.

(a) For any particular value of series resistance R, the relationship between applied voltage E and discharge frequency N is linear, as would be expected on theoretical grounds.

The relationship may thus be expressed in the form $E = AN + V$ where A and V are constants.

(b) For all values of series resistance the lines pass through a single point on the axis of zero discharge frequency. Hence V in the foregoing equation must be of fixed value whatever resistance is employed. The value of V is evidently numerically equal to the mean potential assumed by the shunt capacitance during the charge and discharge cycle and lies somewhere between the striking and extinction potentials of the particular neon tube employed.

(c) It follows from (b) that the difference E-V corresponds to the mean voltage across resistance R. Hence the mean current flowing through the resistance must be given by the expression $\frac{E-V}{R}$. Since $E - V = AN$, it follows that if I be the current flowing through the resistance, then

$$I = \frac{AN}{R}$$

(d) Provided that there is no significant leakage across the capacitance, and/or the neon tube when the latter is not in its conducting condition, it is obvious that the whole quantity of electricity passing as a current through R must correspondingly pass in the form of pulses through the neon tube. The magnitude of these pulses, however, is maintained constant at a value dependent solely upon the size of the shunt capacitance and the characteristics of the neon tube. Hence the frequency at which the discharge pulses occur must be directly proportional to the magnitude of the mean current flowing through the resistance. This implies that the ratio $\frac{A}{R}$ should itself be a constant and that this is in fact the case is shown by the experimentally derived data :—

Value of R Megohms	Value of A	Value of $\frac{A}{R}$
10	0.56	0.056
21	1.17	0.056
46	2.55	0.055

This fresh constant $\frac{A}{R}$, which may conveniently be termed K, is numerically equal to the mean current corresponding to a discharge frequency of one per minute and, in the case of the circuit experimentally investigated, had a value of 0.056 microampere. With lower values of shunt capacitance a correspondingly lower value of K would be obtained and *vice versa*. Strict proportionality between the values of shunt capacitance and K may conceivably not be obtained as it is possible that the striking and extinction characteristics of the neon tube may be slightly influenced by the intensity of the discharge pulses. This point has so far not been investigated but is regarded as of no great importance as empirical calibration must of necessity be employed owing to the inherent variance of individual discharge tube characteristics.

(e) From what has already been said it is evident that the relationship between applied voltage and discharge frequency can now be expressed as follows

$$E = KRN+V$$

where K is a constant depending upon the value of shunt capacitance employed.

For a fixed value of E it follows that if N_1 and N_2 are the discharge frequencies obtained with resistances R_1 and R_2 then $KR_1N_1 = KR_2N_2$

Hence $\frac{R_1}{R_2} = \frac{N_2}{N_1}$ which is the relationship upon which the design of the megohmmeter described in the article referred to previously was based.

Alternatively, since A, the slope of the voltage-frequency line, equals KR, it is evident that the ratio of the slopes of lines obtained with different resistances will be the same as the ratio of the resistance values themselves. If one of the latter is known the other can be derived from the slope ratios.

(f) If frequencies N_1 and N_2 correspond to two voltages E_1 and E_2 with a fixed value of resistance R and a particular shunt capacitance then

$$E_1 = KRN_1 - V \text{ and } E_2 = KRN_2 - V$$

Hence $E_1 - E_2 = KR(N_1 - N_2)$

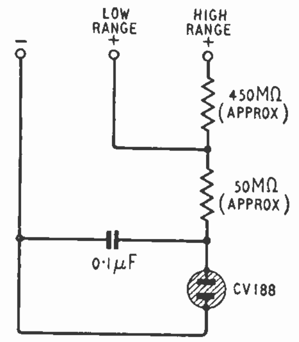
or $K = \frac{E_1 - E_2}{R(N_1 - N_2)}$

Thus if R is of known value the value of K can be determined without having to take an elaborate series of measurements. For a shunt capacitance of $0.1\mu F$ a resistance value of about 20 megohms is convenient for determining discharge frequencies at 200 and 300 volts.

(g) One final conclusion can be drawn from Fig. 3 which, though having no great bearing upon the immediate problem, is nevertheless worth noting. It has already been mentioned that the mean potential V across the shunt capacitance must be less than the striking potential of the neon tube. In practice, therefore, it is not physically possible to obtain discharge frequencies corresponding to applied voltages lying between V and the striking potential (about 140V). A glance at Fig. 3 will quickly show that this frequency gap is greater the lower the value of the series resistance so that if, for any purpose, it be desired to generate a very low frequency discharge, a very high value of series resistance must be employed. The desired result cannot be obtained by using a lower applied voltage in conjunction with a lower value of series resistance though this is possible at frequencies of higher order.

