Wireless World

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Government Views on the B.B.C.

TO us at anyrate the Government's White Paper* on the Beveridge Report is a dull and disappointing document. It accepts—as was, indeed, a foregone conclusion—all the major recommendations of the Report, agrees half-heartedly or with reservations with some of the secondary points, and disagrees only with a few financial or organizational proposals that are rather outside our special province. Excellent as the Beveridge Report was, there were, naturally enough, a few shortcomings to which we have already drawn attention; it is to be regretted that the present publication does nothing to fill in these gaps. We take leave to doubt if the White Paper will serve its avowed purpose of facilitating discussion on the future of broadcasting; still less will it stimulate such discussion.

Wireless World is glad to see that the Beveridge recommendation for licensing "public authorities or approved organizations" to operate local stations (presumably working on metre wavelengths) is approved by the Government, but in a manner certainly not less lukewarm than in the Report itself. We are at the same time reminded that the Postmaster General already possesses power under statute to license other broadcasting stations—which, when one comes to think of it, rather makes nonsense of the "B.B.C. monopoly." Though we regard something approaching a monopoly to be essential, so far as broadcasting on normal frequencies is concerned, we are anxious to see the experiment of independent control given a trial.

On the question of v.h.f. broadcasting in general, the views expressed are not particularly encouraging to those of us who hope to see an early start. One fact of importance emerges: the Government has apparently not fully accepted the B.B.C.'s report on the Wrotham experiment, which was in favour of frequency modulation. The Television Advisory Committee (to be reinforced by members with the necessary technical qualifications) is now to advise on the system of modulation to be adopted—after, we are glad to read, consultation with industry.

* "Broadcasting: Memorandum on the Report of the Broadcasting Committee, 1949." Cmd. 8291, H.M.S.O., 6d

The confusion between point-to-point distribution of television signals to cinemas and the broadcasting of such signals for domestic reception (which was one of the weaknesses of the Beveridge Report) is in no way cleared up in the present document. The Government seems to be over-anxious to protect the B.B.C. against anything approaching competition from the cinemas. In our view the question of cinema television is not inherently linked with broadcasting, and so at this stage the issue should not be confused by dragging it into the picture.

Festival Television

A GOOD deal of sympathy has been shown with the views expressed by a correspondent in last month's issue who deplored the poor showing given to television in the "Telekinema" at the South Bank Exhibition. After all, the purpose of the Exhibition is to show the world something of British achievements in the arts, crafts and sciences: we submit that the big-screen television demonstration given there is a real achievement in every sense of the word, and should have greater prominence.

Without decrying the stereoscopic films which at present occupy the greater part of the Telekinema programme time, we suggest that the position should be reversed. Great efforts have been made to convince Europe that the British 405-line system of television is an eminently practical one and no more convincing proof of its excellence can be brought forward than by demonstrating that it gives a big-screen picture of highly acceptable quality. Unfortunately, the great majority of the demonstrations are on closed circuit; this, we believe, is entirely because it is difficult to fit in distribution of the B.B.C. programme with the short hourly showings in the Telekinema. However, we expect some at least of these difficulties might be overcome, and urge that an effort should be made to present more television programmes, and especially a greater number of "live" transmissions, which are more convincing to most people.

Efficiency Line-Scan Circuits

Part I—Directly-fed Deflector Coil

By W. T. COCKING, M.I.E.E.

THE so-called "economy" or "efficiency" line-scanning circuits are becoming more and more widely used in television receivers. In the U.S.A. they are universally employed because of the widespread use of large cathode-ray tubes with large deflection angles. These angles are about 70° for a deflection corresponding to the picture diagonal, whereas in British practice the angle is rarely much over 50°. Then with tubes of 15–20-in diameter high final-anode voltages are needed for good brightness and operation at 14 kV is common. Highly efficient scanning circuits are thus essential.

In British practice the 9-in and 12-in tubes are still usual and so voltages of more than about 9 kV are unnecessary. Together with the smaller deflection angle and the lower scanning frequency, the deflection requirements are much less severe. However, the need for a.c./d.c. operation has made the use of efficient circuits necessary because of the low h.t. voltage available.

A good deal has been written about efficiency circuits and their general mode of operation is well understood. The actual circuits used are quite simple and so are the ways in which they are supposed to work. However, when one tries out such a circuit the results obtained are often very different indeed from what one expects.

The reason for this is that the explanations usually given of the way in which efficiency circuits operate are over-simplified. They are reasonably accurate only if the transformer used approaches the ideal fairly closely. Success with an efficiency circuit depends more on the transformer than on any other single factor.

The effect of the transformer is rarely, if ever, fully taken into account in explanations of the circuit because to do so would make an analysis prohibitively complex. All too often the transformer is assumed to be an ideal one.

Since it is impracticable to analyse the exact circuit, including the transformer in full detail, it is necessary to approach it in a series of approximations. Accordingly we shall start by considering in detail the simplest possible circuit and this is one without any transformer at all. Such an arrangement is fairly straightforward and once its operation is understood the various changes which occur when a transformer is included can be considered one by one and the means which must be adopted to minimize its unwanted effects become evident.

The simplest circuit, with no transformer, is not much used. In fact, the writer knows of no British receiver which includes it. It is generally thought to be an impracticable circuit, but actually it is not, and there are signs that it is coming into use in the U.S.A. A study of the circuit may, therefore, be more than a preparation for the more usual circuits; it may be a study of a future practical circuit.

This simple deflection circuit is shown in Fig. 1. Here L_L is the deflector coil and C represents the total stray capacitance. There is no coupling transformer. The device indicated at A by the rectangle is a device for controlling the diode V_2; for the present it may be ignored.

The reason why Fig. 1 is usually considered to be an impractical circuit is because there is a mean current in L_L which deflects the picture from the centre of the tube. However, under practicable conditions this deflection may be less than 5 per cent; that is, less than ½-in displacement on a 12-in tube. It is possible to correct for a small displacement such as this and so, although unusual, the circuit cannot be said to be an impossible one.

The requirement for a linear scan is usually considered to be a current in the deflector coil which changes linearly with time. Although there are cases where a controlled distortion of the current is desirable it is certainly unusual for the aim in design to be anything but the achievement of linearity. For the current to be linear the instantaneous current i_L in L_L during the scan must have the value

$$i_L = I_L\,(t/\tau_1 - K) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Here I_L is the peak-to-peak value of the current, τ_1 is the scan period and K is a constant. If there were no mean current in L_L the value of K would be ½.

During the scan period there is an inductive back e.m.f. across L_L of magnitude $L_L I_L/\tau_1$ and it acts in such a direction that it makes the anode voltage of V_1 negative with respect to +h.t.; it, therefore, acts in opposition to the h.t. supply. There is also a resistive voltage drop of $i_L r_L$ because of the series resistance r_L of the coil.

The capacitance C is virtually in shunt with L_L and r_L and the voltage which exists across these elements exists across it also. The constant voltage of the inductive back e.m.f. produces no current in C but the constantly changing voltage of the $i_L r_L$ drop produces a constant current $i_c = I_L C r_L/\tau_1$ in C. The magnitude of this current is only about 0.05 per cent of the scan current I_L and can be ignored. The variations of current in L_L and voltage across it are shown in Fig. 2.

Consider conditions just at the end of the scan. V_2 is cut off by a voltage developed in A and V_1 is passing its peak current. Since the voltage across L_L is nearly constant during the scan C draws negligible current, and so the peak current in V_1 is the peak current in L_L and is $I_L\,(1 - K) = i_p$. The current is shown by the single-headed arrow in Fig. 1.

At this instant V_1 is cut off for the flyback by the voltage applied to its grid. V_2 stays cut off. The anode current drops almost instantaneously to zero but the current in L_L cannot drop instantaneously to zero and so it flows into C as shown by the doubleheaded arrow. When V_1 is cut-off, all that happens is that the current is diverted from V_1 to C. This current charges C and so the voltage across it rises and carries with it the anode of V_1. As C charges the current falls.

If there are no circuit losses the energy $\frac{1}{2}L_L i_p^2$ stored in the magnetic field at the end of the scan is eventually converted into potential energy $\frac{1}{2}CV^2$ in C. The maximum possible voltage across C is therefore, $V = i_p\sqrt{L/C}$. The current is then zero.

The current, however, passes through zero to flow in the reverse direction, for as soon as C has become fully charged it starts to discharge and it can do so only through L_L. The current now grows negatively and is shown in Fig. 1. by the three-headed arrow.

At length, when C is discharged, it reaches a negative maximum when the energy has been transferred from C back to L_L. If there were no losses, the current at this instant would be $-i_p$. In practice, there are always losses and the current only reaches the value $-xi_p$; x is the fractional overshoot.

The value of K in the earlier expression for the current in the coil is easily expressed in terms of x and is equal to $x/(1+x)$.

Current Waveforms

During the whole of the flyback period both valves V_1 and V_2 are, or should be, cut off. While the current is changing from i_p to $-xi_p$ the voltage changes from its negative value at the end of the scan, reaches a positive maximum and then falls to zero. After this the current changes back towards zero at an increasing rate and the voltage increases negatively. It very soon reaches a point where the current magnitude is very slightly less than xi_p, a point at which the inductive back-e.m.f. has the scan value $L_L I_L/\tau_1$ and the total voltage is slightly less than this because of the $i_L r_L$ drop. This point is the true end of the flyback and the start of the scan. It is the point on the cycle where the current in the oscillatory circuit is changing at the proper rate for the scan.

This point is in time so little after the negative current maximum that it is customary to ignore the difference and take the maximum as the end of flyback. Similarly, the current at this point is so little smaller than xi_p that it is again customary to ignore the difference and to take the starting current of the scan as $-xi_p$. Precise calculation of the point is surprisingly difficult and the error involved in the approximations is quite small for the kind of circuits that we are discussing.

At the end of the flyback, V_1 is still kept cut off but V_2 is caused to become conductive by the voltage developed in the device A of Fig. 1. This voltage varies in such a way that the current in L_L now decays linearly to zero. The current is diverted from C to V_2 and flows in the way indicated by the four-headed arrow in Fig. 1. When the current reaches zero A acts to cut off V_2 and the driving voltage on the grid of V_1 causes this valve to become operative and to drive current, as indicated by the single-headed arrow, through L_L. V_1 acts to bring the current from zero to i_p and when it has done this the cycle has been completed and another flyback starts.

In practice, V_1 and V_2 do not cut in and out together in the way described, for this would demand extremely critical adjustment. Actually, V_1 starts to conduct somewhat before V_2 stops conducting and there is a small interval during which both are in operation together.

The variations of current with time in the idealized case are shown in Fig. 3(a). From A to B the coil current decays from i_p to zero and flows into the circuit capacitance. From B to C the capacitance discharges to provide the reverse current of magnitude $-xi_p$ at C. From C to D the diode is in operation and the current decays linearly and from D to E V_1 drives a linear current through the coil. The diode and pentode currents are shown at (b) and (c) respectively, for idealized operation by the solid lines and for a practical case by the dotted lines.

The anode voltage of V_1 with respect to + h.t. varies in the manner sketched in Fig. 3(d) and this is also the cathode voltage of V_2. This valve must be conductive only over the period CD so that outside this period the anode voltage of V_2 must be below the

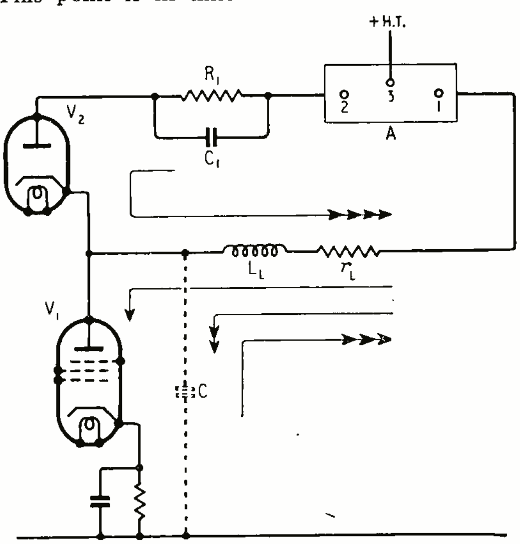


Fig. 1. Basic circuit of directly-fed deflector coil L_L with "economy" diode V_2 and driving pentode V_1. Box A indicates a circuit element for controlling V_2.

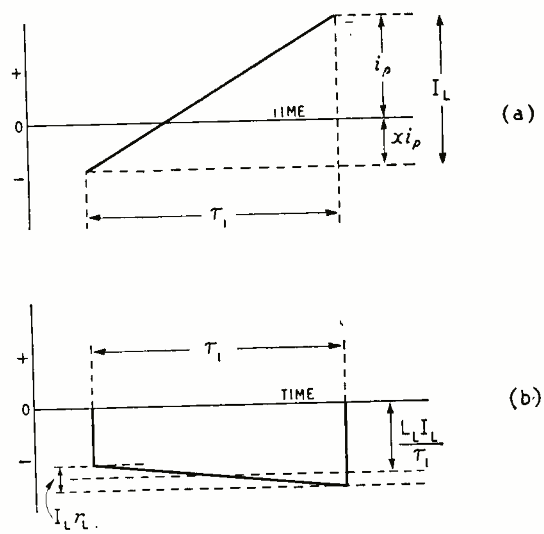


Fig. 2. Deflector-coil current (a) and voltage (b) during the scan period τ_1. The peak-to-peak current is of magnitude I_L.

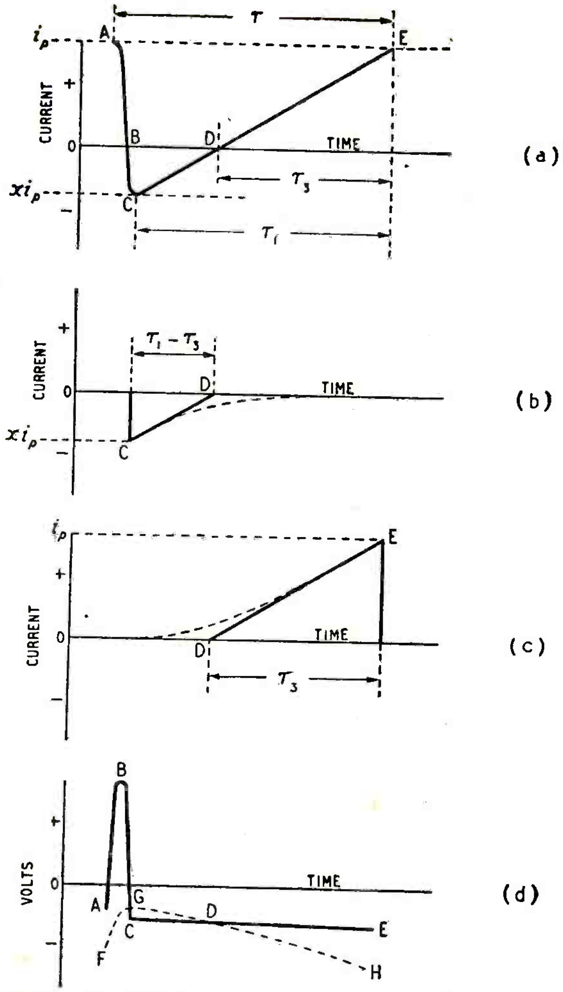


Fig. 3. The waveform of one complete cycle of deflector-coil current is shown at (a) with the voltage across the coil at (d). The current provided by the driving valve is ideally of the form (c) and that through the diode like (b). The dotted curves in (b) and (c) indicate the practical form of the currents and in (d) the dotted curve shows the required variation of the diode cathode voltage.

cathode voltage to keep it cut off. The exact waveform is quite unimportant. During the conductive period CD, however, the anode voltage must vary in such a way that the current decays linearly. The precise waveform over this period is important and controls the linearity over the left-hand side of the picture.

Computation of the waveform requires that the resistance of the deflector coil and the diode characteristics be taken into account. What is needed is shown very roughly by the dotted line in Fig. 3(d); the waveform over the regions FG and DH being unimportant.

This anode voltage is provided partly by a nearly constant voltage developed across R_1C_1 by the diode current and partly by the device A. This is usually a suitably damped and tuned resonant circuit with a secondary winding or its equivalent for phase reversal. It produces the time-varying part of the voltage from the anode current of V_1.

For the idealized waveforms considered it is possible to derive some very simple relations between the currents and even if they are not precise for practical waveforms they are sufficiently accurate to be of great help in determining proper circuit values.

It is plain from the geometry of the waveforms of Fig. 3(b) and (c) that

$$i_p : xi_p : : \tau_3 : \tau_1 - \tau_3$$

From this relation and the fact that the mean value of a triangular wave is one-half of its amplitude multiplied by the ratio of its duration to the time of one cycle, we find that the mean currents i_a and i_d of V_1 and V_2 respectively are

$$i_a = \frac{i_p}{2} \cdot \frac{\tau_1}{\tau} \cdot \frac{1}{1+x} \quad \ldots \quad (2)$$

$$i_d = \frac{i_p}{2} \cdot \frac{\tau_1}{\tau} \cdot \frac{x^2}{1+x} \quad \ldots \quad (3)$$

The mean current in L_L is $i_a - i_d$ and the peak-to-peak deflection current $I_L = i_p(1 + x)$. The ratio of the two gives the fraction of the picture width by which the picture is displaced from the centre of the tube by this mean current. This fractional displacement is

$$\frac{1}{2} \cdot \frac{\tau_1}{\tau} \cdot \frac{1-x}{1+x} \quad \ldots \quad (4)$$

For the British 405-line transmissions $\tau_1/\tau = 0.84$. An overshoot $x = 0.8$ is not difficult to obtain and values up to about 0.95 are not impossible. With the lower value the fractional displacement is $0.42 \times 0.2/1.8 = 0.0466$. With a 10-in picture this is a displacement of under ½-in to the right.

In practice, the shape of the flyback affects the position of the picture and, even with a transformer-fed deflector coil, it results in a small displacement to the left. Although it is very small when the overshoot is large, it is often observable in practice and is corrected by adjusting the focus coil. With a directly-fed coil it tends to offset the displacement caused by the d.c. component of current in L_L. It is plain, therefore, that as long as x exceeds about 0.8 the d.c. component is no very serious drawback to the circuit of Fig. 1.

Valve Peak Current

With very little additional information it is now possible to work out the circuit values needed for any given case. To do this it is necessary to know the peak anode current of which V_1 is capable. This is the anode current for a grid voltage of about − 1 V, since grid current must be avoided in normal time-base operation, and for an anode voltage just above the knee in the anode-volts—anode-current characteristic. This last condition is brought about by the fact that it is usually desired to operate with the minimum h.t. voltage and the maximum voltage drop across the deflector coil occurs at peak current.

This peak current depends on the valve design and increases with screen voltage. With the PL81 it is 350 mA for 60 V on the anode and 170 V on the screen; with the PL 38 it is only 140 mA at 75 V and 175 V respectively, but increases to 165 mA when the screen voltage rises to 225 V. For the EL38 the current is 220 mA at 85 V for 275 V on the screen.

If the h.t. supply voltage is fixed, the maximum voltage across the deflector coil is limited to the difference between the h.t. voltage and the minimum anode voltage. Whatever the circuit arrangement the scan current is then proportional to the peak anode current of the valve.

This peak current is the starting point of design and most of the circuit values depend on it. The first step, therefore, is to choose a valve. Having determined its peak anode current and the minimum permissible anode voltage, it is good practice to carry out the design for a current of at least 10 per cent less and a voltage of 10 per cent more than these figures in order to allow for variations of valve characteristics and deterioration of the valve during use.

For our example, we shall consider the EL38, (220 mA at 85 V). The design figures are thus 220 − 22 = 198 mA and 85 + 8.5 = 93.5 V. In round figures we shall take 200 mA and 95 V.

For an overshoot in the circuit of $x = 0.8$, equation (2) gives the mean anode current as $i_a = 200 \times 0.42/1.8 = 46.6$ mA and the mean diode current, equation (3), is $46.6 \times 0.64 = 30$ mA, while the peak-to-peak deflection current is $I_L = 200 \times 1.8 = 360$ mA.

In practice, the mean currents will be rather higher than this because the instantaneous currents will not change over abruptly from one valve to the other but will tend to the form shown dotted in Fig. 3 (b) and (c). If V_1 starts to conduct while V_2 is conducting it supplies current which is surplus to the requirements of the deflector coil and so, if the scan is to remain linear, this surplus current must be diverted to V_2. The mean currents of both valves must therefore be equally increased by such operation.

Although undesirable from an economy standpoint this overlapping of the conduction periods of the two valves is necessary in practice in order to avoid very critical adjustments. As long as V_2 is non-conductive at the end of the scan this overlapping of the conductive periods of the two valves does not affect the peak-to-peak currents, it only alters the mean currents.

At full output with a typical valve a deflecting current I_L of 360 mA is obtainable for a mean anode current of 46.6 mA (ideal) with the practical overshoot figure of 0.8. In practice, a mean current of 55 − 60 mA would be reasonable. In Class A operation without a diode the maximum output would be 200 mA for a mean current of 84 mA. The improvement with a diode is thus quite considerable, even when conditions are not ideal.

When operating a 51° tube at 5 kV a deflector coil* can have a figure of merit $L_L I_L^2$ of as little as 1 mH-A². It is safer, however, to assume a figure of 1.6 mH-A² as being more nearly representative of general practice. If the tube is operated at 9 kV the figure becomes $1.6 \times 9/5 = 2.9$ mH-A².

If such a coil is used with a current of 0.36 A, which we have seen that a typical valve can provide in the circuit of Fig. 1, the inductance of the coil must be $L_L = 2.9/0.36^2 = 22.3$ mH. This is not enormously high, for values of 6 − 10 mH are common in transformer-fed coils.

In order that the flyback may occur in the time τ_2 allowed for it in the transmission (16 μsec in the British 405-line system) it is necessary that this time should not be less than that occupied by one-half cycle of the natural frequency of oscillation $1/2\pi\sqrt{L_L C}$. Whence

$$C = \left(\frac{\tau_2}{\pi}\right)^2 / L_L \quad \ldots \quad (5)$$

This is an approximate relation since the frequency is somewhat dependent on the damping and hence on x. In practice, it should be somewhat smaller than the calculated figure. For the British transmissions

$$C = 26{,}000/L_L \quad \ldots \quad (6)$$

in pF and mH.

For $L_L = 22.3$ mH, $C = 1160$ pF. The self-capacitance of the deflector coil is unlikely to be more than 200 pF at the most and, in the worst case, the rest of the stray capacitances will not total more than 100 pF. A capacitor of the order of 800 pF must thus be connected in order to obtain the proper flyback time.

In Class A operation, because the current is 0.2 A only, L_L must be $2.9/0.04 = 72.5$ mH and then C must not exceed $26{,}000/72.5 = 360$ pF.

During the scan the inductive back e.m.f. across L_L is $L_L I_L/\tau_1$. With $\tau_1 = 82.77$ μsec, this becomes $12 L_L I_L$ with L_L in mH. It is, therefore, $12 \times 22.3 \times 0.36 = 96$ V. On this is superimposed the $i_L r_L$ drop. A typical value of r_L/L_L is 2 Ω/mH, so that $r_L = 2 \times 22.3 = 44.6$ Ω and $I_L r_L = 44.6 \times 0.36 = 16$ V. The zero of this saw-tooth occurs at the same point as the zero of the current wave so that there is a part additive to the back-e.m.f. of $16/(1+x)$ and a part subtractive of $16x/(1+x)$, or in this case 8.9 V and 7.1 V. The voltage across L_L thus varies from 88.9 V at the start of the scan to 104.9 V at the end.

The peak voltage during flyback would be $0.2\sqrt{22.3 \times 10^{-3}/1160 \times 10^{-12}} = 880$ V if there were no losses. With the losses it will be rather less, but in practice the flyback time may have to be on the average rather less than has been assumed in order to provide some latitude for component variations. As a result the voltage may not be less than this and the deflector coil should be insulated to withstand about 1 kV.

When V_1 is passing its peak anode current, at the end of the scan, the voltage across L_L is at its greatest and as it acts against the h.t. supply, the anode voltage of V_1 is at its lowest. This is 95 V for the valve of this example. The sum of the two gives the minimum permissible h.t. supply voltage, about 200 V in the example. To this must be added the cathode bias voltage of V_1 and any voltage drop across the control device A of Fig. 1.

(To be continued)

* "Deflector Coil Characteristics," by W. T. Cocking, *Wireless World*, March, April and May, 1950.

1951 A.R.R.L. Handbook

THE 1951 edition of the Radio Amateur's Handbook, which enjoys a world-wide reputation as the standard manual of amateur radio communication, is now available. It has been considerably re-arranged and enlarged, five new chapters having been added covering various modulating systems for transmitters, single-sideband radio-telephony technique, mobile equipment and transmission lines.

The handbook is profusely illustrated with circuits, drawings and photographs and there are numerous tables and charts. Its 27 chapters cover 608 pages, 57 of which are devoted to valve data.

Copies are obtainable from the Modern Book Co., 19-23, Praed Street, London, W.2, at 22s 6d (23s 6d by post), also from several other booksellers, or it can be ordered, for delivery direct from the U.S.A., through the Radio Society of Great Britain, New Ruskin House, Little Russell Street, London, W.1, the price being 22s.

Continuously Variable Mains Transformer

Wide Voltage Range by In-Phase and Phase Opposition Connections

By H. E. STYLES, B.Sc.

FOR experimental purposes, a need often arises for an a.c. power supply at a voltage which can be varied continuously over a wide range. Such a source of power is extremely useful for a variety of purposes such as : operation of equipment requiring unusual supply voltage ; calibration of a.c. meters ; determination of characteristics of iron-cored chokes, etc ; determination of rectifier characteristics ; speed control of motors ; control of electrically heated apparatus and provision of a variable d.c. supply in conjunction with a suitable rectifier.

A.C. Voltage Control Methods.—Numerous methods of varying the voltage of an a.c. supply are possible but most of them suffer from disadvantages of one kind or another as may be seen from the following selection :—

Control by series resistance.—This is wasteful of power, provides limited range of control and gives poor regulation.

Control by potentiometer.—This is also wasteful of power and gives poor regulation.

Control by tapped series choke.—This gives limited range of control, poor regulation and is discontinuous unless an excessive number of tappings is provided.

Control by variable core choke.—This provides smooth control but gives limited range and poor regulation.

Control by tapped transformer.—This gives wide range and good regulation but with normal construction the control is discontinuous unless an excessive number of tappings is provided.

Control by toroidally wound transformer with sliding contact.—This gives practically continuous control over a wide range with good regulation. Such transformers, however, are not easily constructed and must inevitably be relatively expensive to purchase.

As will be shown, however, it *is* possible to design a tapped transformer of simple construction from which any required voltage can be obtained at will and it is considered that such a device will meet most experimental requirements.

Principle of Design.—The instrument to be described makes use of a little-known, though by no means novel, property of the following mathematical series :

$$\pm 1 \pm 3 \pm 3^2 \pm 3^3 \pm 3^4 \ldots \pm 3^{n-1}$$

It is possible, by suitable choice of signs, to select terms from this series such that their sum can be made to equal any integral value between the limits of $\pm \frac{1}{2}(3^n - 1)$, or $\pm \frac{1}{2}(3F - 1)$, where n is the number of terms to which the series is taken and F is the positive value of the final term.

Thus, for example, if the first three terms are taken, n equals 3 and F equals 9, the individual terms being ± 1, ± 3 and ± 9. These three values can be combined to give all integers within the limits of ± 13 as shown in the table below. (Positive values only are shown—reversal of all signs gives the corresponding negative values.)

Now isolated windings on a transformer can be connected in series so that their voltages are either in phase or 180 deg out of phase. The resultant voltage is thus either equal to the sum of or the difference between the individual values, which may therefore be regarded as having *positive* or *negative* signs according to the way in which they are connected. It follows that if a series of windings is provided such that their voltages accord with the mathematical series previously referred to, then it will be possible to select combinations of windings so as to obtain any integral value of output voltage up to the maximum given by all windings series-connected in phase.

For normal purposes there is no tangible difference between output voltages of positive or negative sign, since this merely implies a phase difference of 180 deg, but it is possible to make use of this intangible difference in the following manner. Consider the transformer shown in Fig. 1. Four separate secondary windings are provided for outputs of 1, 3, 9 and 27 volts, whilst the 240-volt primary winding is tapped at a point corresponding to 81 volts from one end and 159 volts from the other.

By suitable selection of windings and direction of connection the four secondaries can be combined to give an output voltage corresponding to any integral

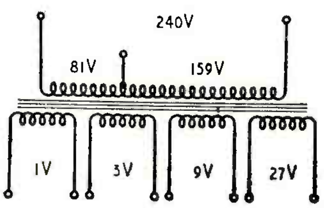


Fig. 1. Voltage rating of the various windings on the transformer.

TABLE

1	2	3	4	5	6	7	8	9	10	11	12	13
+1	+3 −1	+3	+3 +1	+9 −3 −1	+9 −3	+9 −3 +1	+9 −1	+9	+9 +1	+9 +3 −1	+9 +3	+9 +3 +1

value between the limits of ±40. Although the positive and negative values are indistinguishable for most purposes, this is not so if the output from the secondaries is connected in series with the 81-volt section of the primary. When this is done the resultant output lies within the range of 81±40; i.e., 41 to 121 volts. Thus the over-all range can thereby be extended from 1 to 121 volts.

Similarly, the secondary output of ±40 volts can be connected in series with the primary section of 159 volts to give a range of 159±40 volts; i.e., 119 to 199 volts. The over-all range can thus be extended from 1 to 199 volts. (The slight overlap, 119 to 121, results from using a winding of 159 volts instead of the ideal value of 162 which could be attained by a suitable extension of the primary winding but is not necessary.)

Finally, by connecting the secondary output of ±40 volts in series with the whole primary, an output of 240±40 volts can be obtained; i.e., 200 to 280 volts. Hence the simple transformer of Fig. 1 enables any integral voltage between 1 and 280 volts to be obtained, though it must be noted that for voltages above 40 an auto-transformer connection is used and, in consequence, the output is in direct contact with the mains supply. For many purposes this does not matter but if it is not permissible the difficulty can be overcome by providing an additional 240-volt mains winding which need not then be tapped. The auto-connection, however, possesses an advantage in that primary and secondary currents are nearly 180 deg out of phase so that auto-connected windings have to carry a current equal only to the difference between the input and output currents. The winding can therefore be of smaller diameter wire than would otherwise be the case.

If it be desired to obtain a finer control of voltage than is given by the transformer alone, it can readily be obtained by shunting a potentiometer across the one-volt winding. The low voltage permits the use of a low resistance potentiometer and hence a minimum worsening of regulation. The latter will, of course, depend upon the precise design of transformer employed, but the fact that voltage can be finely adjusted will in many circumstances render good regulation less important than would otherwise be the case. It may thus be permissible to work at higher current densities in the windings and thereby reduce the winding area required.

Design Data.—For maximum convenience the transformer can be provided with switches for the purpose of selecting desired combinations of windings and the circuit of Fig. 2 has been found suitable for covering the whole range from 0 to 280 volts. Each of the four independent secondary windings is connected to a three-position double-pole switch by means of which the winding can be introduced in either direction or eliminated and replaced by a short-circuiting connection. Primary tappings can be introduced by means of a four-position double-pole switch, the first position of which provides a short-circuit and eliminates the primary completely.

A further switch provides two " on " positions for the mains supply. In one position a low resistance potentiometer is shunted across the 1-volt secondary winding whilst in the other position the potentiometer is disconnected at one end and serves as a series rheostat only. The latter provides adequate control at the higher values of output current.

The positive and negative signs in Fig. 2 serve to

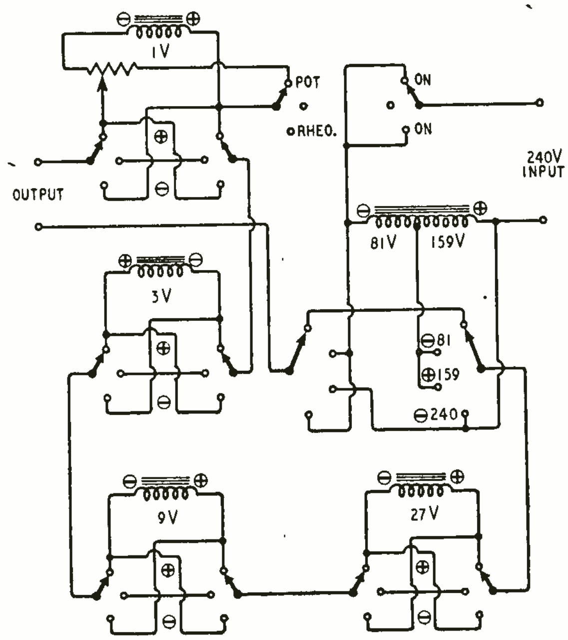


Fig. 2. Voltage selection is most conveniently effected by switching, which for the transformer of Fig. 1 can be arranged as shown here.

show the correct phase relationships and it will be seen that the primary tappings are connected to the selector switch alternately in and out of phase. The reason for this will be made clear later. The correct phasing of connections can readily be ascertained by practical test during construction and there is no need to take special precautions to identify the ends of the secondary windings.

The switches employed must be such that short-circuiting does not occur between adjacent contacts when the controls are operated as any such behaviour will preclude *on-load* voltage adjustment. The author has employed ordinary wafer type rotary switches and avoided shorting difficulties by using alternate contacts only. Such switches have been found to be capable of carrying currents of up to ten amperes and for higher currents it is merely necessary to use two or more wafers wired in parallel.

It is, of course, possible to dispense with switches and to employ wander leads in conjunction with plugs or terminals. Though less convenient, the latter may be preferable when very heavy output currents are required but, to avoid danger at high voltages, the plugs or terminals used should be of the shrouded type.

Transformer Design.—This follows normal practice and depends primarily upon the maximum output wattage required. Since, however, windings may be idle, or in opposition, under some conditions of operation, it is necessary to allow for a winding area greater than would normally be required. To some extent this may be compensated for by the use of thinner wire, as previously explained, but it is desirable to choose a core of ample size.

The gauge of wire required for any particular secondary winding may either be chosen on the basis of a maximum current rating or, alternatively, on the basis of ensuring that the maximum output wattage can always be obtained regardless of the value of output voltage in use. In the latter case it is necessary to calculate the maximum current demand for any given winding on the basis of the lowest output voltage for which the winding in question needs to be in circuit. These lowest voltages will be 1, 2, 5, and 14 for the 1- 3- 9- and 27-volt windings respectively, so that if the maximum output watts be W, then the current carrying capacities of the four secondary windings in the order given above, must be equal to W, W/2, W/5 and W/14 amperes respectively. In practice, the lower voltage windings would probably be current limited rather than wattage limited in order to avoid the use of unduly thick wire though this may be obviated by using windings in parallel.

In the case of the primary winding, the first requisite is that it should be adequate for the maximum output wattage for which the transformer is designed. If this factor alone is considered then the output currents at voltages above 40 must be restricted so as to avoid over-loading the auto-connected primary sections. Since the output and input currents through the sections in question will be approximately 180 deg out of phase it follows that the maximum output current can be allowed to exceed the normal primary current limit by an amount equal to the primary current corresponding to the output actually being taken.

If, however, it be desired to ensure that the maximum output wattage can be obtained at voltages above 40 the primary sections must be designed to carry the resultant currents when output voltages are at their appropriate minimum values. Thus in the case of the 81-volt primary section the minimum output voltages will be 41 so that the output current will be approximately six times the input current at 240 volts. As these two currents are roughly 180 deg out of phase the effective current through the winding will be five times as great as that in the rest of the primary. Similarly, in the case of the 159-volt section, the minimum output voltage will be 119 so that the output current will be twice the input current at 240 volts. The effective current through this section will therefore be equal to the current in the rest of the primary though opposite in phase.

Finally, when the whole of the primary is autocoupled to the 40-volt secondary, the minimum output voltage will be 200 and the output current 1.2 times the input current. The effective primary current will thus be only 0.2 times the normal value so that in this case the output power can be increased to five times the normal value without fear of over-loading the primary.

From the foregoing estimates it is apparent that in order to cater for normal maximum power output it is necessary to wind the 81-volt primary section so that its current-carrying capacity is five times that of the 159-volt section. The latter, however, needs only to be suitable for the normal maximum primary current for full load operation of the transformer.

To summarize, if W be the rated maximum output watts of the transformer, then in order to obtain this output at any operating voltage it will be necessary to ensure that the current-carrying capacities of the various windings are as follows :—

1-V	secondary winding	.. W amperes
3-V	ditto ..	.. W/2 amperes
9-V	ditto ..	.. W/5 amperes
27-V	ditto ..	.. W/14 amperes
81-V	primary winding	.. W/48 amperes
159-V	ditto ..	.. W/240 amperes

These values ignore transformer losses but these can probably be neglected since the calculations were made for the most onerous conditions of operation. Consideration has only been given to a 240-volt input, but modification to the design is unnecessary unless the input is above 243 volts or considerably below 240. A low voltage merely produces a greater degree of overlap when switching from one primary section to another and a reduction in maximum output voltage, but if the voltage exceeds 243 a tapping at that voltage must be provided in order to obtain control of voltage within 1 volt at all points.

As an example of the application of the foregoing design procedure, detailed instructions for the construction of a 100-W. transformer are given in the appendix.

Operation of the Transformer Switches.—To ensure a smooth sequence of switch operations, the procedure for obtaining a steadily increasing voltage should be as follows :— Start with all switches at the central short-circuiting position. This, of course, corresponds to zero volts. Switch to −1, then add +3 to give +2 volts. Move the first switch to zero to give +3 volts and then to +1 to give +4 volts. Switch in −9 to give −5 volts and then move the first switch through zero to −1 to reach −7 volts. Change the second switch from +3 to zero and the first to +1, 0 and −1 to reach −10 volts. Switch in −3 and change through +1, 0 and −1 to reach −13 volts. Switch in +27 to get +14 volts and by procedures as above raise the voltage to +40.

At this stage, the 81-volt primary section must be switched in as a *negative* value to avoid the necessity for reversing all the other switches and it is for this reason that the wiring is arranged in the manner shown in Fig. 2. The output voltage is then increased by reducing the secondary voltage from +40 through zero to −40 to give a final *negative* value of 121 volts. To avoid a sudden jump in output voltage, the 159-volt primary must then be introduced as a *positive* value to oppose the −40 volts of the secondary and give a net output of +119 volts. This is then increased to 199 volts by increasing the secondary to +40. The 240-volt primary section must then be introduced as a *negative* value to ensure smooth increase of output voltage. Thus, by alternating the phase of connection of successive primary sections, it is possible to avoid sudden voltage jumps which would necessitate reversal of switch positions at each alternate change of primary tapping.

APPENDIX

Details for Construction of a 100-Watt Transformer for 240-V 50-c/s. Supply.—The transformer to be described is suitable for an output of 100 watts at voltages from 5 to 280 inclusive but is limited to a maximum output current of 20 amperes at voltages below 5. At voltages above 40, auto-connection is employed and the output is therefore in direct connection with the main supply at such voltages.

Materials Required.

Core : 80 pairs of stampings, of dimensions shown in Fig. 3 to give a core cross-section of 1¼in × 1¼in. (Stalloy or similar material of 0.014in thickness; Sankey No. 33 or 33A, M. & E.A. No. 60 or 60A, Baldwin No. 8C.)

Bobbin : to suit above core.

Clamping brackets, bolts, terminal strips etc. for above.

Wire : 28 s.w.g. enamel covered—5 oz.
22 s.w.g. enamel single cotton covered—11 oz.
18 s.w.g. enamel single cotton covered—13 oz.
14 s.w.g. enamel single cotton covered—21 oz.

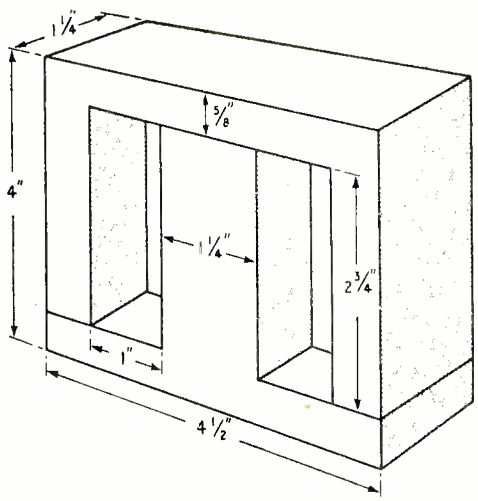


Fig. 3. Typical core size for a 100-W transformer for 50-c/s supply.

"Empire-cloth" and self-adhesive cellophane tape of 1½in. width. (If enamel single cotton covered wire cannot be obtained, plain enamel covered can be used, but lead out wires when twisted together should be covered by insulating sleeving.)

Winding Data.

(a). **159-V primary section.**—This winding should be the first to be put on to the bobbin and comprises 795 turns of No. 28 s.w.g. enamel covered wire. Each layer should be covered by a single layer of the self-adhesive cellophane tape, applied in two sections side-by-side with a small over-lap at the centre. This tape is extremely useful for such purposes, and, provided that enamel covered wire is employed, its insulation properties have been found to be adequate for normal mains voltages.

(b). **81-V primary section.**—This consists of 405 turns of No. 22 s.w.g. single cotton enamel covered wire wound, in effect, as a continuation of the 159-V section. These two windings need only the cellophane tape as insulation between them, the tape again being used for inter-layer insulation of the 81-V winding.

(c). **27-V secondary winding.**—Before applying this winding, the primary should be covered with two layers of "Empire-cloth" to provide adequate insulation between mains supply and the secondary when the latter is isolated from the former. The self-adhesive tape will again be found useful as a means of anchoring the "Empire-cloth." The 27-V winding comprises 135 turns of No. 18 s.w.g. s.c.e. wire with tape inter-layer insulation as before. In using wire of the thickness of No. 18 s.w.g., or more, winding space can be lost by the necessity of bringing back the end of a winding which finishes away from the cheek of the bobbin. To avoid this, note should be made when the final layer of wire is about to be commenced, and, if the number of turns remaining to be put on is much less than the number required to form a complete layer, just over half the turns should be put on. A layer of tape should then be applied and the winding brought back towards the end of the bobbin from which it was commenced so that it terminates close to the cheek. A stepped effect is thereby produced but this can be filled in by subsequent windings and space which would otherwise have been occupied by a single length of wire lying across the original winding is saved.

(d). **9-V secondary winding.**—This consists of 45 turns of No. 14 s.w.g. single cotton enamel covered wire and need only be insulated by tape from the 27-V secondary section. In this case it is even more necessary to proportion the winding so as to bring the final turn adjacent to a cheek of the bobbin and if, at the same time, the beginning and end of the winding are brought to the same end of the bobbin it will be sufficient to twist together the ends instead of passing them through holes in the bobbin cheeks. The latter procedure is somewhat difficult with No. 14 s.w.g. wire and may lead to damage of the bobbin.

(e). **3-V secondary winding.**—15 turns of No. 14 s.w.g. s.c.e. wire are employed for this winding, the ends of which are twisted together as a means of preventing the wire from becoming unwound. Tape insulation is again sufficient.

(f). **1-V secondary winding.**—This comprises 5 turns of No. 14 s.w.g. wire dealt with as in the previous case. If sufficient space remains and it is considered desirable, one or both of the last two windings can be duplicated for the purpose of connecting them in parallel and thereby increasing the permissible maximum output current at voltages below 5.