Practical Applications. Having established the foregoing essential facts concerning the behaviour of neon oscillator circuits it becomes possible to consider the practical applications of the device. These would seem to be as follows :—

(1) *Measurement of High Resistances.* One method has already been described in reference (1); this possesses the advantage of requiring no measuring instruments of normal type and may still be regarded as the best method of using a neon oscillator for resistance measurement. It is evident that, since the neon oscillator can be made to serve as an extremely sensitive microammeter, such an oscillator, once calibrated, could be employed in conjunction with a



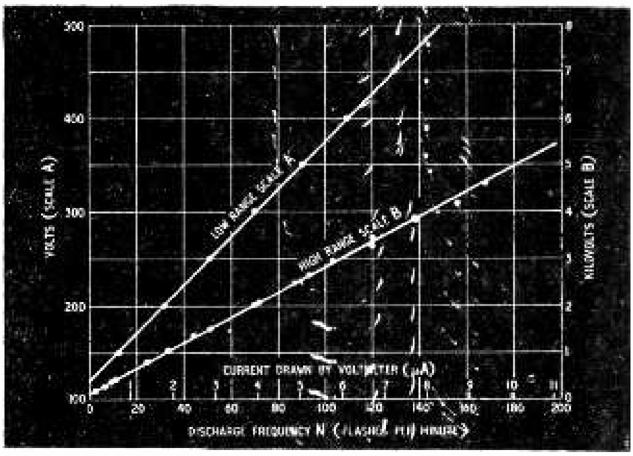


Fig. 4. Two-range neon voltmeter with maximum current of 10 μA
Right : Fig. 5. Voltmeter calibration curves

voltmeter (neon or otherwise) for resistance measurement. In such case, in order to eliminate the possibly unknown effect of the potential drop across the shunt capacitance of the neon microammeter, resistance determination should be based upon the difference in current produced by a known change in applied voltage.

(2) *Measurement of High Voltages.* In radio and television work a need frequently arises for a means of measuring the voltage in circuits of high impedance or of sources of limited power output, e.g., r.f. oscillator e.h.t. generators. For such purposes it normally proves necessary to employ either extremely sensitive moving-coil meters or some form of valve voltmeter, though electrostatic instruments can be used for voltages in the kilovolt range.

All such instruments suffer from one or more of the drawbacks of high cost, delicacy and relative complexity, but the circumstances under consideration are precisely those for which it has been shown that the neon circuit is pre-eminently suited. Fig. 4 shows the circuit of a two-range neon voltmeter and it is difficult to imagine a cheaper, simpler or more robust instrument.

Experimentally determined calibration curves for this instrument are given in Fig. 5, from which it will be seen that the linear relationship between applied voltage and discharge frequency is well maintained with series resistances of the order of 500 megohms. The instrument covers voltage ranges of 150 to 500 and 150 to 5,000 with a maximum current of about 10 microamperes in both ranges. This corresponds to some 100,000 ohms per volt which far exceeds the figure obtainable with straightforward moving-coil meters and is likely to be adequate for most purposes. If necessary, however, the sensitivity could be greatly improved by reduction of the shunt capacitance, but this introduces some difficulty in obtaining the extremely high values of series resistance which must then be employed.

An upward extension of the voltage range can be obtained either by increasing the series resistance or by increasing the shunt capacitance, though the latter will involve an increase in the " full scale " current. It should, perhaps, be noted that for high-voltage work the series resistance should comprise a chain of resistors of lower resistance value in order to restrict the voltage drop across individual components. The author uses twenty such resistors, each of approximately 25 MΩ ; high-stability components should be employed if possible. The shunt capacitor has only to withstand the striking potential of the neon tube, but must possess the highest possible leakage resistance to avoid error from voltage drop.

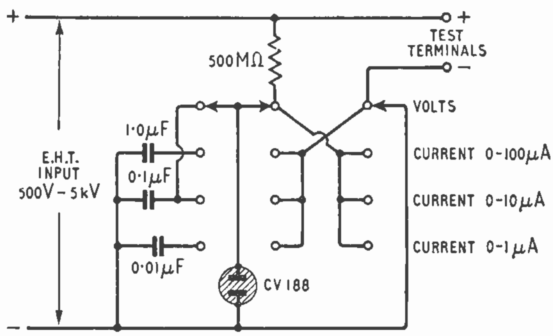
The high-voltage calibration points shown in Fig. 5 were obtained by means of a 2,000 ohms per volt moving-coil meter used in conjunction with an r.f. oscillator e.h.t. supply, and it is of interest to note that removal of the moving-coil voltmeter load resulted in an increase from 4,600 to 5,300 volts at the maximum setting of the oscillator. Deviations of individual calibration points from the straight line in Fig. 5 can be attributed to difficulties encountered in maintaining an entirely steady output from the e.h.t. supply.

(3) *Measurement of Leakage Currents at High Voltages.*

As a microammeter, the neon oscillator becomes inoperative at voltages below about 140 and this precludes its use for a number of purposes for which microammeters are needed. No such drawback applies in testing high-voltage television components, etc., for leakage at working potentials and for work of this character the neon oscillator has definite advantages apart from its great sensitivity.

The author employs an r.f. oscillator as a source of adjustable e.h.t. for tests of the kind in question and originally employed a moving-coil microammeter for measuring leakage currents. It was thought that the limited output available from the e.h.t. generator would automatically protect the meter from damage in the event of a breakdown in the insulation of a component undergoing test, but this proved to be a costly miscalculation. It was observed that when such breakdown occurred a spark discharge sometimes took place within the meter despite its low coil resistance and the fact that it was " earthed " on one side. This was attributed to the inductance of the coil offering a high reactance to the current surges produced by insulation breakdown, but the destructive nature of the spark discharge was not appreciated until eventually the coil became open-circuited. This unhappy experience has convinced the author that moving-coil meters are quite definitely unsuitable for high-voltage leakage tests, whereas the neon oscillator is able to withstand breakdown surges without damage.