Characteristics of the Transformer.—The foregoing windings correspond to 5 turns per volt which, with the particular core employed, implies a peak flux density of 60,000 maxwells (lines) per square inch at 50 c/s A higher degree of core saturation could be employed but the resultant distortion of the a.c. wave-form might render the output from the transformer unsuitable for purposes such as meter calibration.

The magnetizing current amounts to about 70 mA whilst iron losses approximate to 2 W. At full load the copper losses account for about 8 W giving a total loss of some 10 W. The over-all efficiency is thus of the order of 90 per cent so that for an output of 100 watts the input will be 111 watts. The primary current at 240 volts will thus amount to 0.47 A corresponding to a current density of 2,700 A per square inch. For the secondary windings, current densities range from 3,400 A to 4,000 A per square inch which values can be regarded as satisfactory for a transformer of the size in question. Since the area of exposed surfaces of iron and copper amounts to some 75 sq in the energy to be dissipated per square inch of surface approximates to 1/7 W and the transformer should therefore remain quite cool at full load.

Connection of Windings.—If the direction of all windings is maintained constant, then the commencement of the 159-V winding can be regarded as the *positive* end of the primary in accordance with Fig. 2. The end of this winding is joined to the beginning of the 81-V winding to give the primary tapping point whilst the finish of the 81-V section corresponds to the *negative* end of the primary. Since the induced e.m.f. is in opposite phase to the primary voltage, it follows that the beginnings of all the secondary windings will correspond to the *negative* ends shown in Fig. 2.

Switching.—The "on-off" main switch can conveniently comprise a double-pole, three position wafer-type switch with the central position left disconnected. A single wafer is adequate to carry the current in this instance.

The remaining switches must all be capable of carrying 20 A at least in their short-circuit position. For the four secondary switches, double-pole five-position wafer switches are suitable, alternate contacts only being used and two wafers wired in parallel to provide the required current carrying capacity.

In the case of the primary selector switch, the necessity for providing four switch positions precludes the use of double-pole wafers since the number of available contacts is insufficient to permit the use of alternate contacts only. This difficulty can be overcome by using paired single-pole wafers to obtain the necessary double-pole action, two such pairs being employed in parallel to provide the current capacity needed. Using alternate contacts, as before, four single-pole, seven-position wafers will therefore be required for the primary switch.

In deciding the possible suitability of other types of switches, it should be remembered that the energy to be interrupted is restricted to a maximum of 100 W, heavy currents coinciding with low voltages. Thus current capacity is the chief consideration.

Oscilloscope Calibrator

Measuring Signal Voltage

By W. TUSTING

WHEN using an oscilloscope it is often required to know the magnitude of the input signal voltage corresponding to a given deflection on the screen. One can, of course, give the oscilloscope an initial calibration by applying a series of known voltages and noting the resulting deflection. However, this can be regarded as giving only a rough indication of the input because the calibration is unlikely to stay constant. The deflection sensitivity of the tube itself varies with the e.h.t. voltage and this depends on the mains voltage. Then the amplifier gain is not constant and is likely to change with time as the valves age and again with the mains voltage.

Because of this, the writer has come to the conclusion that the best way of determining the input voltage of an oscilloscope is with the aid of a calibrator, which can either be a separate unit or, preferably, built in. The calibrator delivers a known output voltage and in use the procedure for determining the magnitude of a signal voltage is to note the deflection which it produces on the tube screen, to substitute the calibrator output for the signal and to adjust its output for the same deflection. The voltage is then read from the calibrator dial.

The main error involved in this is in judging the equality of the two deflections and this can be made very small if the trace is reasonably large. There is a small possibility of error if the mains voltage changes between the two readings, but even this can be detected by repeating the measurement several times.

There will inevitably be an error if the frequency response of the amplifier is poor, unless the frequency of the calibrator output is the same as that of the signal. This is possible but very inconvenient and it is desirable in the interests of simplicity to make the calibrator provide a 50-c/s output. In using it, therefore, the assumption is made that the oscilloscope response is the same at 50 c/s as it is at any signal frequency. This will usually be true within close limits with any good amplifier used within its pass range. If the amplifier response is known a correction can, of course, be applied.

The writer recently found the need for a calibrating source of this nature. Some initial rough measurements showed that the deflection sensitivity of the oscilloscope was 0.18 V (r.m.s.)/in with the amplifier at full gain and 5.3V/in with it at minimum gain. Assuming that a deflection of more than 4 in on the 5-in tube would not be needed the maximum peak-to-peak signal would be $4 \times 5.3 \times 2.828 = 60$ V. Assuming the smallest useful signal to be of 0.1-in deflection, this smallest signal would be $0.18 \times 0.1 \times 2.828 = 0.051$ V. The calibrating source must thus provide an output accurately known within the range 0.051 – 60 V p-p, a ratio of 1180 : 1.

The best method of doing this is unquestionably to provide a source of rather more than 60 V p-p, to monitor it with a suitable voltmeter, and to attenuate it as required by a combination of a stepped resistance attenuator and a continuously adjustable potential divider. For ease of multiplying 10 : 1 steps are desirable and this is also a reasonable range for the continuous control.

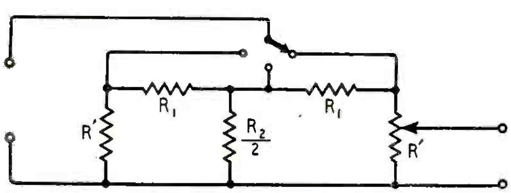
As an initial try-out, let us decide to use a 50-c/s source, since this can be easily derived from the mains. A supply at 25 V r.m.s. would seem suitable giving a peak-to-peak amplitude of 71 V, the insertion of a 10 : 1 attenuator will give down to 0.71 V, a second attenuator step-down to 0.071 V and a third down to 0.0071 V. Two attenuator steps are hardly sufficient, three are more than is needed.

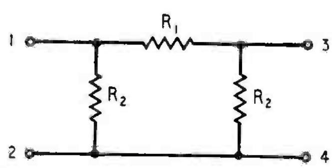
Since 0.051 V gives 0.1-in deflection 0.071 V will give 0.14 in approximately. This is probably sufficient because with a potentiometer control more than a 10 : 1 ratio will be available. The accuracy will suffer, but in any case high accuracy will not be possible with such a small deflection; therefore, it is not worth while to provide a third attenuator step.

One important requirement of the attenuating system is that the input impedance should be constant at all settings of the controls. If it is not the input voltage will vary unless the source is of very low impedance. For practical convenience it is desirable to have a pre-set control of the input voltage, since if it is always precisely the same the controls can be calibrated directly in voltage. This will make the source impedance appreciable.

The calibrator will work only into the input impedance of the oscilloscope amplifier and this will normally be of very high impedance. As long as the output impedance of the calibrator is under, say, 100 kΩ, its actual impedance will not matter nor will variations of it with the setting of the controls. A constant output impedance is, therefore, not needed.

Another requirement is obviously that the switching should be simple. If possible, a single-pole multi-way switch should be used.





Above : Fig. 1. Two-stage attenuator and potentiometer with switching. Right : Fig. 2. Basic attenuator stage.

The most suitable general form of network is shown in Fig. 1 and is based on the single π section attenuator of Fig. 2. The starting point in design is to choose matters so that when a resistance R is connected to terminals 3, 4 the resistance measured between terminals 1, 2 is also R. Therefore

$$R = \frac{R_2\left[R_1 + \frac{R R_2}{R + R_2}\right]}{R_1 + R_2 + \frac{R R_2}{R + R_2}} \quad .. \quad .. \quad .. \quad (1)$$

It is also required that if terminals 1, 2 be connected to R the resistance measured between 3, 4 shall also be R. Since the network is symmetrical this requirement is automatically met if (1) is met.

The attenuation when the network is terminated by R is the ratio of the input voltage to the output and is

$$A = 1 + \frac{R_1(R + R_2)}{R R_2} \quad .. \quad .. \quad .. \quad (2)$$

These two equations are sufficient to permit the resistance values to be determined for any impedance level R and attenuation A. Solving the equations for R_1 and R_2 we get

$$R_1 = R\frac{A^2 - 1}{2A} \quad .. \quad .. \quad .. \quad .. \quad (3)$$

$$R_2 = R\frac{A + 1}{A - 1} \quad .. \quad .. \quad .. \quad .. \quad (4)$$

A value of attenuation commonly required is 10 times (20 db) and for this, $R_1 = 99R/20 = 4.95$ R and $R_2 = 11R/9 = 1.222$ R. The value to be assigned to R depends on the requirements.

Two basic sections of attenuator plus the terminating resistors are shown in Fig. 3, and by combining parallel resistors this can be reduced to Fig. 1 in which $R' = RR_2/(R + R_2)$. For our example, $R' = 11R/20 = 9R_2/20$.

Given the value of any one resistor the values of all the others can now be worked out. One might, for example, start by arbitrarily assigning a value of 10 kΩ to R_1. Then, since $R_1/R_2 = 81/20$ we get $R_2 = 10 \times 20/81 \approx 2.47$ kΩ,

$$R' = \frac{10 \times 20 \times 9}{81 \times 20} \approx 1.11 \text{ k}\Omega.$$

Alternatively, we may start with a known value for R′, since we may have a potentiometer that we wish to use. In a particular case a nominal 2-kΩ wire-wound potentiometer was found to measure 2.074 kΩ. Then $R_2 = 2.074 \times 20/9 = 4.609$ kΩ and the middle shunt resistance in Fig. 1 is 2.3045 kΩ. The value of

$$R_1 \text{ is } 81\,R_2/20 = \frac{2.074 \times 20 \times 81}{9 \times 20} = 18.666 \text{ k}\Omega.$$

The full input of 25 V r.m.s. may appear across any shunt resistance and 22.5 V across any series resistance. The power in the two end resistors may thus be 625/2074 = 0.3 W and in the middle one 625/2304.5 = 0.27 W, while in the series resistors it is 510/1866 = 0.12 W.

Since the output resistor will be a wire-wound potentiometer of 3-W rating this is satisfactory here. 1-W resistors for R_1 are also likely to be satisfactory. Powers around $\frac{1}{4}$ W are rather high in this application for the remaining two resistors, however.

Then the values are non-standard. This, however, can largely be met by combinations of standard values ;

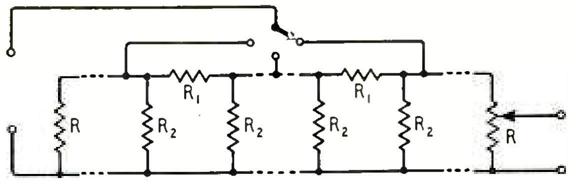
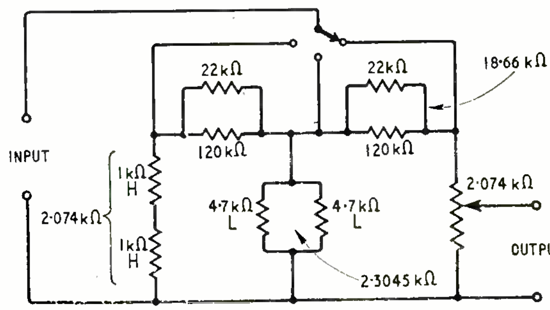


Fig. 3. Two-section attenuator with terminating resistances. Parallel resistors can be coalesced to form Fig. 1.

Fig. 4. Illustrating how the required resistor values can be obtained from combinations of standard values.



thus 22 kΩ and 120 kΩ in parallel give 18.6 kΩ, two resistors of 4.609 kΩ in parallel give 2.3045 kΩ and may be found by picking two slightly low 4.7-kΩ resistors. This will halve the watts in each and be reasonably satisfactory. Similarly, 2.074 kΩ is best obtained by using two high-tolerance 1-kΩ resistors in series.

The complete attenuator thus takes the form shown in Fig. 4. Whatever the position of the switch the input impedance is $R/2 = 10\,R'/11 = 20.74/11 = 1.885$ kΩ. Whatever the source impedance a voltmeter connected across the input will read the same in all positions of the switch and for all settings of the potentiometer.

However, the meter will read differently while moving the switch. If the switch open-circuits between contacts, the voltmeter will jump up between settings ; if it short-circuits contacts, its reading will drop. The amount of the change will depend on the source impedance.

Many switches open-circuit between contacts. If the meter is chosen to read 25 V at half-scale (50 V at full scale) it will jump to not more than full scale if the source impedance is not higher than the input impedance of the attenuator. The source impedance must not exceed 1.885 kΩ in our case.

In the instrument which the writer built the switch was of the type short-circuiting contacts in the half-way position. The complete circuit is shown in Fig. 5. The resistor values were obtained by connecting up to three in series for each and measuring values on a bridge. The a.c. voltmeter resistors are nominal values, chosen to give a reasonable deflection on the meter. This is a 2-in. type reading 0.5 mA full scale and gives a reading of 0.4 mA for 25 V r.m.s. The calibration was made by comparison with another instrument.

The transformer used can be an extra winding on the mains transformer. Such a winding occupies little space because the power is small. In some cases, however, a separate transformer may be necessary

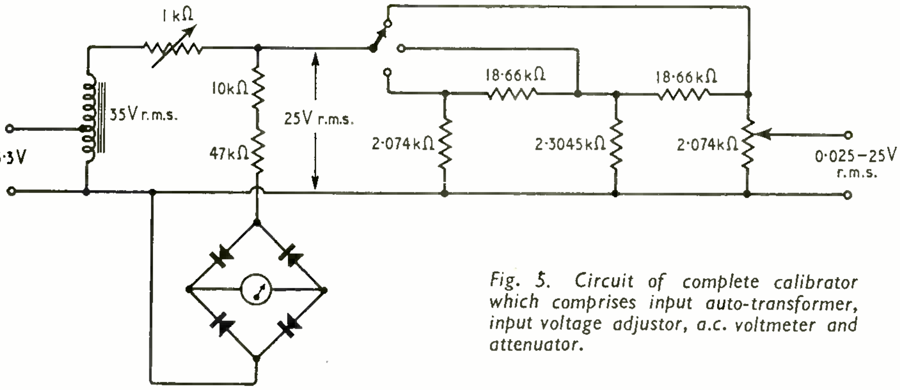


Fig. 5. Circuit of complete calibrator which comprises input auto-transformer, input voltage adjustor, a.c. voltmeter and attenuator.

since the mains transformer may already be in existence. It will then often be convenient to use an auto-transformer working from the 6.3-V heater winding of the mains transformer; this is satisfactory, provided that one side of this winding is earthed. The ratio needed is 35/6.3 = 5.56 : 1.

The writer constructed such an auto-transformer using a $\frac{3}{8}$-in. stack of Magnetic and Electrical Alloys. No. 40 laminations (overall size $1\frac{1}{4}$in by $1\frac{5}{8}$in) wound with 1,740 turns of No. 36 enamelled wire tapped at 315 turns for the 6.3-V supply.

The dial of the output potentiometer was calibrated with the aid of a resistance bridge. The full output is 71 V p-p (= 25 V r.m.s.) and the full resistance is 2.074 kΩ. The resistance between slider and earth with the top end of the potentiometer disconnected from earth is thus 2.074 V/71 = 0.02921 V. Taking a series of voltages for which calibration marks are desired a list of corresponding resistance values can be calculated. The bridge is then set for each value in turn, the potentiometer adjusted for balance and the scale marked.

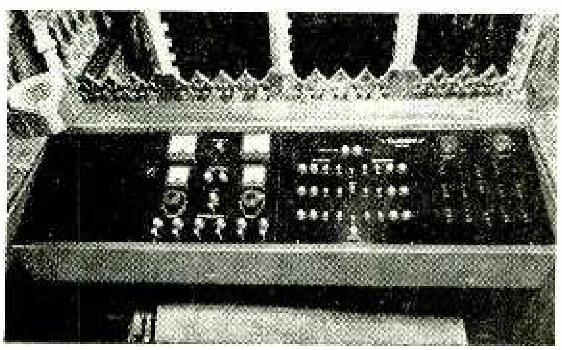
With a linear potentiometer the scale accuracy becomes rather poor below 10 V. This can be partly overcome by calibrating the voltmeter at 25 V r.m.s. and 12.5 V r.m.s. and providing a greater range of control on the input. When working towards the bottom of the scale the input can be halved and the output scale reading doubled.

HOUSE OF LORDS

As briefly mentioned in last month's issue, a new sound reinforcing system has been installed by Tannoy in the refurbished House of Lords. This is the third Tannoy installation in the Houses of Parliament, for the latest one replaces equipment installed in the Chamber of the House of Lords three years ago when the Commons used the Chamber and, of course, new equipment was fitted in the rebuilt Commons Chamber.

The equipment, which is similar to that installed in the Commons, was designed as a result of measurements undertaken with equipment developed in co-operation with the National Physical Laboratory. As in the case of the Commons Chamber, the new installation makes use of a large number of low-intensity reproducers—approximately one to every two seats—and these are grouped in relation to the twelve microphones suspended from the roof. When the Tannoy operator, who is seated in a niche above the Throne, depresses the switch to connect the microphone nearest to the Member rising to speak, the reproducers in that area are automatically muted, and those in the immediately adjacent areas attenuated to a pre-determined level. There are also three microphones on the floor of the Chamber. Associated with the reproducers concealed in the woodwork at the back of the benches, are sockets into which headphones may be plugged for Members who may have a tendency to deafness. Separate amplifiers feed these points.

Control panel showing (centre) microphone selection buttons and indicator lamps. On the right are the microphone level setting controls.



New Zoom Lens

The B.B.C. have been using the zoom lens for several years now on television cameras at sporting events and other outside broadcasts. It enables a distant shot to be brought up and enlarged—as if the camera were actually moving nearer—while all the time keeping the picture in focus. This avoids the inartistic effect of an abrupt change from one fixed lens to another, or from one camera to another, that is otherwise necessary to achieve the enlargement.

Encouraged by the success of their experimental 2 : 1 lens,* the makers, W. Watson and Sons, have now produced a zoom lens with a 5 : 1 ratio. A shot taken with this at 100 yards can be zoomed up in a matter of three seconds to what it would appear at a distance of 20 yards. Areas of objects increase 25 times. The lens consists of five optical components (about $4\frac{1}{2}$in diameter) and the zooming effect is obtained by differential displacement of two of the middle ones; this gives a continuous range of focal length between 4in and 20in, and if the picture is in focus to begin with it remains so throughout the process. Movement is imparted to the two components by a specially cut cam and this is connected by a shaft to a winding handle at the operator's end of the camera.

**Wireless World*, July, 1949, p. 250.

WORLD OF WIRELESS

Television Topics ♦ Extending Decca Coverage ♦ Sales and Service ♦ America's Radio Homes ♦ Television Convention

Holme Moss Tests

BY the time these notes are in print the Holme Moss television transmitter will probably have begun its low-power test transmissions preparatory to the opening of the station early in October.

The 45-kW Marconi vision transmitter will operate on 51.75 Mc/s and the 12-kW sound transmitter (also Marconi) on 48.25 Mc/s (channel 2). The estimated population within the service area of the station is some 11 million.

As has already been stated, the station will be linked with London and Sutton Coldfield (via Birmingham and Manchester) by coaxial cable. Incidentally, it may not be generally known that the radio-relay link between London and Birmingham is being withdrawn from service in favour of the new cable link.

Vestigial sideband transmission is being employed by Standard Telephones & Cables on the cable link between Birmingham and Manchester. This permits the shifting of the vision frequency band without greatly increasing the transmitted bandwidth and at the same time obviates almost insurmountable problems in filter design involved in single sideband television transmission. The equipment is designed to transmit a video bandwidth of 3 Mc/s.

Amateur Television

THE R.S.G.B. announces that in response to the request made by the Society for a lower frequency for amateur television transmission, the P.M.G. has given permission for the use of 1,225-1,290 Mc/s, with a maximum power of 150 watts d.c. input to the last stage. This gives a guard band of 10 Mc/s at either end of the 23-cm amateur band.

It is now some ten months since permission was granted for amateur television transmission in the 2,300-2,450, 5,650-5,850, and 10,000-10.500 Mc/s bands in which the permitted power for television is 150 W although for "sound" it is 25 W.

New Decca Chain

AS mentioned briefly in last month's issue, the third chain of Decca stations—the North British, serving the north-western approaches—was opened in June.

The siting of the new chain follows the accepted "star" pattern, the Master station being at Kidsdale, Wigtownshire; the Red Slave (so named because it generates the pattern of position-lines printed in red on charts) at Clanrolla, Northern Ireland; the Green at Low Buston, Northumberland; and the Purple at Neston, Cheshire.

The two chains previously in use are the English, with the Master station at Buntingford, Herts, and the Danish chain.

Three further chains are in course of preparation. One in Western Germany, which is scheduled to come into service in September, another in France and the third in south-west England.

It is appropriate to mention here that the Ministry of Civil Aviation announces the publication of a new edition of the Decca Navigation Charts. They are based on Lambert's Conical Orthomorphic Projection and are available (price 3s per sheet) for each of the existing chains.

Price Cutting and Service

COMMENTING on the Government White Paper on the proposed abolition of retail price maintenance—manufacturers would be permitted to fix *maximum* prices only—the *Wireless & Electrical Trader* points out that "because of the technical nature of our products the actual purchase does not end the transaction; advice, service and maintenance are essential, and must be made available at all times by the seller."

Stress is laid by the *Trader* on the "inevitable reduction in service to the consumer" if price-cutting gets out of hand, and it suggests that "representations to the President of the Board of Trade for some special dispensation for 'technical' industries are clearly desirable."

ONE-MAN television transmitter and camera developed by the Radio Corporation of America for roving commentators. The 2-watt transmitter, which weighs only 53 lb can operate at distances up to a mile from the mobile control station.

Radio-minded U.S.

AS there is no licensing system for broadcast receivers in the U.S.A. it is only by such means as polls and censuses that an estimate of the number of radio- and television-equipped homes can be obtained. According to preliminary figures obtained from the April, 1950, U.S. census, 95.6 per cent of America's homes have broadcast receivers. The actual figures are: 40,093,000 of the country's 42,520,000 homes have sets.

The 1940 figure was 28,048,219 (82.8 per cent).

The number of homes with television is given as 5,120,000. It is, however, pointed out by our Washington contemporary, *Broadcasting*, that the television figure is now estimated as 12,263,000—approximately 40 per cent.

It is perhaps worth noting that the licence figures for the U.K. at the end of May were: sound only, 11,570,700; television, 869,200, giving a total of 12,439,900.

European Amateurs

AS a result of the decisions made at last year's conference of the International Amateur Radio Union in Paris, the R.S.G.B. has set up a committee to plan the operations of the European Bureau of the I.A.R.U. Whilst the headquarters of the Union will, of course, remain in the U.S.A., the European Bureau will concern itself with the operation of amateur radio in Region 1—Europe, Africa and Saudi Arabia.

Brit. I.R.E. Convention

THE fifth session of the Convention organized by the Brit.I.R.E. opens in the Clerk Maxwell Lecture Theatre of the Cavendish Laboratory, Cambridge, at 9.30 on August 22nd. It will be devoted to "Television Engineering" and will include, on the last day (24th), the inaugural Clerk Maxwell Memorial Lecture to be delivered by Prof. G. W. O. Howe, technical editor of our sister journal *Wireless Engineer*. The chairman of the three-day session will be L. H. Bedford (Marconi's).

The papers include:—

"Fischer Large-Screen Projection System," by Prof. E. Baumann (Germany).

"New Amplifier Technique," by V. J. Cooper, B.Sc. (Marconi's).

"Television Wire Broadcasting," by E. A. H. Bowsher (Rediffusion).

"Scanning and E.H.T. Circuits for Wide-Angle Picture Tubes," by Emlyn Jones, B.Sc. (Mullard).

"Television in the Telekinema," by T.M.C. Lance (Cinema-Television).

"The Watson 5:1 Zoom Lens," by H. H. Hopkins, Ph.D. (Imperial College).

"Applications of Some Recent Developments to Television Problems in the United States," by Irving Wolff, Ph.D. (R.C.A.).

"Improvements in Design and Operation of the Image Iconoscope Type Television Camera Tube," by J. E. Cope, L. W. Germany and R. Theile (Pye-Cathodeon).

"Focusing of Cathode-Ray Tubes for Television Receivers," by J. Alan Hutton, B.Sc. (Murphy).

"Reactive Scanning," by A. B. Starks-Field (Marconi's).

"Production of T.V. Receivers," by F. A. Allan (Ekco).

"Application of Negative Feedback to Flying-Spot Scanners," by R. Theile and H. McGhee (Pye).

"An Experimental System for Slightly Delayed Projection of Television Pictures," by P. Mandel (France).

"Evaluation of Picture Quality," by L. C. Jesty and N. R. Phelp (Marconi's).

Electronics Scholarships

A FOUR-YEAR "sandwich"-type course in electronic engineering was introduced by E.M.I. Institutes at the beginning of the year, but in order that the commencing date of the course should fit in with the normal school leaving time, the next course will begin on August 27th. A quarter of the total duration of the course is spent in the factories and workshops of the E.M.I. Engineering Development Co. Candidates for the course must be 17 years of age or over and have a good general education up to Inter-B.Sc. level in mathematics and physics.

The fee for the course is £100 p.a. but scholarships valued at £50 p.a., and, in some cases, grants towards maintenance, are offered.

The closing date for applications was July 6th, but as the details were not received until after our last issue went to press, the Institute has agreed to consider applications from *Wireless World* readers if lodged by August 10th.

PERSONALITIES

Dr. C. F. Bareford, M.Sc., who was appointed head of the Mullard Electronic Research Laboratory at Salfords, near Horley, Surrey, four years ago, has been made a director of Mullard Equipment, Ltd. Prior to joining Mullards he was for some ten years at the Admiralty Signal Establishment.

Major Edwin Armstrong, the f.m. pioneer, who is professor of electrical engineering at Columbia University, has been presented with the Washington Award by the Western Society of Engineers (America) for "outstanding inventions basic to radio transmission and reception." This is the first time the award has been made in the world of wireless. The previous twenty-eight recipients include Henry Ford and Orville Wright.

Dr. V. K. Zworykin, vice-president and technical consultant of the Radio Corporation of America, has been awarded the Medal of Honour by the American Institute of Radio Engineers "for his outstanding contributions to the concept and development of electronic apparatus basic to modern television. . . ."

Dr. Harry F. Olson, director of the Acoustical Research Laboratory of R.C.A. Laboratories, Princeton, N.J., has been elected president of the Acoustical Society of America for 1952. From 1939 to 1942 he was a lecturer on acoustical engineering at Columbia University.

G. E. Sugden, who, prior to joining the Sperry Gyroscope Co., Ltd., in 1947, was in the Applications Laboratory of the M.O. Valve Co., Hammersmith, has been appointed assistant manager of Sperry's aeronautical department.

G. E. SUGDEN.

IN BRIEF

U.S. Colour Television. — The Supreme Court of the U.S. has upheld the Federal Communication Commission's right to authorize the adoption of the C.B.S. frame-sequential system of colour television. A temporary injunction restraining the F.C.C. from enforcing its order was brought before the Chicago Federal Court by R.C.A., but the legal battle went finally to the Supreme Court with the result already stated.

Larger Valve Bases.—We understand from the General Electric Company that the base diameter of a number of Osram valves is being increased from 30 mm to 34 mm. The affected types are X61M, W61, DH63, Z63, H63, L63 and W63; some of these have been changed already and the others will be changed in the near future. The increased size, which will eliminate the trouble of bases becoming loose, should be borne in mind when fitting screening cans.

B.S. for B.A. Screws.—General dimensions for all the common types of B.A. screws, bolts and nuts (0 to 16 B.A.) are included in the revised edition of B.S.57, and the ranges of nominal sizes given in the tables are classified as "preferred," "second choice" and "not normally stocked." Copies may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1, price 3s, post free.

Electronics and Aeronautics.—Reference was made by the retiring principal of the College of Aeronautics at the Open Day at Cranfield, Bucks, to the College's new two-year course in aeronautical engineering, with special stress on the application of electronics in this field. Details of the course are available from the College.

EARL MOUNTBATTEN, vice-patron of the Brit. I.R.E., seen here with Paul Adorian, president, and (centre) G. D. Clifford, general secretary, presided at the dinner at the Savoy Hotel, London, at which the Institution's Convention was launched.

Service Sheets, covering both broadcast and television receivers, have been a feature of our associated journal *Wireless & Electrical Trader* for very many years, and in the July 7th issue the 1,000th sheet is included.

Red Sea Communications.—Wireless services operated by Cable & Wireless, Ltd., in the Red Sea area were recently extended. A ship-shore radio telephone service, opened at Aden on July 1st, provides for communication with ships within about 50 miles of Aden, as well as those in the harbour. By agreement with the Government of Aden, C. & W. has taken over two wireless stations on the Red Sea island of Kamaran, which is about 200 miles north of Aden. One of them operates a ship-shore service and a point-to-point telegraph service with the C. & W. station at Aden. The second is an aeronautical station.

Radio-man's Dream or Nightmare?—Addressing the Apprentices at the Passing Out Parade at No. 6 Radio School, R.A.F., Cranwell, Air Marshal C. W. Weedon, Controller of Engineering and Equipment at the Air Ministry, stated: "Electronic equipment now comes first and the aircraft to carry it second. . . . The bomber of the future is likely to have up to 1,000 valves in it."

Student Apprenticeships.—In view of the introduction of the General Certificate of Education in place of the former School Certificate, the Education Committee of the British Electrical and Allied Manufacturers' Association has recommended that the standard of entry for Student Apprentices should be the General Certificate of Education, with passes at the Ordinary Level in English, mathematics and a science subject. Applicants are also required to produce satisfactory evidence of a broad general education. The course of training will normally be four or five years; the minimum age of entry remains at 16 years, but apprentices starting at 17 or 18 will be expected to have passed in at least one of the three subjects at Advanced Level.

Two more aerials recently appeared on the Shot Tower at the South Bank Exhibition. Antiference Ltd., have supplied two Antex—crossed dipole—aerials for the reception of the Alexandra Palace transmissions for distribution by Central Rediffusion to all the 405-line television receivers in the exhibition. These aerials are being used in place of the original multi-element array.

Exports to China.—Electronic equipment, including radar, valves, communication gear and some materials used in electronic apparatus, is among the list of goods on which an embargo for China has been placed by the Board of Trade following the resolution passed by the United Nations regarding shipments to areas under the control of the Government of the People's Republic of China.

Draft Specification for a standard hearing aid similar to the Medresco issued under the National Health Service in this country has been prepared by the South African Bureau of Standards.

International Acoustics.—Further details are now available of the international journal of acoustics, *Acustica*, which, as announced some time ago, is being sponsored by the Acoustics Group of the Physical Society in this country and similar organizations in France and Germany. It will be issued six times a year and the subscription rate is 36 Swiss francs. The publisher is S. Hirzel Verlag, Claridenhof, Gotthardstrasse 6, Zurich.

"**Vacuum**" is the title of a new quarterly journal being published by W. Edwards & Co. (London), Ltd., of Worsley Bridge Road, London, S.E.26, reviewing developments in vacuum research and engineering. In addition to forty pages of original matter in the first issue, it includes 32 pages of abstracts printed on one side only to facilitate filing. The annual subscription is 25s.

Safety First.—It was learned at the recent Jubilee Exhibition of the British Standards Institution that an amendment to BS415/1941 "Electric Mains-operated and other Apparatus for Radio Acoustic and Visual Reproduction (Safety Requirements)" will be issued shortly by B.S.I.

INDUSTRIAL NEWS

Norway's broadcasting authority has ordered from Marconi's a 200-kW air-cooled long-wave installation for Oslo which will comprise two 100-kW transmitters in parallel, similar to those recently installed at Daventry for the B.B.C. Third Programme.

Ever Ready.—To mark the fiftieth year of the manufacture of batteries by the Ever Ready Co. (Great Britain), Ltd., the company's annual report takes the form of an illustrated survey of the manufacturing processes from the raw materials to the finished product.

Mullard, Ltd., announce the appointment of Dr. D. B. Foster as chief engineer of their Equipment Division. He has also been appointed executive director of Mullard Equipment, Ltd., the subsidiary company manufacturing scientific and telecommunication equipment. The Company also announces the retirement of J. E. M. Johns, who has been with the Mullard organization for twenty-four years and was latterly general manager of the Valve Division.

Tape Recording.—The opportunity of acting as distributors of British tape recorders and recording tape is being sought by Tape Recording Industries of 3335, East Michigan Avenue, Lansing, Michigan, U.S.A. Further details are available from the Commercial Relations and Exports Dept., Board of Trade, Thames House North, Millbank, London, S.W.1, quoting ref. C.R.E. (IB) 63844/51.

Electronic Equipment for India.—The Green Radio Co. of Mount Road, Madras, is opening an electronics division and is anxious to receive from British manufacturers details of industrial electronic equipment suitable for marketing in India.

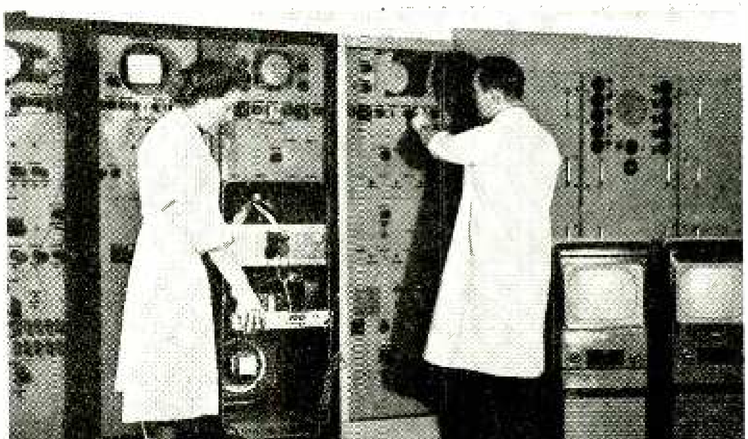
Radio equipment, comprising 19 short-wave transmitters, associated drive units, monitors and remote-control gear, has been ordered from Standard Telephones & Cables for the R.A.F. station at Nairobi. The transmitters, which vary in power from 5 to 40 kW, provide facilities for single, double and independent sideband transmission and frequency-shift keying.

S.T.C. announce that they have appointed A. W. Gordon, Ltd., 11, Gloucester Street, Belfast, as their sole selling agent in Northern Ireland for a considerable number of their products, including r.f. heating equipment, cables, rectifiers and intercom. gear.

Marconi Marine radio, radar and sound-reproducing equipment has been installed in the British India Steam Navigation Company's new 15,000-ton passenger liner *Kenya*. Her sister ship, *Uganda*, will also be equipped by Marconi's. The company is also installing similar equipment in the 17,000-ton New Zealand line vessel *Ruahine*.

Grampian Reproducers, Ltd., provided the sound-reproducing equipment for the Sports Arena at the South Bank Exhibition.

Metropolitan Radio Service Co., manufacturers and repairers of transformers, chokes, etc., have moved from Finchley Road, London, N.W.11, to 75, Kilburn Lane, W.10 (Tel.: Ladbroke 3120).



ROUTINE mechanical and electrical quality control check of Sobell 'Stargazer' television receivers. Vision and sound signals for the five television channels are fed from the racked equipment to the production lines.

Square-Law Rectifier Voltmeter

Graphical Methods of Designing Non-Linear Circuits

By THOMAS RODDAM

IF you look in most of the standard textbooks you will notice a unanimous disregard of the problem of designing non-linear circuits. Of course, a Class B amplifier is a non-linear circuit, but the textbooks concentrate on telling you how to avoid the disadvantages of the non-linearity. Clipping networks are non-linear circuits, too, but they are characterised by discontinuities in the input-output characteristic. The continuous non-linear circuit is one in which the output is not directly proportional to the input, although it is dependent on the input. The most common non-linear system with which we deal in the radio field is the valve itself. As everyone knows, the output current (the anode current) is given in terms of the grid bias by an equation of the general form

$$I_a = I_o + Ae_g + Be_g^2 + Ce_g^3 + \dots$$

When we design Class A amplifiers, we pretend that B, C . . . are all zero, and that the system is linear: the finite values of B, C, etc., are lumped together as distortion. In push-pull stages we are prepared for a finite value of B, and since we can accept this we work the stage with more bias, in Class B. But always we seek to provide an overall linearity between input and output.

We are not so limited when we consider phenomena as functions of time. Here, in addition to the linear sweep of the ordinary cathode-ray oscilloscope, we seek to design hyperbolic sweeps for air-to-ground p.p.i. displays and other waveforms which are, as the schoolboy said, too numerous to mention. Recently, in the development of television, the need has grown for circuits to control the "gamma" of the picture, to compress the brightness so that white flannels will not look whiter on the television screen and shadows will not merge into a complete cut-off. As this compression does not have to fit any exact curve, the design can be carried out on a subjective basis, which is a great help to the designer.

There is one non-linear circuit, which is of special importance, for which an accurate control of the input-output characteristic is essential. This is the r.m.s. voltmeter, which reads the true root-mean-square value of voltage with a complex waveform. If a number of different a.c. voltmeters are connected to measure the noise or speech level in a resistor it will be found that the readings obtained are not the same for different types of voltmeter. Very peaky waveforms, especially, give widely differing results according to whether the voltmeter is a peak circuit, using a diode, or some sort of average device. To obtain a true measure of the power, the voltmeter must indicate the root-mean-square voltage: then, and only then, the introduction of a phase shift will not cause a change in the reading.

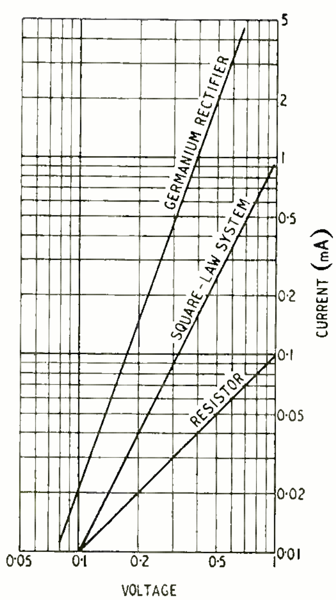
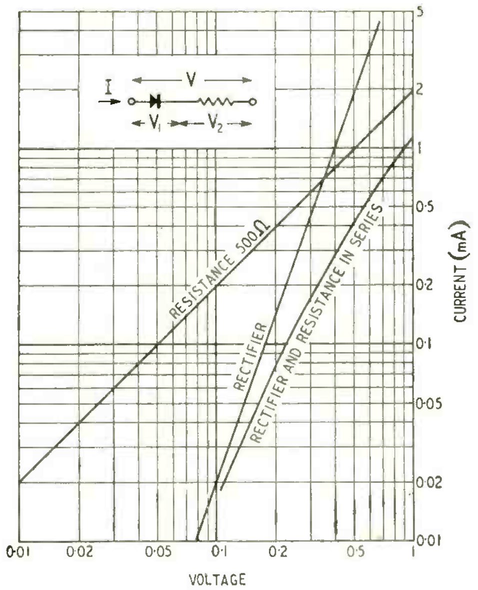


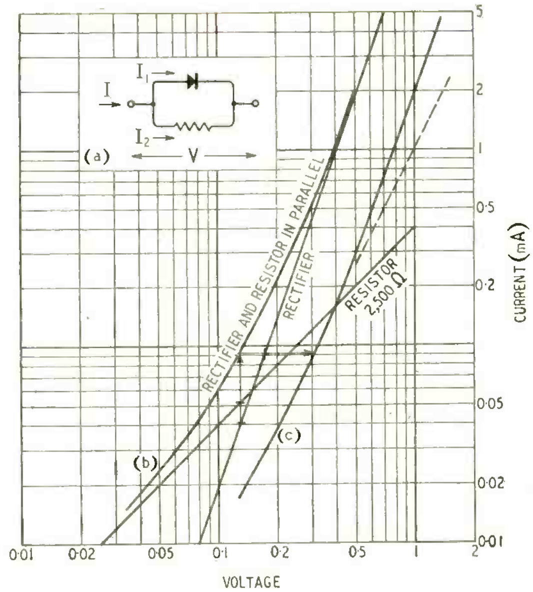
Fig. 1. Current-voltage characteristics of germanium rectifier (1N34), resistor (10,000 ohms) and square law system.

One solution of this problem is to dissipate the power to be measured, or part of it, in some sort of temperature-sensitive resistor such as a "thermistor," and to measure the change in resistance. The power heats the resistor, and since the power is directly proportional to the root-mean-square voltage, the temperature depends only on the r.m.s. voltage. Systems of this kind can be calibrated by means of direct current, and are used up to the highest frequencies. Instead of using the change in resistance, the temperature rise may be communicated to a thermocouple, the voltage from which is again directly proportional to the power. The disadvantages of these arrangements are that the heated element is usually burnt out by relatively small overloads and that they are slow in operation. A thermistor circuit will take at least one second to reach its final reading, which is not very satisfactory for measuring speech powers.

What we require is some sort of device which passes a current proportional to the square of the applied voltage. This current can then be measured by means of a conventional moving-coil meter, and the time constants of the circuit are those of the meter itself. We shall consider one way in which this relationship can be achieved, using a combination of elements which do not satisfy the square-law requirement. One type of element is just the ordinary resistor: the other is the contact-resistance rectifier, either copper-oxide or germanium. The detailed study is based on the germanium rectifier characteristic, but the method is obviously applicable to any other non-linear device, and to any other required law.

The method adopted is a graphical one. It is no doubt possible to provide an elegant, and involved, mathematical analysis: it is certainly very difficult. Furthermore, the justification of a precise analysis is usually that it provides an exact solution. Here we must begin with a graphical expression of the characteristic of the rectifier, and to turn this into an equation, just to enable us to indulge in mathematics, seems to be stretching pedantry too far. Our main errors arise from the non-uniformity of the rectifier characteristics, not from the inaccuracy of our solution of the





Left: Fig. 2. Current-voltage characteristic for series rectifier-resistor circuit. Right: Fig. 3. Rectifier and resistor in shunt (a), combined characteristic (b), and effect of adding a series rectifier (c). The dotted line is the wanted square-law.

problem. Why, then, try to provide a more exact solution to a problem which cannot be precisely defined? Cost inflation is caused by too many engineers chasing after too many significant figures.

Our first requirement is a graph of the current-voltage characteristic of the rectifier to be used. Fig. 1 shows this for a germanium crystal, type 1N34. Using a logarithmic scale, which we shall require later, this characteristic is a straight line, with a slope of 2.95. Suppose that we write the characteristic as

$$I = kV^n$$

$$\log I = \log k + n \log V$$

$$\frac{d\,(\log I)}{d\,(\log V)} = n$$

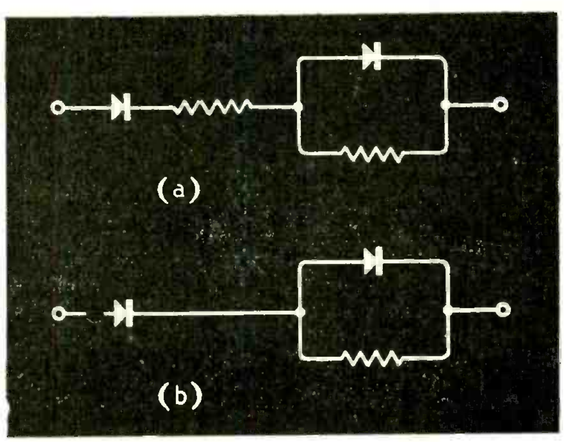
Thus $n = 2.95$. If we wish, we can calculate the value of k, but we shall not require it here. Also plotted in Fig. 1 are lines with unity slope, corresponding to a normal resistance, in this case 10,000 ohms, and with a slope of 2, for which $I = kV^2$. This is the slope we require for our root-mean-square meter. The wanted square law is intermediate in slope between the rectifier law and the resistance law: the problem is then to combine resistors and rectifiers to give the required shape over a suitable range.