The circuit of Fig. 6 indicates how a single neon



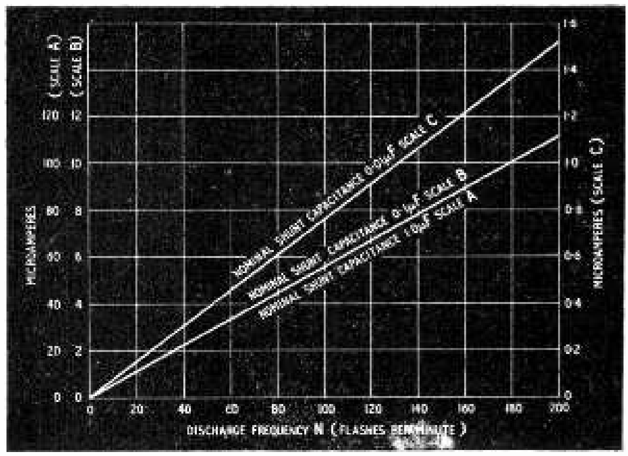


Fig. 6. Circuit for high-voltage leakage tests
Right : Fig. 7. Microammeter calibration curves

tube may be employed for both voltage and current measurements, the switching being such as to permit a choice of shunt capacitances for current measurement purposes. These capacitances can, of course, be calibrated at lower voltages in the manner already described and Fig. 7 shows curves which were thus obtained for capacitances of the values given in Fig. 6. The fact that the curves for the 1.0 and 0.1-μF capacitances are superimposed in Fig. 7 is purely fortuitous, no special selection of capacitors having been made, though this could be done if considered necessary. The 0.01-μF capacitor was evidently of higher capacitance than its rating compared with the other two.

A word of caution may perhaps not be amiss at this point regarding the dangers associated with high-voltage equipment. Whilst an e.h.t. generator of the radio-frequency or fly-back type may itself be quite safe by virtue of small storage capacitances and low power output, such a device can charge circuits of high capacitance with potentially dangerous amounts of energy. Very great care should therefore be exercised in such circumstances, bearing in mind the fact that high voltages can spark across gaps which would be quite safe at lower voltages. A golden rule is to keep one hand in a pocket when working with live equipment ; this at least ensures that a shock is not taken from one hand to the other via the chest.

Finally, there is one feature of neon discharge tubes which has to be taken into consideration in the design of equipment based upon them. The striking potential of a particular tube may be increased considerably if the tube is completely screened from light as the latter radiation serves to promote ionization of the neon gas within the tube. It is important therefore to design the equipment so that the tube itself is subjected to light radiation though a moderate amount of shading is permissible. Other components should preferably be housed in a well-closed box in order to obviate as far as possible the accumulation of surface deposits which may cause undesirable changes in the values of series resistors, or may give rise to leakage across capacitors or tube holder.

HIGH PULSE-RATIO RADAR

Methods of Range Extension in the Decca "45"

THE new Decca marine radar, Type 45, is a modified version of the Type 12 in which range scales having maxima of ½ and 45 miles have been added to the existing ranges of 1, 3, 10 and 25 miles. The minimum range and range dicrimination remain at 25 yards (with a pulse width of 0.1 μsec), and the new ½-mile range gives an effective scale of 168 yards to the inch.

The 45-mile range, which has been added at the request of shipowners to enable earlier landfalls to be made, would not be effective without a substantial increase of power and/or overall efficiency, compared with that required for the 25-mile range which has hitherto been regarded as an adequate maximum. Decca have achieved this partly by increasing power 2.5 db (from 10 to 18 kW peak in the pulse), but chiefly by increasing the pulse length to 1.0 μsec in the longest range, and by general improvement in the aerial and receiving circuit efficiency.

Specifically, the increased power output has been obtained with a more efficient type of magnetron and the power supply conditions are substantially unchanged, so that externally the appearance is the same as the Type 12, and the advantages of compactness, and ease of installation and maintenance have been retained. The aerial scanner aperture has been increased and the width is 6ft, giving a beam width of 1.2 deg compared with 1.6 deg in the Type 12—an effective increase of 4.5 db in gain. The increased energy returned from a 1-μsec pulse is supplemented by an increase in receiver efficiency, since a narrower bandwidth can be used. An overall gain of 8 db results from the use of this long pulse. In the mixer and pre-amplifier circuits an improvement of 3 db in noise factor has been effected, bringing the total gain improvement of the Type 45 over the Type 12 up to a total of 18 db. This is a maximum theoretical figure, but in practice 15 db (measured) is consistently achieved. To obtain a comparable performance solely by increasing power would require 320 kW in the pulse compared with the original 10 kW. This may seem a big increase for an extension of only 50 per cent in range, but it must be borne in mind that the range in radar is proportional to the fourth root of the power employed.

In the interest of long life, the h.t. supplies to the relatively expensive cathode-ray tube and magnetron are now controlled by a separate stand-by switch.

The price of the Type 45 is £1,900, compared with £1,750 for the Type 12 which will still be made.

Reflex Push-Pull Receiver

Two-valve Local-station Set

By G. J. POPE

A SMALL self-contained receiver forms a useful addition to the home as it can be taken from room to room which is not always convenient with a larger set. It is also invaluable in the case of illness. The set described here has three valves only, two being SP61 war-surplus type and the third is an EA50 diode. It is a t.r.f. set with the unusual feature that the r.f. valve forms one half of a push-pull output stage using a reflex circuit. This arrangement was particularly attractive since a ready means of achieving the necessary phase reversal between the output valves' grids suggested itself.

Considering the circuit diagram, Fig. 1, it will be seen that a conventional series diode detector feeds V_2 via the gain control. A common cathode return circuit is arranged to give the correct Class A bias condition for both valves. At r.f., V_1 cathode is by-passed adequately by C. An a.f. signal appears across R which is approximately half that available between V_2 grid and earth. This relationship may be shown to hold if the amount of negative-feedback occurring is calculated.

The gain of a feedback amplifier is given by the formula,

$$\text{Gain} = \frac{A}{1 + A\beta}$$

where : A = gain in absence of feedback
and β = fraction of output fed back

The feedback circuit is shown in Fig. 2, where series current feedback occurs due to a fraction $\frac{R_k}{R_k + R_l}$ of the output acting in opposition to the input signal voltage e_g. Now since V_2 is a pentode, its gain is given by :—

$$g_m R_l \text{ approximately}$$

The optimum load for the SP61 is 20 kΩ, hence gain without feedback

$$= 9 \text{ ma/V} \times 20{,}000$$
$$= 180 \text{ times.}$$

$$\text{With feedback, gain} = \frac{180}{1 + 180 \times \frac{100}{20{,}000}} = \frac{180}{1.9}$$

$$\simeq 95 \text{ times}$$

It will thus be seen that the gain is reduced by approximately 6 db. The voltage across R_k will be :—

$$\frac{1}{200} \times 95 \simeq \frac{e_g}{2}$$

Since this voltage acts in opposition to e_g, the grid cathode voltage of V_2 is also $= \frac{e_g}{2}$

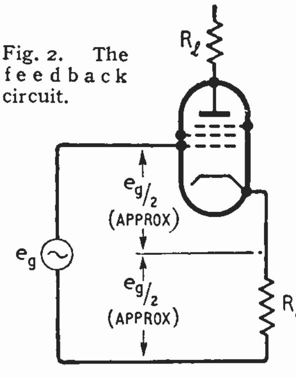


Fig. 2. The feedback circuit.

Since the cathode circuits are common, V_1 acts as a cathode driven push-pull stage, its grid being at earth potential to a.f. Approximately the same ratio of cathode volts to grid drive volts is obtained if the anode load is varied over wide limits, so that the exact value of anode load is

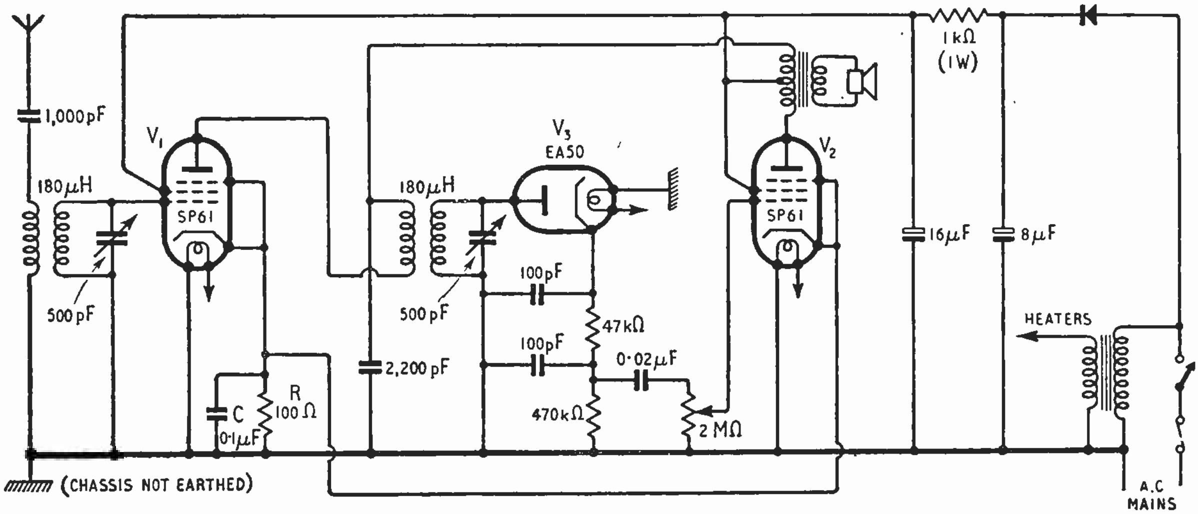


Fig. 1. Circuit diagram of the receiver, with the r.f. valve forming one half of a push-pull output stage using a reflex circuit.

unimportant on this account. This may be an advantage if a standard push-pull component only reflecting somewhat lower loads is available. The value of C at a.f. is insufficient to materially affect the response. The connection of this form of a.f. drive to the second valve causes 6-db drop in sensitivity as mentioned above, but a 3-db increase results from the added output stage, so that the final arrangement is 3-db less sensitive. The receiver is, however, capable of giving an extra 3 db output power, that is, twice that of a single valve. Since the receiver is built for local-station use the question of sensitivity is relatively unimportant, ample output being obtained on about 10 ft of aerial in London.