Let us consider the circuit in Fig. 2. The voltage across the circuit, V, is obviously equal to $V_1 + V_2$. At any prescribed current, therefore, we can find the total voltage drop by adding the rectifier voltage and the resistance voltage. This is easily done on the graph of Fig. 2 which shows the result for 500 ohms in series with a 1N34. For very high currents, the curve is asymptotic to the curve for the resistor: for very low currents it is asymptotic to the resistor curve. Again, the slope is 2 in the neighbourhood of 0.1 mA, but now it deviates in the opposite direction. At high voltages the shunted rectifier passes too much current, while the rectifier with a series resistor passes too little.

These two combinations are the building blocks for the final network. The complexity of this network will depend on how accurately we wish to fit the square-law characteristic, and how wide the working range is to be. This, in turn, depends on the sort of waveform we expect to measure. For example, pulses with a duty ratio of 1/1000 will pass a peak current of 1A for an indicated meter current of 1 mA. This is an extreme example, because when we get to signals of this kind we obviously are going to adopt other methods. For ordinary audio-frequency work it is sufficient to design for sinusoidal signals up to 2 or 3 times the amplitude for maximum deflection. Signals of ordinary peakiness are then indicated quite accurately.

We may now try to assemble a network which will provide the required characteristics. Notice that we must use a network of the type shown in Fig. 2 in series with networks of Fig. 3(a). The unshunted rectifier is needed to convert from a.c. to d.c., and the

Fig. 4. (a) The two basic blocks combined, and (b) approximation valid at low levels, giving the curve of Fig. 3 (c).



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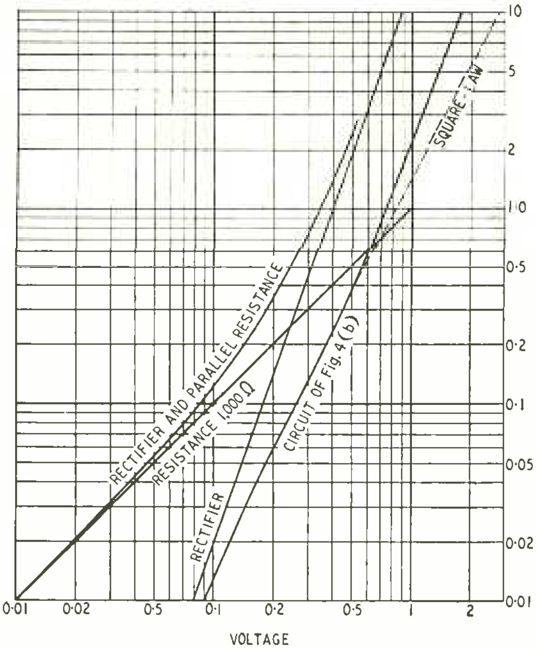
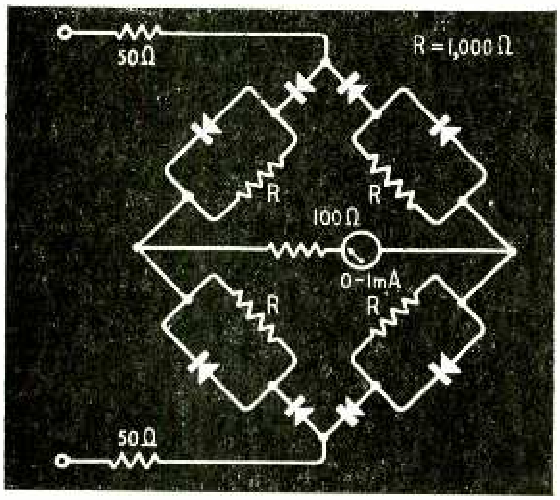


Fig. 5. Development of the final characteristic, using 1,000 ohms in parallel with one rectifier.

Fig. 6. Complete rectifier bridge circuit for root-mean-square measurement. Using Type 1N34 germanium rectifiers.



series resistance is needed to account for the meter resistance and the external circuit resistance. The design which will be considered here is the simplest combination of these two building blocks, Fig. 4(a). I am not convinced that the use of more complex networks is justified, when the tolerances and ageing effects in the rectifiers are taken into account. At very low levels, the effect of the series resistor can be neglected, at any rate as a first approximation. The network then reduces to that shown in Fig. 4(b), and the curve of Fig. 3(c) can be obtained by first adding the currents for resistance and shunt rectifier, and then adding the voltage for the series rectifier. The curves shown in Fig. 3 are, of course, for 2500 ohms, a value selected as a first trial. It will be seen that it fits the square-law line very well down to currents below 20 μA. The fit is no longer good above about 200 μA. We shall assume that the design range is to extend up to 1 mA indicated, or up to about 2-3 mA peak. Clearly it is not important to have a good fit below 50–100 μA, because meters are not very accurate in this region. Without more consideration, therefore, we can proceed to move the curve upwards. The reader who distrusts this can check, by the method to be described, the need to do it.

It is, I think, fairly obvious that we can assume that by taking 1000 ohms instead of 2500 ohm the linearity will be good down to at least 50 μA instead of 20 μA. Making this assumption, we proceed to generate a new characteristic, which actually turns out to be rather better than we expected. This is shown in Fig. 5. The deviation from linearity is just noticeable at 20 μA, but the characteristic is good up to 0.5 μA. At higher levels there is a deviation from the square-law line, but it is in the right direction for correction by a series resistor.

The required series resistor is obtained by calculating the value required to correct the top end of the characteristic at a number of different points. The result is tabulated below, and the method of calculation is obvious from the form of the table.

Current (mA)	Correction (V)	Resistance (Ω)
1	0.1	100
2	0.21	105
3	0.33	110
4	4.3	107
5	5.2	104
10	9.5	95

Remembering the sort of tolerances we are dealing with, and the errors in the original curve, this looks like a pretty solid vote for the round 100 ohms, with a good fit to the square law to round about 3 volts input and a current of 10 mA, and down to 0.1 volts, with a current so small that the meter errors become dominating.

This design procedure is, as the reader can see, a rather arbitrary one. It may seem that too much has depended on a lucky choice for the low-end value. How far this is a justifiable criticism I cannot decide. The exact order in which the network is built up seems to be the key to the problem and the order described gives a very satisfactory convergence to a solution. It is tempting to consider elaborations: these are sometimes necessary. Two rectifiers in series or in parallel may be used in place of either or both of the single rectifiers shown. This technique is useful for shifting the scale of the device to suit a particular requirement. When copper-oxide rectifiers are used, the wide variety of types permits the designer to try an even wider range of designs. The copper-oxide characteristics do not appear to be so linear, on the logarithmic scale, and this does make the drawing work more tedious.

We must now consider the actual network to be used. We can, of course, take the simple network of Fig. 4(a). Since we are assuming that we want to measure a non-sinusoidal wave, however, it is desirable to measure both halves of the waveform. The full-wave bridge shown in Fig. 6 is the simplest structure which we can use. We now have two of our standard networks in series, and the meter can be regarded as part of the conducting branch at any instant. Thus we must have a meter resistance of less than 200 ohms. For convenience in construction the meter resistance normally about 50–70 ohms, is assumed to be built out to 100 ohms, leaving 50 ohms for each branch. This resistance, by a well-known theorem, or here, just by common sense, can be extracted from the bridge, to give the form shown in Fig. 6. The final design will then give a deflection of 1 mA, the maximum assumed for the meter, for an applied voltage of 1.7 V.

The next step depends on the intended use of the meter. If it is to be used as a voltmeter in the ordinary sense, it should be driven from a cathode follower. This will give a high input impedance, but the cathode follower impedance, seen from the cathode, must be counted as part of the series resistance. A cathode follower twin, made up of a twin triode, amplifier and cathode follower, with feedback from the cathode to the input to reduce the gain to unity, will provide a very low driving impedance and the desirable gain stability. Often, however, the meter will be used across a voice-coil impedance. Then the low impedance of the voltmeter (1000 ohms at full scale) will not cause any inconvenience. A simple low impedance (say 135 ohms-15 ohms) voltage divider can be used to extend the range by a factor of 10, giving a full-scale reading for 20 watts across a 15-ohm loudspeaker.

There are two ways in which the accuracy of the square law can be tested. Both require the use of two oscillators. The first requires, in addition, an accurate attenuator. In the first, two signals of different, and unrelated, frequencies are applied separately to the voltmeter through networks which are matched. The two signals are then applied simultaneously, with a 3db pad inserted in the common path (this is the reason why the connecting networks must be matched for impedance). The same reading should be obtained for both single signals and for the combined signal attenuated by 3db. In the second test, the two oscillators are connected simultaneously, but one is set to give about 3 times the output of the other. The low-level oscillator is adjusted to exactly 3 times the frequency of the high-level oscillator. By allowing the two oscillators to beat slowly, the phase of the 3rd harmonic drifts relative to that of the fundamental, and the waveform of the combined signal changes regularly from "peaky" to "square." The meter deflection should remain steady if the system is a true r.m.s. system.

Amateur Television

IN the early days of radio, amateur enthusiasm had a way of getting round obstacles and difficulties which taxed the professionals. In the present television age this same quality is manifested in rather a different way. Not content with merely receiving pictures on home-built equipment, amateurs in many parts of the world are now constructing and operating their own cameras and transmitters. With limited means and simple equipment they emulate the high standards of picture quality already set by the public television services.

In this country their activities are co-ordinated by the British Amateur Television Club. Formed in February, 1949, the Club first attracted attention by demonstrations of closed-circuit television at the 1950 R.S.G.B. amateur exhibition, and recently, in London, it held a National Television Convention at which an interesting selection of members' equipment was on view. One notable exhibit was an iconoscope camera, built by G. G. Short, for working on 250 lines, 50 frames per second non-interlaced. It was fitted with a 3-lens turret and an electronic viewfinder, and contained an 8-stage video amplifier, while the necessary pulse and waveform generators and power supplies were built into a separate unit.

The iconoscope in this camera was an RCA type 5527, a small tube about 9 inches long which has been designed specifically for experimental work. It has electrostatic deflection and focusing, and the mosaic, about 1½in across, is perpendicular to the axis of the tube. The resolution capability is about 250 lines and the sensitivity is sufficient to give a satisfactory picture, say, out-of-doors on a bright day. This, in fact, is the only tube at present available that is at all suitable for amateur purposes—and it costs somewhere in the region of £25. An import licence is required, however, and as these are not easy to come by, the Club has been trying to persuade British manufacturers to produce a comparable tube in this country.

Because of this difficulty in obtaining pick-up tubes —not to mention the £25—some Club members are contenting themselves with the transmission of pictures on transparent slides and films, as this can be done, on the flying-spot principle, with comparatively simple and inexpensive equipment. A short-persistence c.r. tube is arranged on one side of the transparency for scanning, while a photocell on the other side responds to the variations in transmitted light;

Ivan Howard with the iconoscope camera he has constructed. Inset: Iconoscope tube RCA type 5527.

the raster of the receiving c.r. tube being, of course, synchronized to that of the flying-spot tube. At the Convention one of these equipments was demonstrated by member F. Rose, who being also a servicing technician, finds it very useful as a pattern generator for testing domestic receivers. Another member has experimented with flying-spot scanning on a "live programme" in a darkened room, collecting the reflected light with a photocell. Both electronic scanning with a c.r. tube and mechanical scanning with a Nipkow disc (100 lines) were tried, but the results were not very encouraging. The only other method by which the flying-spot principle can be used on a live scene is the intermediate-film process, but this is somewhat cumbersome and would probably be more expensive in the end than a pick-up tube.

About two-thirds of the Club's members are at present confining themselves to closed-circuit television, as many difficulties stand in the way of actual transmission. In the first place, the wavelengths on which amateur vision transmissions are permitted are all in the centimetre region, and this demands a type of equipment which is not easy to construct and operate. Then there is the question of the Post Office licence. Under provisional arrangements the vision licence is to cost £3, but in practice there is another £1 10s if the amateur wishes to transmit sound (assuming he has passed the P.M.G.'s tests), and another £2 if he wishes to operate a television receiver—making an annual total of £6 10s.

Altogether, then, it seems that something more than just enthusiasm is needed!

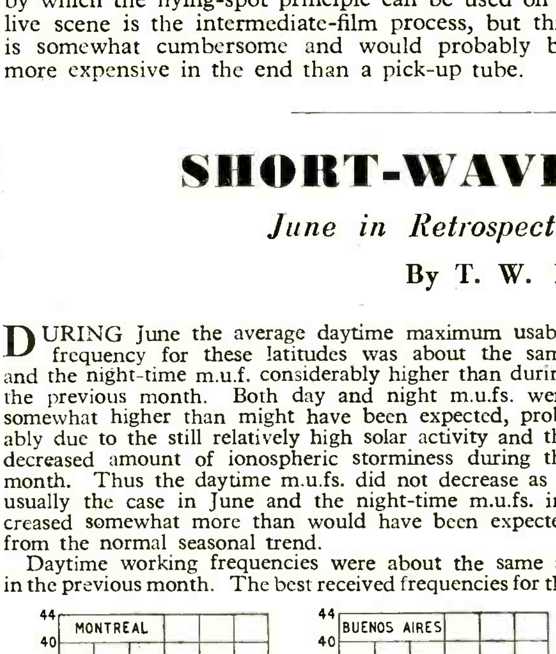
SHORT-WAVE CONDITIONS

June in Retrospect : Forecast for August

By T. W. BENNINGTON *

DURING June the average daytime maximum usable frequency for these latitudes was about the same and the night-time m.u.f. considerably higher than during the previous month. Both day and night m.u.fs. were somewhat higher than might have been expected, probably due to the still relatively high solar activity and the decreased amount of ionospheric storminess during the month. Thus the daytime m.u.fs. did not decrease as is usually the case in June and the night-time m.u.fs. increased somewhat more than would have been expected from the normal seasonal trend.

Daytime working frequencies were about the same as in the previous month. The best received frequencies for the east to west paths were of the order of 17 Mc/s. Although 21 Mc/s was sometimes usable, frequencies above 21 Mc/s were hardly ever heard. In north/south directions 21 Mc/s was occasionally received during the day. At night 11 Mc/s was usually workable till midnight and frequencies below 9 Mc/s were seldom necessary.



——— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS
– – – – PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY
–·–·– FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

In accordance with the usual trend there was an increase in the amount of Sporadic E observed during June. It was very likely due to this cause that the nearer continental stations on frequencies of the order of 40 Mc/s were often audible in this country.

On a number of occasions German and Dutch stations on frequencies of the order 90 Mc/s were heard, most probably by means of tropospheric refraction.

Sunspot activity was, on the average, slightly lower than during the previous month.

Although six sunspots crossed the sun's central meridian in June, two of which were very large, the month was relatively quiet and there was less ionospheric storminess than during the previous month. Disturbances did, however, occur during the periods 2nd-5th, 18th-20th, 25th-26th and 29th. The number of Dellinger fadeouts, although smaller than in May, was still considerable. Seven of these were reported of which only the one occurring on 13th at 0555-0830 g.m.t. was of severe intensity.

Forecast:—During August daytime m.u.fs. should increase slightly and those for night-time should decrease somewhat as compared with those for July. Working frequencies for long-distance communication should, however, be still relatively low by day and high by night. The highest regularly usable daytime frequency over the east/west circuits may be of the order of 17 Mc/s, and 21 Mc/s may be sometimes usable. On the north/south circuits 21 Mc/s should be a regularly usable daytime frequency but 28 Mc/s may become occasionally usable. At night 11 Mc/s should be usable till after midnight and 9 Mc/s the night through.

During August Sporadic E is likely to continue to be prevalent thus facilitating at times medium-distance transmission on exceptionally high frequencies. Normal communication over medium distances will be controlled for several hours daily by the E or F_1 layers and the usable frequencies for such communication should during those hours be relatively high.

The curves indicate the highest frequencies likely to be usable over four long-distance circuits from this country during the month.

* Engineering Division, B.B.C.

LETTERS TO THE EDITOR

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

"*Bass Without Big Baffles*"

I SHOULD like to reply to the interesting points raised by F. D. C. Baker in the July issue, regarding certain details of the circuit employed in my amplifier.

By analogy with the ear and the wide range of subjective harmonics which it produces in response to a low fundamental tone, I have not considered it necessary, or advisable, to suppress higher order harmonics appearing at the anode of V_3. In fact, the range of harmonic production may be increased (profitably in the case of very small baffles) by reducing the capacity of C_4 to 0.05 μF or even 0.03 μF before higher order harmonics become in any way obtrusive to the ear.

The distorted output from V_3 (which is not itself subjected to negative feedback) is fed into the amplifier, as Mr. Baker mentions, at a point within the feedback chain. However, this state of affairs is highly desirable in order to maintain good speaker damping—even though a previously distorted signal is being handled by the output stage.

I agree with your correspondent that the proportion of harmonic bass to signal will tend to decrease as the volume control is turned down. Such a phenomenon is inevitable in a device exhibiting a sigmoidal type of characteristic curve, and may, in the case of the ear, be involved in the assessment of relative loudness at low frequencies. By making R_{12} suitably large I have endeavoured to introduce a degree of distortion which would prove optimum within the usual range of listening levels.

The circuit modifications suggested by Mr. Baker would overcome changes in the ratio of harmonic to signal due to adjustments of the volume control, but not those due to variations in strength of the incoming signal itself.

Leeds, 6. K. A. EXLEY.

HAVING had an opportunity of listening to the results produced by Dr. K. A. Exley from his amplifier, I am able to confirm that at low domestic volume there is a most unusual degree of bass response which is entirely free from audible distortion. In fact, I have never heard such satisfying bass output from low-level reproduction.

It ought to be pointed out, however, that Dr. Exley uses a loudspeaker which has been specially "doctored" to bring the natural resonance down to about 30 c/s, and the unit is mounted in a fairly large radiogram cabinet. The results would obviously not be so good if a speaker were used with a bass resonance in the more usual region of 60 to 90 c/s.

I am not quite happy about the explanation given by Dr. Exley, by which he attributes the absence of *audible* distortion to the shortcomings of the human ear. It seems to me that if the ear cannot detect distortion then distortion does not in fact exist, because the object of producing sound is for the benefit of the ear, and not for any scientific purpose. Would the real explanation be that the effect of the distortion at low frequencies, which is deliberately produced in the amplifier, is removed by limiting the frequency response of the circuit to the region below 100 c/s? The objection to distortion at low frequencies is the production of spurious harmonics at higher frequencies. If these harmonics are removed by filtering, there is no distortion left to worry the ear.

Wharfedale Wireless Works, Idle, Yorks. G. A. BRIGGS.

PLEASE allow me to thank Dr. Exley for his 5-watt amplifier circuit, published in the April, 1951, issue. I built the amplifier (unlike Mr. Bourn, his critic in the June issue, who, I gather, did not).

On 3rd June, using a simple germanium-crystal receiver 15 miles from London, I found myself listening to a Bach choral and orchestral programme from the Royal Albert Hall. Volume was too great and had to be reduced. The superb reproduction, combined with the wonderful beauty of the music, absolutely amazed me; I had never heard anything approaching it from a wireless set. I do not listen to choral items normally, but on this occasion I could not switch off, although I was impatient to get out into the summer afternoon. That's my reply to Dr. Exley's critic. Anyhow, there is a switch which eliminates the "distorting valve."

Dr. Exley's circuit is a wonderful acquisition. I knew just enough about wireless to understand that none but a fool would build or buy a 10-watt amplifier for use in an ordinary living-room. This one, with a 15-ohm Goodmans speaker costing about £2 10s (not an expensive speaker mind you), reproduced with a clarity and beauty of tone (it can be made to imitate almost any other radio on account of its three tone controls) far in advance of any commercial radio I have ever heard—and I have listened to many, some costing nearly £100.

Orpington, Kent. O. G. KERSLAKE.

Nomenclature

THE indiscriminate use of the words "multivibrator" and "flip-flop" appears to be increasing. Since the two circuits are extremely different in behaviour this causes much confusion. I trust the following explanation will result in an avoidance of the error.

The word "multivibrator" was first used by Abraham and Bloch in 1918. It means a vibrator which produces a multitude of frequencies, i.e. a square-wave output. The important point is that the circuit vibrates and that it is in continuous operation or, as is sometimes stated, it is "free-running."

The word "flip-flop" was first coined by A. Allen of A. C. Cossor, Ltd., and it denotes a circuit which has one stable and one unstable condition. A circuit of this description has one valve (or one electrode in a single valve circuit) which is so biased that, in the absence of an input signal, the circuit is stable. When a suitable signal is applied, the circuit flips to an unstable condition and, after a certain lapse of time, flops back to the stable condition and remains so until a further signal arrives.

Moreover, in America a flip-flop is sometimes referred to as a "one shot multivibrator," but the terms "one shot" and "multivibrator" are antipathetic and the word combination has no meaning.

There is another circuit, devised by Eccles and Jordan, which has two stable states and this might, with advantage, be called a two-state stable trigger circuit. During the last few months a three-state and a five-state trigger circuit have been developed. O. S. PUCKLE.

Beaconsfield, Bucks.

Legitimizing the "Puff"

WOULD it not be of considerable advantage now to make a slight rearrangement of the units of capacitance? Instead of having the farad as the basic unit and dividing downwards to the microfarad and the micro-microfarad or picofarad, why not use the picofarad as the basic unit and express all capacitances in terms of it? It would probably be necessary to rename the picofarad —I suggest a short name such as "pif,"* having the sym-

* Why not "puff," which already has a wide colloquial circulation?—Ed.

bol P—and the microfarad would then become the "megapif" (MP). (This is the reason for the renaming, of course, since one could hardly have a "megapicofarad.")

This change would have the great advantage of avoiding the use of decimal points and noughts, except for very small capacitances. At present, radio and other electronic circuits use many condensers of sizes between a microfarad and a picofarad, such as 0.01 μF and 0.0001 μF; these two examples would become 10 kP and 100 P respectively, whilst 10 μF would become 10 MP. Circuit diagrams would be easier to read and one would not be faced with the problem of deciding whether 0.0003 μF equals 300 pF or 3000 pF! The new units of capacitance would be similar to those of resistance or frequency, with symbols P, kP, MP corresponding to Ω, kΩ, MΩ and c/s, kc/s, Mc/s.

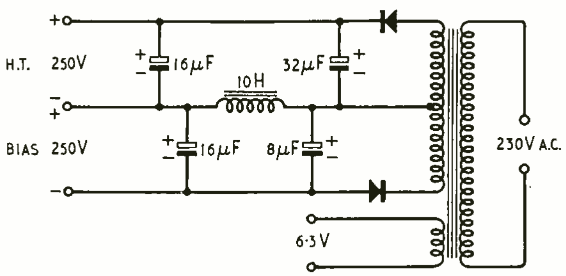
There would be the incidental advantage—not a small one to those concerned with technical literature—that the new units would not use the Greek symbol μ and could be typed on an ordinary typewriter.

The proposed change would not, in fact, be so big as might at first appear, since it is already normal practice to express capacitances in terms of picofarads in some spheres. For instance, the condenser colour code does so. In fact, the real change boils down to the renaming of the picofarad to allow the prefixes "mega-" and "kilo-" to be used, so that, in turn, the values become whole numbers. A. C. KAY.

Brookman's Park, Herts.

"*Square-Wave Generator*"

I RECENTLY constructed the square-wave generator described by O. C. Wells in your January, 1951, issue. H.t. and bias supplies were somewhat difficult, being +400 V and —400 V. Perhaps fellow readers would be interested in the method I adopted to overcome this difficulty whilst exercising the utmost economy in components. The accompanying circuit was employed, all components



being available at present on the "surplus" market. The transformer was a standard receiver type, 250-0-250 V and 6.3-V filament supplies, and the rectifiers were ex-Government half-wave selenium types rated at 300 V, 80 mA. The power pack delivers the voltages as shown under load, the percentage of ripple being low enough to be unnoticeable in the waveform of the generator at all frequencies.

Although the voltages are considerably less than specified in the design, the output is quite adequate for most purposes, being about 30 V peak-to-peak.

Norwich. R. WILLIAMSON.

Automatic Monitoring

AFTER having read "Diallist" in your May issue, and having heard the reading of the paper "The Automatic Monitoring of Broadcast Programmes" at the Institution of Electrical Engineers, I should like to point out that the general principle involved was outlined by me in 1948 and published in the June, 1948, issue of *Wireless World* under the heading "Dynamic Distortion Detector." Furthermore, I learned recently that in August, 1940, a U.S. patent (2,213,099) was granted to P. Adorian, London, for a "Distortion Indicator for Electrical Amplifying Systems," which is very similar, at least as far as the purpose is concerned, even if somewhat "less electronic." R. DANZIGER.

London, W.1.

"*The 1,000-Line Will o' the Wisp*"

BECAUSE I share the strong views so forcefully put forward by R. W. Hallows in your May issue, may I be allowed to make one point which was not covered and to elaborate another?

Major Hallows undoubtedly proves the difficulties of eliminating ghosts with decimetre-wave transmission. There is, however, another direction in which a super-high definition picture could be marred. A close scrutiny of the vertical sides of the average television picture invariably reveals small random displacements of individual lines to right or left. These are due to the inevitable modicum of interference accompanying the synchronizing pulses or to sudden mains fluctuations. In spite of the scaling down of time constants which would naturally accompany an increase in number of lines or frequency, such displacements would be expected to amount to much about the same percentage of the picture width at 1,000 lines as at 405 lines. The same would probably apply to random vertical movements. Accordingly, the level of interference from all sources would have to be substantially reduced for the full benefit of the increased picture definition to be realized.

The author concludes with an appeal for research aimed at effecting improvements within the present television specification. Here are a few items for such an agenda:—

(1) Weeding out of poor-quality cameras.
(2) An increased regard for tone gradation in the greys and an extension of the range of constant gamma at both transmitting and receiving end.
(3) A stricter maintenance of black level.
(4) Reduction of ringing.
(5) Some reduction of the random displacements referred to above.

All these lines of improvement naturally take the form of continuous processes—a fact which would help to avoid large increases in cost—and there would be no question of existing receivers becoming obsolete as a result of them.

Slough, Bucks. H. G. M. SPRATT.

F.M. and Exports

THE arguments over the comparative merits of f.m. and a.m. will certainly be both long and legion, but there is one, the importance of which must surely at this stage override all others.

For better or for worse, we find that, following the U.S.A. lead, Western Europe already has forty-three metre-wave stations operating in the broadcasting band and forty-two of these use f.m. Other Empire countries have not yet needed to develop broadcasting in this band.

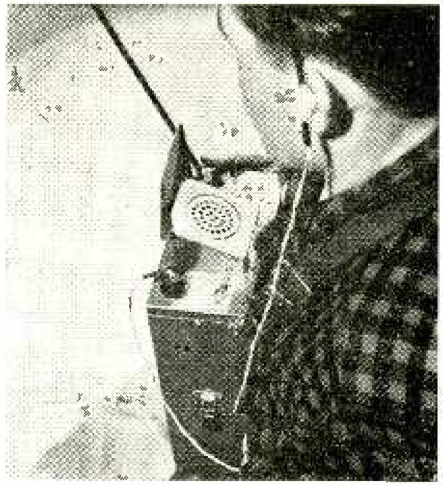
Surely at to-day's date we do not want to back a system which is different from the rest of the world unless our alternative is immeasurably better. A good export trade depends on large-scale home production of similar products. I hope, therefore, that this argument in favour of f.m. will not be overlooked.

I recognize that if we had started a v.h.f. service in 1945 we might have swung the non-dollar world in line with our thoughts, but I submit that we must face the facts as we find them to-day, and adopt f.m.

House of Commons. C. I. ORR-EWING.

Miniature Walkie-Talkie

Self-contained Radio Telephone for Operation in the V.H.F. Band 60-100 Mc/s

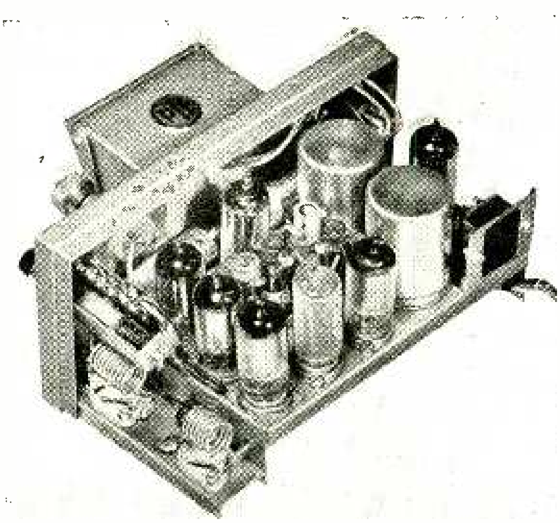


Pye miniature walkie-talkie. The combined transmitter-receiver occupies the top part and the batteries the bottom part of the container.

A NEW walkie-talkie which is claimed to be much smaller, considerably lighter, more economical in operation and cheaper than other equipments of this kind has been introduced by Pye Telecommunications of Cambridge. Incidentally, the description "walkie-talkie" may not be very elegant, but it does manage to describe in the fewest possible words the exact nature and function of the apparatus. For the benefit of those who may like a more precise definition, this type of equipment can be described as a self-contained portable radio telephone transmitter-receiver capable of being carried by one person and operated while on the move. So there is something to be said in defence of "walkie-talkie."

The new Pye equipment, which has the type number PTC120, is built into a case measuring 9½ in high, 6½ in wide and 3¼ in deep and is designed to be carried on the chest like the Service-type gas mask used in the late war. The set complete with batteries weighs 8½ lb.

Chassis of Pye's new walkie-talkie. It contains six valves and the use of miniature parts throughout has enabled the size to be reduced to a minimum, yet all parts are very accessible.



Convenience of operation has been studied carefully, for example, the microphone is fitted on top of the case at an angle that brings it close to the mouth by bending the head forward slightly. When not in use the microphone, which is a G.P.O.-pattern carbon type, is protected by a snap-down lid. There are two controls only, one is an on-off switch, the other a send-receive switch, the latter being the push-to-talk variety. A single earpiece miniature telephone fixed to a light metal headband is employed, thus the hands are left entirely free except when actually transmitting.

It is most unfortunate that full details of the circuit cannot be given, as it is quite unorthodox and includes a number of very interesting features, but it can be said that six valves only are used in the whole equipment. There is one germanium crystal and two quartz crystals in miniature valve envelopes, one for the transmitter and one for the receiver. The equipment operates in the v.h.f. band of 60-100 Mc/s, using one or two spot frequencies as required. For example, send and receive can be on a common frequency or a different frequency can be used for each, hence the provision of two crystals.

The receiver is basically a superheterodyne with one r.f. amplifier, crystal-stabilized local oscillator (after frequency multiplication, of course), mixer, i.f. stage and audio amplifier. Two valves only are used in the transmitter; one is a crystal oscillator and combined frequency multiplier, the other functions as a frequency doubler and power output stage. Miniature valves are used throughout. The r.f. power output of the transmitter is 0.1 watt and it is amplitude modulated, the audio stage in the receiver being used for this purpose.

Power for the set is supplied by dry batteries: the l.t. has a life of about 15 hr intermittent operation and the h.t. about 75 hr.

It is difficult to assess the range of portable equipment of this kind as it depends so much on the conditions of operation. The minimum distance covered would be between two walkie-talkies, but one to two miles should be obtained under reasonably favourable conditions. With both equipments located on high ground and no obstructions between them the range of operation should be the optical path; on the other hand, in built-up areas the range may drop to a few hundred yards only.

Greater ranges will be obtained under all conditions between walkie-talkie and a mobile equipment in a vehicle and still greater between walkie-talkie and a fixed station.

The receiver and transmitter are assembled on a single chassis which occupies the top half of the container. The battery compartment is below and the two are held together by a snap-fastener on each side.

The small number of valves employed makes a reasonably simple layout possible and, as the illustration of the chassis shows, all parts appear to be, and in fact are, quite accessible. The underside is equally free from complication and it has been possible to arrange for its manufacture on a production line basis in much the same way as ordinary broadcast sets are produced. It is a creditable achievement that a v.h.f. equipment for 100-Mc/s operation can be produced in this way and without the need for highly skilled workers.

The chassis view shows most of the principal features of the equipment; for example, the send-receive changeover switch is seen on the left with the transmitter and receiver aerial circuits mounted on the small sub-chassis immediately below. The transmitter output circuit is nearer the camera and just above and in line with it along the bottom edge of the chassis (the cover plate with the microphone housing is, of course, the top when the chassis is fitted in its case) are the two transmitter valves with the quartz crystal mounted in a miniature valve envelope between them. On the extreme right and behind the two cylindrical cases, which incidentally house microphone and modulation transformers, is the audio-output-valve-cum-modulator. The socket on the right-hand edge of the chassis is for monitoring the various stages. The connector for the quarter-wave rod aerial can be seen on the left of the microphone housing when viewed from this angle. It is mounted on a polythene feed-through insulator the lead from which can be seen connected to the nearby changeover switch.

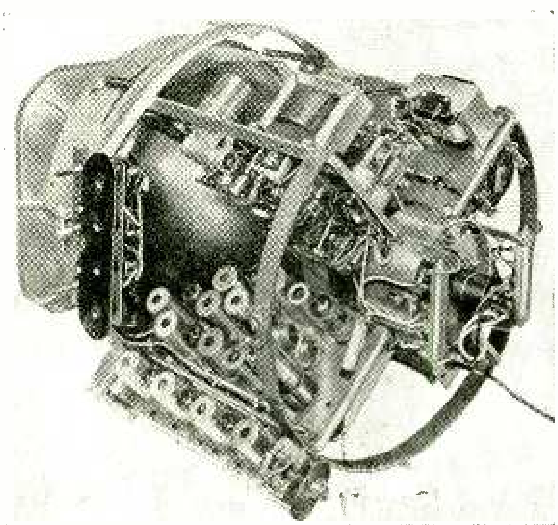
Cylindrical Chassis

Better Spacing of Components and Reduced Overall Size

THE baseboard-and-panel form of construction began in the earliest days of radio and has been the main influence in chassis design ever since. For some applications it still cannot be bettered, but fundamentally it does not lend itself very well to the modern demands of miniaturization and space saving; components tend to be clustered on two surfaces only, so that when the chassis is put in a box or cabinet a considerable amount of space remains unused. In other words, a better distribution of the same components would reduce the overall size of the equipment.

Modern trends, therefore, make it necessary to depart from the old formula and go in for new methods of construction making fuller use of the available space. One recent example is the almost cylindrical chassis in which Murphy embody their V200 table-model television receiver. It illustrates very well the art of getting into a pint pot not a quart but simply a pint—and perhaps in more ways than one, for the design is very reminiscent of aircraft equipments which have to be "potted" for pressurization purposes. The receiver is actually split into four separate sub-chassis and these are arranged radially around the neck of the cathode ray tube, in a space that is not often utilized because of its awkward shape; thus the diameter of the chassis is not very much greater than that of the tube face. A smaller cabinet than normally to be expected has been made possible in this way, and it is claimed that the arrangement gives better spacing between components and easy access for servicing. Another point is that the chassis can be rolled over conveniently on the servicing bench, and the metal loops prevent the parts from getting damaged in the process.

Showing how the four sub-chassis are arranged radially around the neck of the cathode ray tube.



The four radial sub-chassis carry the receiver, the frame time-base, the line time-base and the e.h.t. transformer, but there is also a detachable r.f. unit (bottom left of picture) on the outside of the metal hoops. This external unit is actually Murphy's solution to the problem of the different television channels; the receiver proper remains standard for all parts of the country but a separate r.f. unit is available for each frequency. It can be changed easily through the bottom or the back of the set.

"How to Choose a Valve"

Correction.—On page 222 (June issue) the expression in the first column for second harmonic distortion should be

$$\frac{Be^2}{2g_m e} \cdot 100\% = \frac{B}{2g_m} \cdot e \cdot 100\%$$

In the following line, ". . . as B is the slope . . ." should read ". . . as 2B is the slope . . . ."

SAMPLING

Is it the Answer to the Wavelength Problem?

By "CATHODE RAY"

MOST people nowadays realize with sorrow that it is only when things become scarce and dear that they stop using them wastefully. Coal, for example. And in the spacious days of Edward VII nobody bothered much about the bandwidth of radio communication channels, if indeed they ever heard of such a thing. The spark transmitter, then in vogue, was often considered to have a positive merit in spreading itself over a large part of the receiver tuning scale. It was less likely to be missed!

But now every kilocycle is fiercely coveted and fought for at international conferences, and a wealth of ingenuity goes to devising means for squeezing more and more through less and less frequency bandwidth. The problem is so important that much study has been devoted to the basic theory of communication, with the object of steering practical work into the most promising directions and avoiding waste of time chasing impossibilities. Theoretical scientists have in the past saved an enormous number of man-hours that used to be expended in the search for perpetual motion, the elixir of life, and so on. (But they have to be kept in their place, for at one time they proved that it was impossible to send radio signals over long distances because of the curvature of the earth!)

I dealt with the subject of communication theory in "Channels of Communication" (June and July, 1947), and so more recently has Thomas Roddam (May 1949; June 1950). One of the most important facts is that in order to send any sort of information at all (messages, sounds, pictures, etc.) you have to *vary* the electric current, radio waves, or whatever you employ as information carrier. An endless steady current, or even a.c. in which every cycle is the same as the last, conveys information at zero rate. The greater the rate at which you transmit information, the faster you have to vary the carrier, and the wider the band of frequencies you are bound to generate. To leave room for anything else, I shall have to take that fact as admitted. It follows (after due consideration) that the amount of information that can be sent is proportional to the frequency bandwidth occupied, multiplied by the time it is occupied. This is what is known as the Hartley Law. For example, suppose the information you want to send over a telephone line is an accurate reproduction of one side of a gramophone record. And suppose that you are lucky enough to get a line that transmits the whole band recorded, say 60—10,000 c/s. Played straight, the record would occupy that band for, say, four minutes. If you wanted to pay for only two minute's use of the line you could perhaps run the record at double speed. But all the frequencies to be transmitted would thereby be doubled, so Bandwidth × Time (call it BT) would be the same as before. Or if you had to squeeze the record through a 5,000-c/s band you would have to run it at half speed, so it would take twice as long and what you gained in B you would lose in T.

One next inquires how much information can be sent in a given amount of BT, B being in c/s and T in seconds. This is rather like asking how many articles can be packed in a given crate. It depends on the articles and on how they are packed. How can one measure information?

This is, as you might expect, a very tricky question, too involved to discuss in detail here. For the time being we can think of the smallest unit of information as being a single smoothed-off Morse dot or pulse. If the maximum information that can be passed through a bandwidth B in time T, after it has been broken down into these units, is denoted by M, we can express the situation as $M = kBT$ where k is a factor to cover our ignorance. It had been calculated that k should be $\frac{1}{2}$, but recently it has been shown to be more complicated than that. When Einstein came along with his relativity and showed that the simple and neat ideas of Euclid and Newton were wrong, it seemed as if he had removed the foundations of science. But for most everyday purposes science has gone along as before. It is much the same, I think, with the simple form of the Hartley Law; it is still broadly true that you can only economize in B (or T) at the expense of T (or B). It may prove to be possible to get round this by elaborate devices, but I cannot believe that medium-wave high-definition television is in sight, even metaphorically.

One thing that can be done, however, is to study our packing methods. It is obvious that speech, for example, is not the most economical form in which to organize information for transport. In full, it occupies a bandwidth of something like 15,000 c/s. With the sharp corners knocked off so as to squeeze it into about 3,000 c/s it is still reasonably intelligible, though a good deal less natural. Even this is quite loose packing, if all one is concerned about is getting a message across. To transmit consonants like "h", "f" and "s" in their own waveform occupies a lot of bandwidth, but almost the same effect can be obtained by transmitting simple narrow-band signals that turn sound generators on and off, making those sounds whenever they occur in speech. This scheme has been successfully applied in the Vocoder. The same sort of thing is done in television. The information to be transmitted (light) exists in a frequency band from 400-800 million Mc/s, which as a modulation frequency would be rather formidable! Instead of attempting to treat it as such, the B.B.C. sends signals that control the generation of light in and by the receiver.

A cable, line, radio link, etc., is a more or less expensive piece of capital equipment, and the people who own it naturally want to get the best financial

PERIOD →	1	2	3	4	5	6	7	8	9	10	11	12
CHANNEL A	C -.-.			A .-			L .-..			L .-..		
B		W .--			E .			L .-..			L .-..	
C			J .---			O ---			A .-			N -.
LINE SIGNALS	C -.-.	W .--	J .---	A .-	E .	O ---	L .-..	L .-..	A .-	L .-..	L .-..	N -.

Fig. 1. Short specimen of signals in a 3-channel time-division-multiplex system. Each of the three senders, A, B, and C, takes it in turn to have the use of the line for a period sufficient for sending a single letter in morse. The mixed-up line signals are sorted out at the receiving end by a synchronized switch or "gating" valve.

return. So they squeeze the "information" as tight as they dare. Speech and music are sometimes almost unrecognizable after the course of slimming they have to undergo. When B has thus been reduced as much as possible it may happen that it will go more than once into the bandwidth of the link. If so, there is scope for the type of benefactor who, in other fields than telecommunications, makes two blades of grass grow where there was only one. He divides the link or whatnot into two or more channels. Here I had better explain that technically a channel is a means of one-way communication. If one link can be made to provide more than one channel it is worth while, provided that the extra channelling equipment doesn't cost more than additional links.

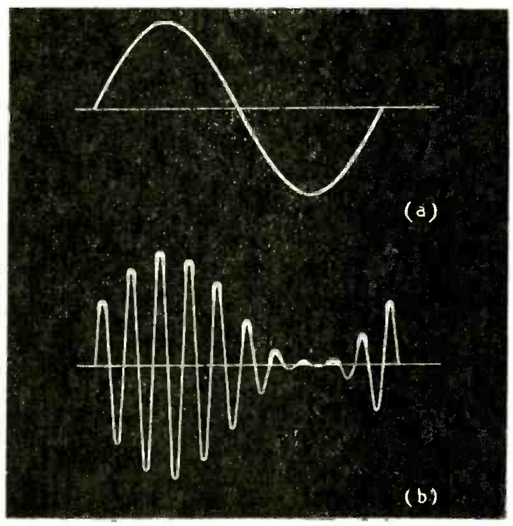
Dividing up the bandwidth of a link so as to make several separate channels is called frequency-division multiplex (f.d.m.) It is quite common practice. If a special cable can transmit frequencies up to, say, 100,000 c/s, it would be very wasteful to use it exclusively as a single telephone channel, for which 100-3,000 c/s would suffice. What is done is to make other telephone conversations modulate carrier waves, shifting their frequencies into bands such as 50,100-53,000; 54,100-57,000, etc. At the receiving end these have to be separated by band-pass filters, and of course if the filters get off-tune or fail to cut off sharply enough there is "cross-talk" (probably in more ways than one). This difficulty is painfully familiar to every broadcast listener. In point-to-point systems such as those operated by the G.P.O., elaborate balanced modulator and crystal filter equipment is used, and the cost of this eats very considerably into the saving in line or link costs.