The push-pull circuit allows the use of a small output transformer since the core flux due to each valve's anode current cancels out. In practice for a given size component this means better low-frequency response. The writer uses a midget component and the bass response is very good. Another small advantage push-pull has is that a common un-bypassed cathode resistor can be used, so saving a low-voltage electrolytic capacitor which would otherwise be necessary. The omission of the bias by-pass capacitor from a power amplifier of this kind is usually not recommended, but no serious distortion has been apparent.

The author's model employs switched station selection which was considered adequate and possibly simpler for the rest of the household to handle. When operated in the London area it may be found advantageous to make the aerial connection switchable from the primary side of the aerial transformer to the grid connection, so that the sensitivity may be increased for the reception of weaker stations. This was found necessary for Third Programme reception with a short aerial and connections may obviously be adjusted to fit individual geographical locations.

Any coil with a tuned winding "Q" of approximately 100 and inductance of 180 μH or so may be used in both positions, but for constructors not in a position to make their own, Osmor Q-type QA11 and QHF11 are suitable for aerial and intervalve transformers respectively.

There is no reason why a germanium crystal should not be used for the detector but in this case the value of the diode load should be dropped to about 100 kΩ. This may result in some loss of selectivity, but it is not likely to be troublesome.

With the output stage and loudspeaker matched to give an anode-to-anode load of 20 kΩ an output of about 0.75 W is provided. If a lower load figure is taken the output will be correspondingly reduced.

MANUFACTURERS' LITERATURE

Tubular M.C. Microphone of unobtrusive appearance, 1in in diameter and weighing 9oz. Leaflet giving brief specification and frequency response curves from Standard Telephones and Cables, Connaught House, Aldwych, London, W.C.2.

Rotary Switch Wafers with improved fixing of contact clips on stators to avoid loosening during soldering. Engineering data sheet on type DH and DM "Oak" sections from NSF, Keighley, Yorks.

Television Aerial Feeder Cables, coaxial solid, coaxial semi air-spaced, balanced screened twin and unscreened twin. A leaflet giving characteristics and dimensions from The Edison Swan Electric Company, 155, Charing Cross Road, London, W.C.2. Also new data booklets on Mazda receiving valves and c.r. tubes and Ediswan industrial and transmitting valves.

Crystal Microphones made by Ronette. A new illustrated catalogue giving technical specifications of the complete range is available from the Mail Order Supply Company, 33, Tottenham Court Road, London, W.1.

High-Voltage Capacitors, tubular paper types, suitable for smoothing television e.h.t. supplies, with working voltages of 20 kV and 25 kV. Technical bulletin No. 40 from The Telegraph Condenser Co., North Acton, London, W.3.

Small Soldering Iron, $\frac{5}{16}$in diameter and $9\frac{1}{2}$in long, with four interchangeable bits and designed to operate from a 20-V bus-bar installation. Leaflet from the Electrical Remote Control Co., East Industrial Estate, Harlow New Town, Essex.

Dry Electrolytic Capacitors and others, with ratings, sizes and prices, listed in a booklet intended for the servicing trade. From A. H. Hunt (Capacitors), Bendon Valley, Garratt Lane, Wandsworth, London, S.W.18.

Sound Reproducing Equipment, a leaflet giving brief descriptions and prices of the products of Grampian Reproducers, Hanworth Trading Estate, Feltham, Middlesex.

Portable P. A. Equipment with vibrator power pack working from a 12-V battery. Descriptive leaflet from Easco Electrical, Brighton Terrace, London, S.W.9.

Interference suppressors for various types of electrical apparatus. A booklet describing the models available and methods of fitting them from Belling & Lee, Cambridge Arterial Road, Enfield, Middlesex. Also a booklet describing their sound, television and anti-interference aerials and accessories and a catalogue of components and accessories.

Coaxial Connectors, American military types for 50Ω and 72Ω and for various cable diameters between 0.2in and 1in Also a leaflet giving information on how to connect cables to them. From Besson and Robinson, 6, Government Buildings, Kidbrooke Park Road, London, S.E.3.

Accessories and Electro-mechanical Devices, a list of Government surplus equipment from A. T. Sallis, 93, North Road, Brighton, Sussex.

A.C. Voltage Stabilizers for regulating mains voltages, including heavy-duty types for currents of 30A to 130A. Full descriptions in a supplement to their "Variac" catalogue V549 from Claude Lyons, 180, Tottenham Court Road, London, W.1.

"Moulded Plastics for Industry," an illustrated booklet describing the moulding processes carried on by the G.E.C. works at Witton and listing some typical products. From the General Electric Company, Magnet House, Kingsway, London, W.C.2.

P-N Junction Crystal Diodes with similar characteristics to standard American types. A leaflet giving general features and prices from Detectron, 25, rue de Toulon, Bordeaux, France

Television Aerials with elements already assembled but folded up. Single and multiple types described in leaflets from Antiference, Bicester Road, Aylesbury, Bucks.