An alternative system of sharing is that which was adopted in distant ages by the mythical sisters who possessed only one visual link of communication between them (to wit, an eye)—they took turns to have the use of it. This scheme is referred to as time-division multiplex (t.d.m.) Its justification is that dividing up time is technically easier than dividing bandwidth. Its obvious drawback is its discontinuity. No doubt each sister was firmly convinced that the only things really worth seeing were those that took place when she hadn't got the eye. Providing for extra channels by t.d.m. depends on how the information is organized. If in the form of morse signals, it is quite easy to space out the letters so that none of them are missed. Fig. 1 shows a sample of communication through a 3-channel system. Both ends are provided with synchronized switches or their equivalents, so that during periods 1, 4, 7, 10 etc., the line is available to channel A, during periods 2, 5, 8, 11, etc., to channel B, and so on. At the foot is shown the sort of signals that would come over the line, and of course they make no sense until sorted out into the respective channels.

The essence of the contract is that each channel has to save up its utterances for its allocated time periods and then utter them very quickly. It might seem that such a system would be no good for speech, which would be unrecognizable if broken up in this way. Or would it?

An analogy I used a few years ago seems to have stuck in some people's minds. I drew a picture of an avenue in autumn, just after the leaves had fallen and an industrious road sweeper had organized them neatly into heaps spaced at equal intervals. If distance along the avenue is interpreted as time, this picture represents t.d.m. in some ways; for example, the spaces left between the heaps would make room for leaves from other avenues to be stacked between them. And notwithstanding the extra space thus provided there is no loss of leaves (information). But the information has to be redistributed in the time dimension, by pushing it closer together. That means increasing frequency, which offsets the saving of time.

Fig. 2. A modulated carrier wave (b) can be regarded as a succession of plots or samples of the modulating waveform (a).



Now suppose that instead of pushing the leaves together into heaps a rather eccentric road man carted them straight away from where they had fallen, except from small patches spaced at equal intervals. These would not only indicate directly the original leaf density at those points but would also enable the passer-by to reconstruct the original scene, provided that the variations in density had been gradual compared with the distances between the patches.

But can this sampling process be applied to speech waveforms? Can chunks be cut out, leaving only a sort of skeleton service, without making it unintelligible?

The crucial point is whether the periodic samples of speech that are transmitted fully represent the rest. When we are told that at any given moment 62.5% of listeners to the B.B.C. have chosen the Light Programme we are not expected to suppose that forty million people were questioned about it. Actually, so few people are questioned that they never include oneself nor one's friends nor anybody one has ever come across, but they are supposed to be typical of the great unquestioned masses. Sometimes, as when the public opinion polls declared that President Truman had no chance at all of being re-elected, one has one's doubts. A better analogy is a workshop production line, because it involves the time element. It would be bad economy to test only every tenth unit coming off, if wide differences in size or quality were liable to occur at closer intervals. The assumption is that changes in the product develop comparatively slowly, due say to gradual wearing of a machine tool. In particular, the rate of change must not be so rapid that it might deviate "there and back" between one sample and the next.

In case anybody feels that sampling may be all very well for crazy road men or even in the factory, but doesn't necessarily work with speech waveforms, may I point out that it works in every broadcast receiver. The detector receives the a.f. waveform as a series of waves at a much higher frequency—the r.f. carrier—and varying amplitude, as in Fig. 2. Here (a) represents one cycle of the audio programme, possibly a sample of speech. It has a continuous waveform. But it reaches the detector as (b), and since the usual kind of detector responds to the peaks of the r.f. waves it actually receives its a.f. information as a rapid succession of isolated samples. It knows nothing of what the a.f. is doing in between the r.f. peaks, because it is biased right off. But anything done completely between successive r.f. cycles would involve an even higher frequency than the r.f., and we know that the highest a.f. is normally much lower than the carrier frequency. If we started to reduce the carrier frequency, when would the samples per a.f. cycle become too few to convey the a.f. properly?

This is one of those things that are quite easy to prove mathematically but not at all easy to visualize. But I may, I hope, take for granted that when signals of two different frequencies are passed through a non-linear device such as a modulator or detector a number of new frequencies are added to the original two; in particular, multiples of those two (harmonics), and sum and difference frequencies. For example, if a carrier wave, say 200 kc/s, is modulated by a.f., say 5 kc/s, frequencies of 200+5 and 200−5 (sideband frequencies) are created. The 5 kc/s a.f. is left behind in the transmitter, and in due course the other three present themselves to the detector. This, being non-linear, creates sum and difference frequencies, and the difference between 200 and 200±5 is of course 5,

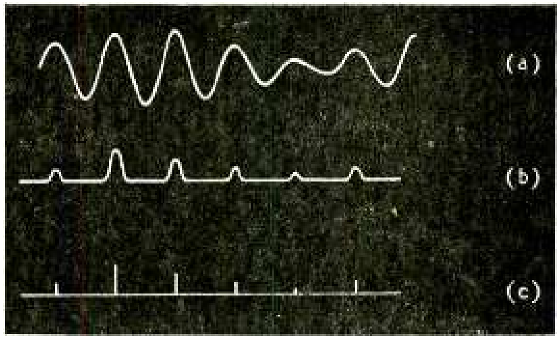
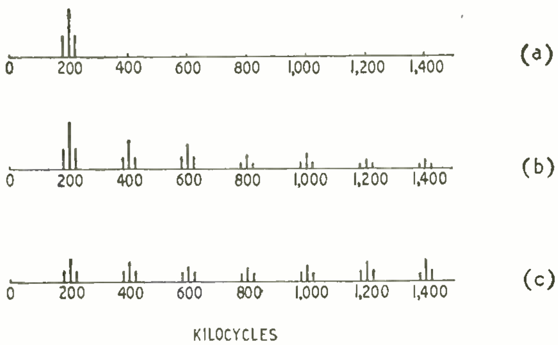


Fig. 3. (a) is similar in nature to Fig. 2. (b)—a modulated carrier wave. Passing it through a suitable distorter gives isolated pulses (b) which still convey the original modulating waveform, but at the same time harmonics of the carrier wave are created, so the band-width is increased. The extreme limit of the process is shown at (c), in which the infinitely narrow pulses necessitate an infinite bandwidth.

Fig. 4. Frequency spectra of the waveforms shown in Fig. 3, showing how the compact signal of the continuous wave (a) spreads out enormously when it is broken up into pulses. The spectrum of a train of infinitely narrow pulses continues theoretically to an infinitely high frequency.



which is the original a.f. The high frequencies can easily be separated from it by a simple filter.

But if the carrier frequency is reduced it becomes increasingly difficult to separate the lower sideband frequency from the a.f. The limit is reached, in our example, when the carrier is 10 kc/s because 10−5 cannot be distinguished from 5. In fact, 11−5 would need a very sharp filter, and would be a great nuisance if some of it got through.

So it appears that at the very least the sampling frequency must be more than twice the highest "information" frequency, otherwise the sampling process introduces signal frequencies that cannot be filtered out at the receiving end.

Here is another way of looking at it. If you had to dictate a waveform to someone on the telephone, you could of course do it to any desired accuracy by reading off the ordinates at sufficiently close intervals for him to plot as a graph. But it may come as a surprise to know that it is sufficient to give only about two plots per cycle of the highest frequency represented in the waveform. One might expect more data would be needed to make sure that every little peak and hollow would be reproduced. But it must be remembered that the highest frequency necessarily has a sine waveform. Any other waveform would contain harmonics, which would be still higher frequencies. Since the shape of the wave is known in advance, then, all that has to be signalled is its amplitude and frequency, and very close plots are not needed.

Carrier Sampling Pulses

Although an ordinary modulated carrier wave is, in a sense, a sampling system, it fails to achieve the object we had in view—to provide spaces in between for inserting samples of other conversations, so that they can be transmitted along the same circuit. What we really want is to narrow the separate r.f. cycles of the carrier into isolated pulses. The effect of doing this, as regards frequencies, is to introduce harmonics of the carrier frequency and of the sideband frequencies. Fig. 3 (a) is an example of an ordinary modulated carrier during one a.f. cycle. It occupies the whole time, but contains no frequencies higher than its own plus the audio frequency; and the total bandwidth is only twice the a.f. (Fig. 4 (a)). If we distort it so as to leave only isolated peaks (Fig. 3 (b)) we create harmonics of the original three frequencies, and obviously the channel must have a much greater bandwidth to pass them (Fig. 4 (b)). Having studied the Hartley Law we are prepared for this, as the price of making time for other channels (though perhaps not for such a stiff price). In the limit (purely theoretical!) the pulses would be infinitely narrow (Fig. 3 (c)), so that an infinite number of other channels could be accommodated; but the harmonics would extend to infinite frequencies (Fig. 4 (c)), so the bandwidth required would be infinite.

An attempt to cheat the Hartley Law by passing Fig. 3 (b) through a circuit that cuts off frequencies higher than the fundamental reduces the waveform to (a), and if other sets of pulses have been inserted they all run into one another and get muddled. One of the articles by Thomas Roddam* describes a scheme for avoiding the muddle by balancing out the over-spill from one channel to its neighbours. We are so used to thinking of interference between neighbours in *frequency*, due to lack of selectivity in tuning circuits, that I must perhaps emphasize that we are now talking about interference between neighbours in *time*, due to *excessive* selectivity in tuning circuits. (Incidentally, seeing that time and frequency have such a close mutual relationship, like voltage and current in circuits, one may wonder if a corresponding scheme couldn't be devised for balancing out the *frequency* over-spill in the broadcast wavebands and so end the present muddle there.)

As always when one is offered something for nothing, the natural tendency is to look for the catch. In this case it appears to consist of practical difficulties. Until these are completely solved it seems that sampling is not the answer to the bandwidth problem; in fact, systems that have been operated so far have tended to accentuate it. There is, of course, the Pye scheme for making use of the gaps between lines in television to insert pulses sampling the sound waveform. Since the vision necessarily occupies a channel running into megacycles, there is plenty of bandwidth to spare for sound frequencies even when multiplied by the sampling process; the scheme makes use of a potential channel that would otherwise be wasted. In our 405-line system the line frequency is 10,250 per second, and as the highest a.f. that can be represented by samples at that frequency and filtered out is less than half, the sound channel is limited in practice to about 4,000 c/s, which is not too good. But sampling would be worth considering in 625-line television.

There is one important aspect of the communication problem that we have not yet considered—noise. When that is taken into account it sheds a new light on sampling, as we shall see next month.

* *Wireless World*, June 1950, p. 202

"Frequency Modulation"

I MUST apologize to readers for my explanation of the f.m. discriminator (p. 271, July issue) having gone somewhat astray. To correct it, Fig. 2 here should be substituted for Fig. 4 in the original. The circuit diagram (originally Fig. 3) is shown here as Fig. 1, with the primary and secondary currents marked. In both diagrams, *b* is shown joined to *c*, as in the actual discriminator, so as to bring out more clearly the relative magnitudes of V_{ad} and V_{ae} as the frequency varies.

Briefly, I_p lags V_{ab} by nearly 90 degrees at all frequencies, and so does Φ, the magnetic flux due to it. The voltage induced thereby in the secondary is 90 degrees out of phase, but the phase of the secondary current, I_s varies with frequency, leading when it is below resonance and lagging when it is above. The phase of V_{cd}, set up by I_s across the secondary tuning capacitance, always lags it by 90 degrees.

"CATHODE RAY."

Fig. 1

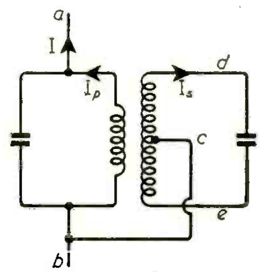
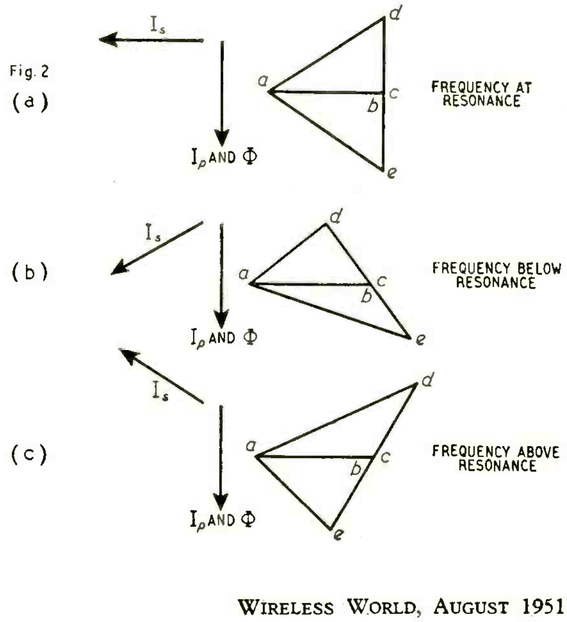


Fig. 2



Air Navigational Aids

Review of the Various Systems in Current Use

By BASIL CLARKE

A CONFERENCE has just finished in Montreal which is yet another of the efforts to standardize the radio navigation aids to be used in world civil aviation. So far no findings have been produced and it may be a long time before any agreement is reached.

It may be helpful to make a survey of the various navaids at present available so that readers may be brought up to date in an ever-changing scene. These aids will be broken down into four groups, long range, medium range, local airport systems and miscellaneous.

Long Range.—Loran is the most complete system which comes into this group. Working in the frequency band between 1.8 and 2.0 Mc/s it has an effective range in excess of 1,000 miles. Opinions seem to differ as to its accuracy but the writer can quote two personal experiences which may be pertinent. A series of observations taken in the vicinity of 60 deg N, 20 deg W showed a position accuracy within the limits of 500 yards to one nautical mile when compared with those obtained from meticulously careful sun sights over a period of three weeks. These positions were within 200 to 300 miles of the Icelandic Loran chain and were taken at sea-level.

The other incident was of a totally different character and involved one position only. It was taken in daylight at 9,000 feet at the extreme range of the Icelandic chain and a visual fix on St. David's Head checked the position. The accuracy was within 5 miles of the true position.

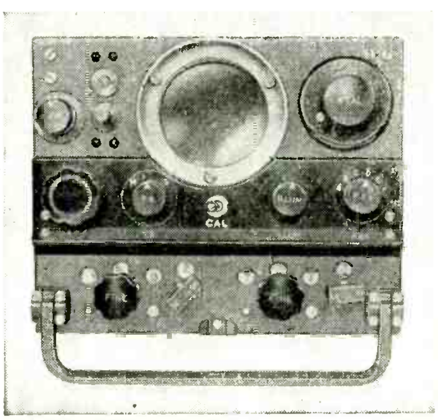
This system employs the hyperbolic grid notation already familiar in the war-time Gee and depends on pulse technique. A special airborne receiver weighing about 100 lb is required. Another version of Loran on low frequencies is under development but no information is available regarding its performance.

Consol is another long-range aid. It is a system of transmission developed from the German "Sonne" and provides d.f. information in the 300-kc/s band. An ordinary receiver without a loop aerial is used for reception, directional information being obtained by counting dots and dashes and referring to a special map. It is a slow method but it achieves a much higher accuracy than that usually obtained with a loop. Bearings taken on two stations, Bush Mills (Northern Ireland) and Stavanger (Norway) will give a close approximation to the actual position of the receiver.

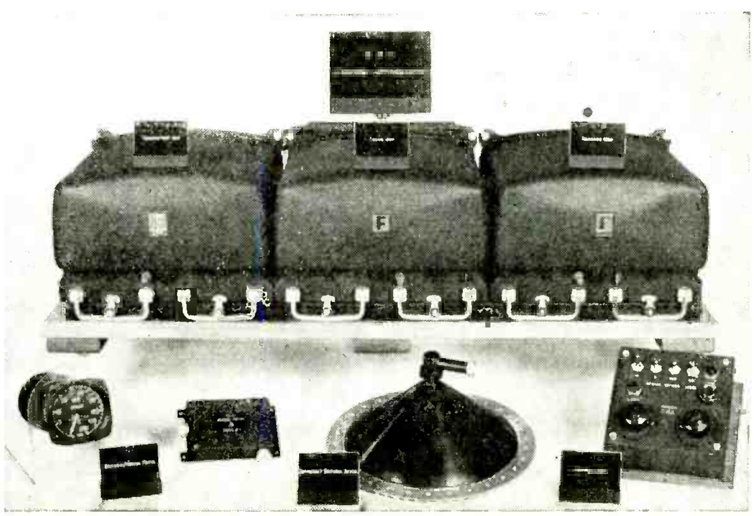
Medium Range.—Chronologically the American radio range takes first place in this group. The range stations generally in use employ frequencies in the band 300 to 400 kc/s. The method is well known, so that a very brief description will suffice. A number of beams, usually four, is propagated from a station, normally situated near an airport or emergency landing ground. These beams may be directed north, south, east and west, but more often they point the shortest way to the next principal airfield along a trunk route.

Gee, that well-tried aid for our bombers, is the next in order of birth. It is a pulse hyperbolic system operating in the band 22 to 85 Mc/s. Its range at 5,000 feet is about 250 nautical miles.

A very high degree of accuracy is obtainable, the maximum error being not worse than ±0.5 per cent



The indicator unit of the Gee navigational aid fitted in the aircraft.


The DME airborne interrogator made by Ferranti gives visual information on distance and homing to a selected ground beacon.

of the range at extreme distance, but a special receiver is needed weighing around 90 lb. A new miniature version of the airborne equipment has now been developed which will show a marked reduction of weight and giving at the same time greater simplicity of operation. The presentation is on a cathode ray tube and some training in the art of interpreting the picture is needed. Gee is not seriously affected by interference.

The Decca Navigator, more recently developed, also calls for a special receiver and thus increases the airborne weight. It operates in the l.f. band between 70 and 129 kc/s and uses a c.w. hyperbolic grid notation. Being a c.w. system depending on phase-difference measurement it is possibly more subject to interference than a pulse system, but to set against that there are several advantages.

The range is greater than Gee and the presentation is on a series of dials giving a direct reading of the grid line numbers on which the aircraft is positioned at the time of reading. These readings are automatic and continuous. Presentation can also be on the flight log, recently described in the *Wireless World*.* Here the actual course of the aircraft (or ship) is continually traced on the route map thus giving pilot or navigator a second-to-second record of flight progress.

An experimental range system on v.h.f. has been developed in the United States, known as VOR (Very High Frequency Omni-range). This, making use of a phase-difference measurement system, provides the pilot with a meter presentation at his bearing as seen from the VOR station. The meter is so designed that it also indicates the bearing of the VOR from the aircraft. The stations so far built operate in the band 113-117 Mc/s. Glowing reports of this system were at first received but later statements have been rather more depressing and even the Civil Aeronautics Administration in Washington, which had previously sponsored the system, is now expressing guarded doubts. An experimental station is now at London Airport but no British reports as to performance are as yet available.

Local Systems.—The word local is rather a vague term. In this article it is intended to cover the area within which an aircraft is likely to commence its approach to its destination airfield. Since a Comet aircraft operating at 40,000 feet or above may begin to lose height some 200 miles or more away from the touch-down point this might be regarded as "local" but in fact the writer draws the boundary at 50 miles, still only 6 minutes' flying time for the Comet at 500 m.p.h.

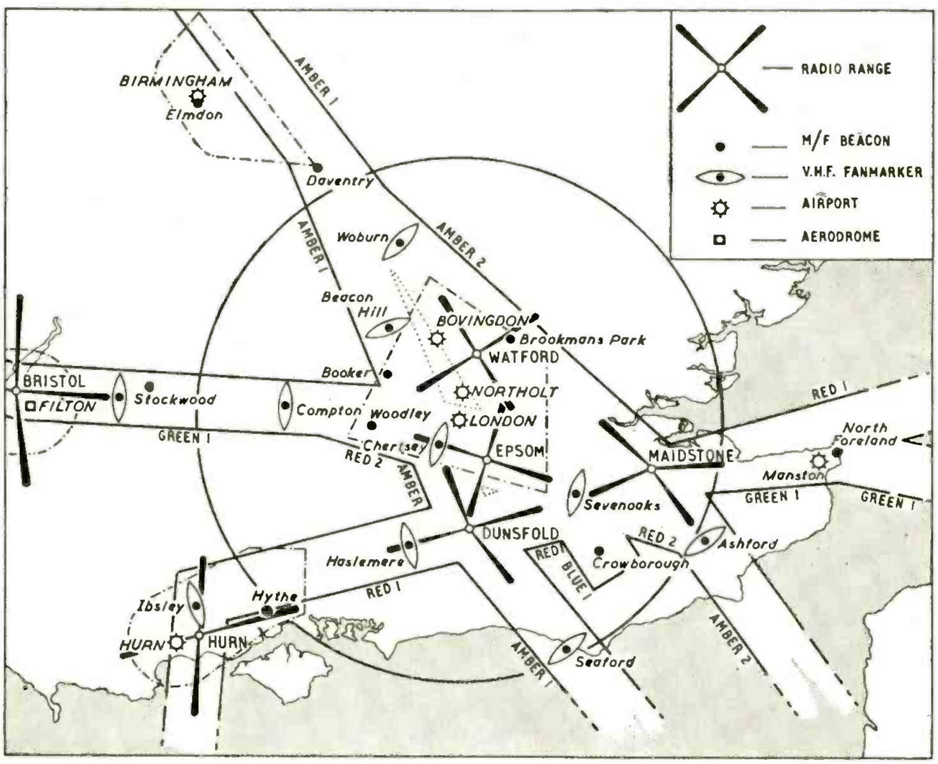
Apart from the fact that all the medium-range systems are still useful at distances far less than 50 miles, it can reasonably be said that the local systems are divided into two main sections; radar, both primary and secondary, and landing aids of the beam type.