Components and Accessories, tools and test gear; a comprehensive illustrated catalogue of 150 pages from Rudolph Schmidt, Gl. Kongevej 64, Copenhagen, Denmark.

Preferred Valves List, second edition, 1953. Takes into account greater range of miniatures now available and includes American and military equivalents. Full data and base diagrams are given. Available from the Scientific Instrument Manufacturers' Association, 20, Queen Anne Street, London, W.1, price 3s 6d, post free.

Valve Voltmeter for measuring the maximum amplitude of transient phenomena having a duration of at least 1 millisecond. It has a range of 0-20V and an input impedance of 33kΩ and there are two meters to cater for positive and negative peaks. Explanatory booklet with diagrams from Standard Telephones and Cables, Transmission Division, North Woolwich, London, E.16.

Aerials and Accessories for sound and television reception. A 1953/54 comprehensive catalogue from Aerialite, Castle Works, Stalybridge, Cheshire.

Pressure Transducers, one type for measuring static pressures in ranges from 0-25 to 0-4,000lb per sq in and another for fluctuating pressures in ranges from 0-250 to 0-50,000lb per sq in. Also a dynamometer for measuring tensile loads in ranges from 0-50 to 0-10,000lb. Descriptive leaflets from J. Langham Thompson, Springland Laboratories, Bushey Heath, Herts.

Small Motor Blowers with weights between 2lb and 40lb and power consumptions between 33 and 440 watts. Leaflet from Air Control Installations, Ruislip, Middlesex.

Glass Marking Colour, suitable for writing on valves, available in black, white, red, orange, yellow, green and blue. Leaflet from George T. Gurr, 136, New King's Road, London, S.W.6.

Manufacturers' Products

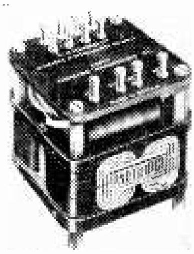
NEW EQUIPMENT AND ACCESSORIES FOR RADIO AND ELECTRONICS

Output Transformer

THE illustration shows one of the latest type of push-pull output transformers now produced by Partridge Transformers, Roebuck Road, Tolworth, Surrey, using grain orientated strip-wound cores (generally known as "C" cores).

This model is the Type P3064 having a power handling capacity of 20 watts for less than 1 per cent distortion. The maximum d.c. per half-primary is 100 mA and a 20 per cent out-of-balance current can be tolerated. The d.c. resistance of each half primary is 100 ohms.

Four separate secondary windings are provided which by series or parallel connection give correct operating conditions with a primary loading impedance of 10,000 ohms for



Partridge Type P3064 push-pull transformer giving the choice of several output impedances.

loudspeakers of 0.95 ohm, 3.8, 8.5 and 15 ohms impedance respectively.

With the equivalent of 10,000-ohms resistive load on the primary the frequency characteristic is virtually flat having a deviation of ± 0.5 db only over the range 30 c/s to 30 kc/s. The leakage inductance is claimed to be less than 8 mH.

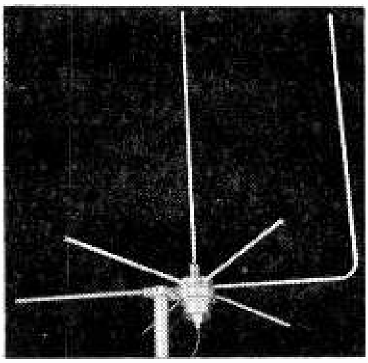
This transformer measures $2\frac{7}{8} \times 2\frac{7}{8} \times 3\frac{1}{4}$ in, weighs $2\frac{1}{4}$ lb and costs £4 18s.

Television Aerial-Amplifier Unit

A NEAT and workmanlike way of obtaining a good television signal with a simple aerial in fringe areas is shown in the illustration. It consists of a ground-plane aerial with reflector and in the centre hub of the system is housed a two-stage head amplifier. One valve is a neutralized triode amplifier, the other is a cathode follower.

The vertical elements of the aerial are a quarter-wavelength long and the horizontal members, which serve as an artificial "earth," measure a half-wavelength from tip to tip. It is reasonably light in weight and can be mounted on the usual 2-in o.d. tubular mast.

The necessary heater and h.t. supplies are fed to the amplifier along a two-core screened cable which is



Spencer-West Type AC8 television aerial embodying a head amplifier.

also the feeder for signals from the aerial to the receiver. A small power supply unit is required and is mounted close to the receiver.

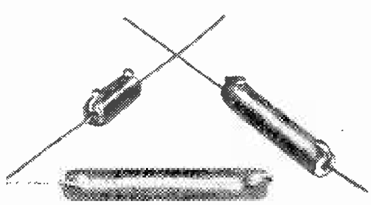
The aerial system can be fitted with a relay for automatically switching on the head amplifier when the main receiver is switched on.

The makers are Spencer-West, Quay Works, Great Yarmouth, and the aerial, known as the Type AC8, costs £33 15s including 65 ft of feeder and a power supply unit.

Vitreous Resistors

A RANGE of vitreous-enamelled resistors wound with nickel-chrome resistance wire on ceramic formers is now in production by Labgear, Ltd., Willow Place, Cambridge. They are at present available in $4\frac{1}{2}$-, 6- and 10-watt types, these being the commercial ratings, but for Service equipment the ratings are lower at 3, 4.5 and 6 watts respectively.

All three types have the same outside diameter of $\frac{1}{4}$ in approximately, but differ in length, the smallest being $1\frac{3}{8}$ in and the largest $1\frac{3}{4}$ in. The resistance ranges are as follows: 4.5-W, 10 to 12,000 ohms; 6-W, 5 to 33,000 ohms and 10-W, 5 to 47,000 ohms. The normal tolerance is ± 5 %.



Labgear range of vitreous-enamelled wire-wound resistors in $4\frac{1}{2}$-, 6- and 10-watt types.

RANDOM RADIATIONS

By "DIALLIST"

Oh for V.H.F.!

THIS COUNTRY'S v.h.f. sound broadcasting service can't come into being too soon for me; or, I expect, for a good many others who are growing very tired of the interference on the medium- and long-wave bands. Myself, I can seldom receive the Light Programme even reasonably well. To bring in the medium-wave transmission without interference from one or more stations selectivity must be pushed up until there is a marked decline in quality: on the long waves there is too often a poisonous heterodyne whistle. The Home Service from Brookmans Park is also liable to heterodyne troubles, while at times some foreign station provides an annoying background. I'm coming to rely more and more on the 90-Mc/s transmissions from Wrotham with their almost entire freedom from interference. The snag is that Wrotham sends out only one programme at a time; and too often it isn't the one I want.

It Shouldn't be Long

I haven't a doubt that f.m. will win the day for the official service. To two important points I can testify without reserve. The first is that, given a.f.c. (which you must have, anyhow, to look after oscillator drift) the f.m. receiver isn't the tiniest bit more difficult to tune than the a.m. The second is that f.m. is not just a little more effective than a.m. against impulsive interference: it's *vastly* better than a.m., even with a limiter. Once the modulation question is decided, it shouldn't take long to get the services going. Note that I say services in the plural, for the slot aerials below the dipole arrays on the mast of every television transmitting station can transmit two v.h.f. programmes on different carrier frequencies. It would seem hardly necessary to build giant transmitters, to begin with, at any rate. The 18-20 kilowatts of the now well-proved Wrotham transmitter appear to give a service area quite as large as that of either of the medium - wave Brookmans Park giants. I'm speaking, of course, of the f.m. transmissions with which the minimum necessary field strength is much smaller than with a.m. The signal need only be strong enough to work the limiter to give you all that's going.

A New Contributor

TURNING THROUGH the pages of a learned American journal, I was electrified by finding in it a reference to a recent *Wireless World* article "by R. W. Hallows and M.A. Cantab." The latter belongs, of course, to the *coterie* of writers which includes such authorities as B.A. Oxon, M.D. Lond., D.D. Dunelm and M.B. Leeds amongst its English members. Well-known Scottish members of it are the Mac Antabs and Mus. B. Edin.

They Have a Word for it

I REALLY CAN'T swallow without many grains of salt Malcolm S. Morse's statement in the October correspondence columns that motor car ignition interference with television reception is unknown in the U.S.A. Nor can I accept for a moment his suggestion that American sets, though used in a veritable welter of radiation from millions of unsuppressed cars, provide undisturbed pictures because they are so much better designed than ours. There's no mystery about the design of the sets made on the other side of the Atlantic. They incorporate nothing in the way of anti-interference devices that our manufacturers don't know and use. There may be differences in the ways in which we use them, but these are due to our positive modulation. I suspect that Mr. Morse's "unsuppressed" means that the owners of the cars haven't deliberately had suppressors fitted. No need to do so if your new car has already been treated as a matter of course before delivery. But there must be noticeable interference, or one wouldn't read so many references to "auto-ignition static."

Useful Jobs of Work

THE SUBMARINE television camera is destined to play a very useful part in salvage operations. A diver working in deep water uses a cable with a heavy weight at its lower end, known as the shot-rope. It used to be impossible to tell whether the shot-rope had been put into the right position until the diver went down to find out. He can't move more than a foot or two from it with safety; if it is wrong, he must come up and another attempt must be made. You'll see that this can be a very slow business; a whole tide may, in fact, be wasted. With the TV camera it's just too easy. The camera goes down and the shot-rope is moved until it is seen on the receiving screen to be in exactly the right place. The diver then goes straight to his job. His partnership with the TV camera doesn't end there either. He can telephone for the camera to be moved to where he needs it when he wants to show observers above something of special interest that he has found. They can then make a permanent record by means of photographs or ciné films of the screen.

Not So Hot

MANUFACTURERS of television receivers can be pretty badly let down when their sets are installed by careless or inefficient service-men. The other day a non-technical friend told me he was a bit disappointed in the set (his first) which had cost him a tidy sum. When I dropped in to see how it was performing, I wasn't surprised. The first thing that struck me was that on the 14-inch screen the image was barely 10 inches in width. The aspect ratio was nothing like 4:3; the image appeared badly distorted, and this was confirmed when I tried the set on Test Card C a few mornings later. Though the set was in a back room, the aerial had been fixed to a chimney stack at the front of the house where it brought in the maximum amount of interference from every unsuppressed motor vehicle. Had it been mounted on a convenient high chimney at the back, the dipole would have been 40ft further from the road and probably outside the ignition interference zone. Luckily, one doesn't often see sorry jobs of that kind; it's sad that one should ever come across them.

Taxi!

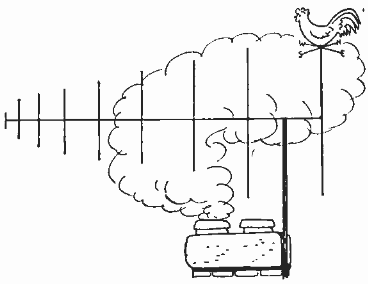
WHEN I WAS just on the point of sending off the manuscript of this month's jottings the postman brought a letter from a reader in the W.9 district of London. In the early part of last year he made a tape recording on his own machine. On playing it back, he was amazed to hear two voices: his own and that of a taxi driver speaking to his headquarters. He now sends me a cutting from September 20th issue of *The Observer* describing a similar occurrence (except that on this occasion a voice speaking from headquarters and not the taxi man's was recorded). I haven't had time before writing this to think of an explanation of this queer business. Can any reader suggest one?

UNBIASED

By FREE GRID

Strange TV Aerials

TRAVELLING to the wilds of East Anglia recently I was struck by the changing character of the TV aerials as the train receded from London. At first there was nothing but the familiar "H" type to be seen among the chimney pots, with here and there a plain dipole. As we drew nearer to that part of the country made famous and hallowed by Hereward the Wake and St. Etheldreda respectively the aerials began to assume strange shapes; weird and wonderful multiple arrays sprouted up here and there in an



Xylophone TV aerials

endeavour to catch the ever more elusive signals from the transmitter.

Eventually we passed the lofty West Tower of Ely Cathedral soaring majestically over the flat fen country surrounding it—surely a veritable gold mine for the Dean and Chapter if and when commercial television eventually goes a site-seeking. Beyond Ely the only TV aerials to be seen were what I can only describe as the xylophone or dulcimer type which I have endeavoured to illustrate in my sketch.

I subsequently had cause to visit Alexandra Palace and expected to see the aerials become less and less conspicuous until in the vicinity of the transmitter they disappeared altogether as being unnecessary. To my surprise, however, I found that in one district bordering on the Palace they seemed more conspicuous than in remoter suburbs.

I naturally suspected the existence of some inexplicable pocket of low signal strength and I dropped in to a local dealer's place to discuss the matter. He shook his head, however, and pointed out that signal strength was so great that an attenuator rather than an aerial was needed. He went on to say that the people in the district were so afraid the neighbours would think they couldn't afford TV that they always demanded an aerial; in fact, one of his customers who had the largest car and the most beminked and bejewelled wife in the district insisted on his erecting a mast having not an H but the letters TV at the top so that there could be no misunderstanding.

Etheric Anarchy

THERE HAS BEEN a lot of talk about the difficulties of clearing Band 3 of such things as business radio in order to make it safe for television. In my opinion, however, if v.h.f. communication goes on spreading at the rate it is doing at present TV will eventually be squeezed out of the ether altogether. I feel rather strongly on the matter as I have some personal experience of what is going on.

It so happened that a few weeks ago my eye was caught by a remarkable shop-window display of the potential and actual uses of business radio. One of the chief features of the display I saw was an errand boy on a bicycle with a v.h.f. "X-eiver" in his bicycle basket, and headphones over his ears, receiving instructions from his employer. I cannot tell you where this remarkable display was—and probably still is—as the Editor won't have any suggestion of advertising in these columns. However, when I tell you that it was in a part of London with street names recalling the past glories of the de Vere family you obviously only need to ring up the Editor of Burke or Debrett in order to find out where I mean.

In a foolish moment I told Mrs. Free Grid all about it and then promptly dismissed the matter from my mind until a couple of weeks later I observed a friend of hers pushing a pram and apparently talking to herself. Closer observations revealed dainty hearing-aid type earphones, a mike and a neatly mounted rod aerial. The set, I discovered, was under the baby; a place where I should have thought it would be subject to a heavy damping effect.

This was not all as I presently encountered Mrs. Free Grid herself, complete with pram, grandchild and "X-eiver," and also several others of her coterie all busy chattering away nineteen to the dozen and spoiling good ether. If this sort of thing is allowed to spread we shall be faced with etheric anarchy.

The "Elevated Electrode"

I WAS TALKING the other day to a friend who had been attending the meetings of the C.C.I.R. in London and he was telling me of the weighty matters which had been occupying its attention. One incidental question which cropped up was the correct form of the plural for antenna. There can be no doubt that it is antennæ but some delegates seemed to favour antennas as is used in America. It was, moreover, pointed out that "aerials" was also used in some of the official documents. After some discussion, the delegates agreed to accept the ruling of the *Concise Oxford Dictionary*.

This apparent climb-down on the part of the Yanks rather surprised me as the *Concise Oxford* says without any equivocation that "antennæ" is the plural and it has no truck with "antennas." The *Concise Oxford's* big brother, *O.E.D.*, is far more tolerant of the weaknesses of human nature and gives "antennas" as a permissible alternative.

"To what base uses . . ."