Since the beam landing aids are now well established they can be dismissed fairly quickly. They all make use of the same basic principles, using a beam which is directed from the end of the runway at such an angle that an aircraft making a correct approach would fly straight down the centre of the beam.

Meter indication in the aircraft shows the pilot whether he is to left or right of the correct line and also whether he is above or below his proper glide path. Vertical marker beams, suitably coded, indicate the distance from touch-down at several points along the main beam.

The most commonly used systems are the British SBA (Standard Beam Approach) and the American SCS-51.

Continuing the landing aids there is, of course, GCA (Ground Controlled Approach), or, as the Ministry of Civil Aviation has now decided to call it, PAR (Precision Approach Radar). This is the well-known talk-down system in which, by means of a narrow beam radar propagation, the progress of an aircraft from some 15 miles out can be watched in azimuth and elevation so accurately that the ground



A 50-mile circle round London Airport includes a number of short and medium distance radio navigational aids. It also represents an arbitrary distance for local radar devices.

* Automatic Course Plotting. *Wireless World*, April, 1951, pp. 143-144.

controller can literally "talk" the pilot right on to the ground. The original GCA was American; now Standard Telephones are producing an up-to-date version of PAR, one of which is soon to be installed at London Airport.

To go with PAR is SRE (Surveillance Radar Element). One model of this is the Cossor ACR6 (Airfield Control Radar Mark 6), which will also shortly go to London Airport. Working in the 3,000-Mc/s band, it has a range of about 50 nautical miles and has numerous refinements not present in existing radar systems. Permanent echo suppression is one of these, whereby the clutter and more pronounced echoes from stationary objects are eliminated, thus leaving the PPI (Plan Position Indicator) clear except for echoes from moving aircraft. By a scanning system somewhat akin to television a "video" map can be superimposed on the screen showing what landmarks or imaginary boundaries the controller requires, thus giving much more precise information than the rather uncertain fixed echoes would provide, and this map can be changed at will.

The Standard Telephones v.h.f. cathode ray d.f. signals can be superimposed on the PPI, thus indicating the direction from which the transmission is coming.

Miscellaneous.—Into this section come devices which are not limited to any particular purpose. Numerous m.f. beacons exist for use with loop aerials, but this method is liable to be highly inaccurate at certain times of the day. Nevertheless, it is an aid of proven value and must not be omitted from a general list.

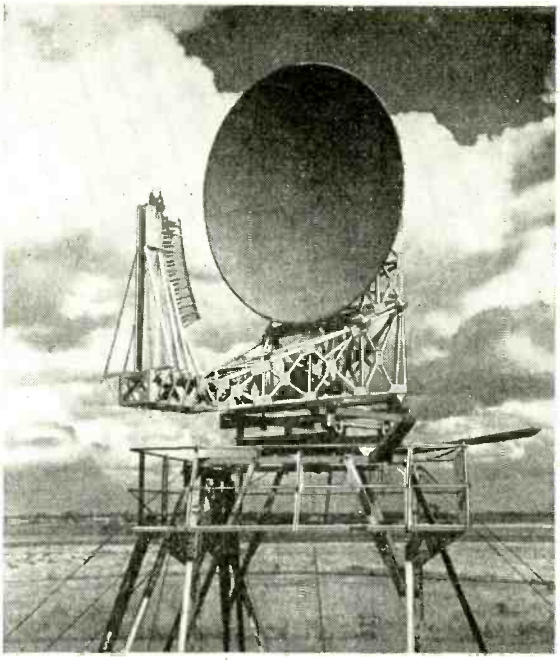
Cloud and collision warning radar, designed by E. K. Cole, is another application of airborne radar. PPI presentation gives a forward picture of cumulonimbus clouds, or any solid object such as a mountain or other aircraft, in plenty of time for suitable evasive action to be taken.

The radio altimeter is another device of great importance. It gives the height of an aircraft above the ground or sea immediately below as distinct from the height above sea-level indicated by an aneroid altimeter, and it remains accurate whatever the barometric pressure whereas the aneroid does not. It is an essential item in "pressure pattern flying," a method much used on long ocean flights. Accuracy to within 10 feet is obtainable. The system employs frequency modulation.

DME (Distance Measuring Equipment), developed by Ferranti, is a secondary radar system which gives accurate distance measurement from a beacon up to 200 nautical miles away. It works in the 1,000-Mc/s band and, by use of a pulse coding system, 100 channels are available. Up to 50 aircraft can obtain a response from the beacon simultaneously, the distance measurement being accurate to within ± 400 yards.

Interrogation by more than 50 aircraft causes the beacon to select only those 50 aircraft which are nearest to the beacon and reply to them, it being held that the aircraft farthest away are in a better position to await an answer. Combination of DME, with a suitable omni-range station and the inclusion of an R-θ computer (range and bearing as seen from ground station) in the aircraft, would enable a pinpoint fix to be obtained as range and bearing from a known point are all that is necessary to establish a position. This system is at present being developed in Great Britain and the United States.

DME beacons are now being installed at London, Rome and Cairo in readiness for the Comet route trials later this year.



Scanner of the Cossor Airfield Control Radar equipment type ACR6. The paraboloid is 14 ft. in diameter and the waveguide terminates in multiple horns.

With so many devices, all good in their own ways, to choose from, it is not easy to know which to adopt as a standard. None of them is cheap, they all add weight to the aircraft and they all drain some power directly or indirectly from the engines.

If the writer may venture an opinion on the ultimate selection he would say that only those systems which provide, in the air, an indication of position or distance from a known point on an easily read meter are likely to survive. Interpretation of "blips" on a cathode ray tube or counting of dots and dashes are methods too ponderous and too slow when airliners are already covering nearly 10 miles in one minute and are reasonably likely to travel much faster in the foreseeable future.

TELEVISION EXPLAINED

ADDRESSED mainly to those who, having some knowledge of radio circuits, are desirous of knowing something of the circuitry of television receiving equipment, "Television Explained," by W. E. Miller, provides a non-mathematical exposition of both the receiver and the aerial system and also deals with the installation and operation of a set. The fourth edition of this book, by the Editor of our associated journal, *The Wireless & Electrical Trader*, is published by the Trader Publishing Co. and issued by our Publisher, price 5/- (postage 4d.).

Book Received

Pianos, Pianists and Sonics. By G. A. Briggs. A symposium of the history, construction, acoustics, adjustment and playing of the pianoforte, illustrated by many oscillograms taken by the author. Includes chapters on room acoustics and recording, and the views of leading British concert pianists. Pp 182+X; Figs. 105. Wharfedale Wireless Works, Bradford Road, Idle, Yorks.

The Ekco V.H.F. equipment installed at the head office of the Southend Waterworks Company. The rack iccludes a 25-W transmitter, double superheterodyne receiver and control unit.

Waterworks Radio

V.H.F. Radio Link for Maintenance Staff

THE Southend Waterworks Company has installed v.h.f. radio telephone equipment in several of its maintenance and repair vehicles as a means of improving the communications between the head office and mobile working parties in outlying areas.

The equipment, which has been designed by E. K. Cole, Ltd., Southend-on-Sea, comprises a fixed station located at the company's head office in Southend and a number of mobile units for use in vehicles.

The fixed station is a rack assembly comprising a 25-watt transmitter, a double superheterodyne receiver and a control unit. Crystal control of both transmitter and receiver is employed with the former operating on a carrier frequency of 85.325 Mc/s and the latter on 7L825 Mc/s. Frequency modulation is employed with a maximum deviation of ±15 kc/s. Selective calling facilities are provided by means of which individual mobile units can be called without alerting all vehicles. Tone modulation is used for this purpose and the calling signal rings a bell in the vehicle. Another useful facility afforded is that, although the mobiles cannot communicate with each other direct, since they operate on fixed frequencies with the mobile receivers tuned to the headquarters' transmitter not to their own transmitters, they can intercommunicate *via* the headquarters' station.

This is possible as a simplex system is employed and the signals received at the fixed station are used to modulate the transmitter and so relay one mobile's signals to all others, or to a selected few at the discretion of the controller at head office.

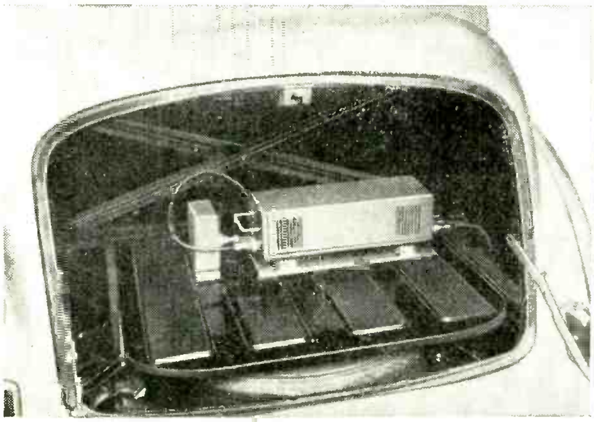
Greater ranges are obtained between mobiles in this way than would otherwise be possible as the fixed transmitter is five times the power of the mobiles whose transmitters give about 5 watts r.f. output. Moreover, the 100-ft high aerial at the fixed station gives a far wider coverage than the short quarter-wave vertical aerials used on the vehicles. Distances up to 30 miles have been covered in this way.

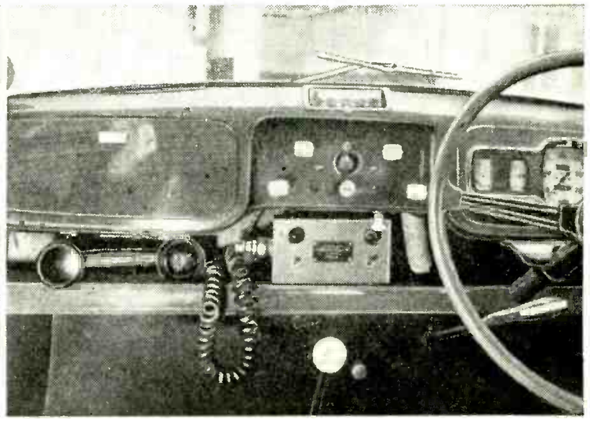
The mobile transmitters and receivers are both crystal controlled, and by using low-consumption valves and adopting economy measures wherever possible the power consumption has been kept to within very reasonable limits. For example, on "stand-by" the consumption is about $2\frac{3}{4}$ A at 12 V and 3 A when receiving. In the "stand-by" position some of the receiver's valves are inoperative, but the set is responsive to the calling tone. The transmitter takes 5.5 A, but it is used intermittently and for short periods only.

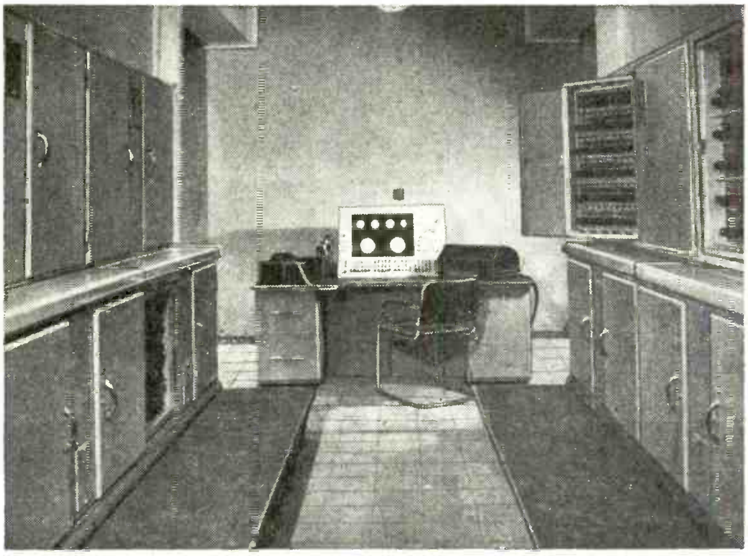
The mobile transmitter, receiver and power supply form a single unit, and the use of miniature valves and components has enabled both the size and weight to be reduced to a minimum. The illustration of the equipment fitted in the luggage boot of one of the company's cars exemplifies its small size. The unit on the left of the transmitter-receiver is a voltage control device to maintain a steady supply to the v.h.f. equipment despite any changes in battery voltage.

In addition to these two units there is a small control box in the driver's compartment. It is mounted just below the dashboard and is readily accessible to driver and passenger.

(Left) The small size of the Ekco mobile equipment is exemplified by this view of it fitted in the luggage boot of a car. The unit on the left is a voltage control device. (Right) The control box of the Ekco v.h.f. equipment fitted in the driver's compartment of one of the Southend Waterworks Company's vehicles.







New Digital Computor

Built on an Engineering Basis

ALTHOUGH the Manchester University automatic digital computor inherits most of its general principles from its famous forbears, the ENIAC, the EDSAC and the ACE, it has some important distinguishing features. In the first place it has been manufactured by a commercial organization, and is, in fact, the first of a series to be produced on an engineering basis. The work was done by Ferranti from designs which originated in the University of Manchester. Secondly, it has comparatively few valves—3,500 to the ENIAC's 20,000. Thirdly, it is believed to have a greater storage capacity, or "memory" than any other computor in the world.

The machine is designed to undertake numerical computations that would be far too lengthy and laborious for a human being to attempt. It doesn't waste any time over them. Two 12-digit numbers can be added in 1.2 milliseconds or multiplied in 3 milliseconds, while something like 500 numbers can be totted up in the time it takes to say "addition." Numbers are fed in as punched holes on teleprinter tape at the rate of 200 digits per second, and the results of computations are automatically typed out on a teleprinter at the end.

In common with others of its kind, the Manchester machine has the same sort of abilities as a human computor: it calculates, remembers and makes decisions. It is not capable of creative thought, however, so the necessary instructions for doing each computation must be fed in first by a human operator. All numbers are represented on the binary system in terms of two electrical conditions, off and on, so the basic circuitry is quite simple and uncritical. Most of the valves, in fact, are merely electronic switches or relays. Information is conveyed in the form of pulses—generated by a crystal-controlled oscillator—and these provide a standard time scale for the whole machine. On the binary system, then, the absence or presence of a pulse at a particular instant of time in the machine has the same significance as the presence of a 0 or a 1 at a particular position on paper. Incidentally, the computor is notable for a new type of c.r. tube "memory" system.* Digits are represented by a charge pattern on the fluorescent screen, and this is continually regenerated by scanning. The charges are picked up by an external plate capacitance coupled to the screen. A magnetic drum "memory" is also used, for long-term storage.

The equipment is built in two bays with the control desk in between. Everything is underrun to give good reliability and shielded against interference pulses, while the heat generated by the 27-kW power consumption is led away by air cooling.

* F. C. Williams and T. Kilburn. *Proc. I.E.E.*, 96, part III, p. 81 (March 1949).

RANDOM RADIATIONS

By "DIALLIST"

The Quality Question

MAKE A SLIP or a mis-statement in *Wireless World* and you very soon know *all* about it! If I sowed the wind last month by saying (p. 299) that the sound transmissions from Sutton Coldfield had a cut-off at 5,000 cycles or even a bit below that, I certainly reaped the whirlwind in the flood of letters of protest that came my way. The statement was made in good faith—no one would be so foolish as to stick out his neck by making such a statement if he had not good reason to feel sure that it was correct. It appears, though, to have been based on a misunderstanding. When I visited Sutton Coldfield at the time of its debut, I noticed that the "sound" was being sent from London over the land line. The ordinary telephone service between London and Birmingham is conducted mainly, if not entirely, over co-axial cables on the multi-channel "wired wireless" system, in which each speech-channel is quite narrow. This made me wonder whether any kind of high quality could be achieved in the sound broadcasts. When I put the question to one of the engineers, I was querying in terms of channels whilst he, it now appears, was answering in terms of modulation frequencies. I offer my apologies to both the B.B.C. and the G.P.O. They and those readers who were kind enough to write to me will now, I'm sure, realize how the misunderstanding and the consequent mis-statement occurred. Actually, the "sound" portion of the television broadcasts is sent from London to Sutton Coldfield over a line equalized up to 10,000 c/s or better.

The Neon Problem

IF I MAY BE permitted to boil them down into one glorious marmalade, the metaphors used by one section of the many readers who were kind enough to send suggested solutions to my neon problem (June, p. 249) amounted to this: I had drawn, they asserted, so many red herrings across the wood-pile that I hadn't been able to see the nigger for trees! In their opinion the trickle-charger and the secondary cell to which it is connected are unimportant. They maintain that the gas within the bulb of the neon (a miniature, by the way) becomes increasingly de-ionised as the days pass. The further this process has gone, the more sluggish will be the neon about striking. In other words, the delay in striking when the switch is closed (after remaining open for, say, a week with the receiving set in normal daily use) is not a measure of the state of discharge of the battery but of the "staleness" of the gas in the tube. Being, by nature, all for the proving of puddings by eating them, I promptly removed the plug from the wall-socket switch (thereby completely severing all connection with the trickle-charger) and left it out for exactly a week. At the end of that time and before replacing the plug, I turned over the switch with my left forefinger, simultaneously my right forefinger started a stopwatch. . . . The neon "fired" with a delay so unexpectedly short that I was late in stopping the watch. It was certainly considerably less than the 0.6 second recorded.

Further Experiment

Clearly, the next thing to do was to repeat the experiment with charger and cell connected as they normally are. Having charged the cell, I kept the switch open for another week. On the last day of the experiment the cell was discharged so far that the e.m.f. registered by a 2,000-ohm-per-volt meter was 1.48V. No doubt this time about the neon doing its stuff. It struck 22.4 sec. after the switch had been closed. It is pretty plain, then, that the trickle-charger and the cell *have* something to do with the effect and that it is not just due to "staleness" of the gas in the bulb. No reader has offered what I believe to be a complete and correct solution of the problem; but a satisfactory solution emerges when one tabulates the points made and then picks out those that really matter.

Humps, Peaks and Half-Cycles

First of all, the actual striking voltage of a neon rated at 200V a.c. is not 200V: it is $200 \times \sqrt{2}$, or 282.8V, for it is the peak, and not the r.m.s. voltage, that does the trick. Next, when the cell under charge has an e.m.f. not far below the fully charged 2V, the current flowing into it from a half-wave trickle-charger is in the form of "humps" at the rate of 50 per sec. The angle of flow is probably less than 120°, so that even if the cell were not in circuit the humps would not have the shape of half-cycles of 50c/s sinusoidal current. With a cell in circuit showing an e.m.f. in the neighbourhood of 2V each current hump rises steeply to a peak, then falls steeply a little way, then levels out for a space and finally falls steeply to zero. These current peaks in the transformer secondary induce corresponding voltage peaks in the primary which are sufficient to make the neon strike. But when the cell is in a run-down state the humps of the charging current are much less sharply peaked; and the peaks not so tall. The result is that the primary voltage peaks are lower and do not build up to a value sufficient to "fire" the neon until the e.m.f. of the cell has had time to rise. That this e.m.f. does rise to about 2V in about 20-40 seconds I know from experience. If the cell peters out in the middle of, say, a news bulletin, one has only to switch on the charger, switch off the set for half a minute or so, and when the set is again switched on, reception is restored to full volume. One can endure the accompanying 50-cycle boom, with the cell "floating" on the charger, if the news item is one of particular importance. I must try, as one correspondent suggests, to "poke about" with a cathode-ray oscilloscope. The trouble is that a full week must elapse between one test and the next if one is to make sure that the gas in the bulb of the neon is "stale" and that the cell is adequately run down.

The Bad Old Days

IN THE DAYS OF MY YOUTH I was taught mathematics just about as badly and as dully as that subject, which is really so fascinating, could possibly be taught. All of my instructors were mathematical honoursmen; one (the worst of the lot as a teacher) had been but a few marks behind the Senior Wrangler of his year. The trouble, in fact, was that most of them were so good as mathematicians that they just could not see the difficulties that presented themselves to all save a few specially bright fellows in their maths sets. It never occurred to them to make the drudgery of elementary maths more interesting by explaining what it was all about; nor did they ever bother to give us a glimpse of the thrilling things that lay ahead, once the rudimentary parts of the subject had been slogged through. I must have been quite 16 when I made, what was to me, the remarkable discovery that $x^2 - y^2 = (x + y)(x - y)$ is a short-hand method of stating that if you subtract the square of *any* number from the square of *any* other number, the result is equal to the sum of the two numbers multiplied by their difference! If only one had been shown earlier that algebra meant something and led somewhere.

And the Good New Ones?

Matters are very different now. At least, I thought they were until I received a visit from a young friend, in the fifth form of one of our most famous public schools, who dropped in one day during the holidays to ask me to clear up one or two things in elementary electricity that were puzzling him. One of these seemed most easily demonstrated with the aid of what one of H. G. Wells' characters called "hexes and wyes and little two's hup hin the hair." Maths, however, did not appear to be my young friend's strong point. I'll admit that he knew a whole heap more of the subject than I had done at his age; but he was in much the same kind of fog as I had been years ago. It was the same with electricity. He had all the usual elementary formulæ and equations pat; but he had little idea of their applications or of their value. And this, mind you, is an unusually intelligent boy, who had obtained a School Certificate with credits in an imposing number of subjects the previous year. I wonder what readers' experiences are. Is there still too much of the bad old type of teaching.

"RADIO VALVE DATA"

IN our June issue we published a note saying that a new edition of this well-known *Wireless World* reference book would be available from our Publisher at 3s 6d (postage 3d). This was a mistake—the postage is actually 4d. Nevertheless, with the main characteristics of over 2,000 British and American valves and over 100 cathode-ray tubes, the book is well worth the extra penny. All the usual classes of valves are included and new sections have been added for television valves, small transmitting valves, crystals and thyratrons. The c.r. tube section covers all British television and oscilloscope types. The valves are further classified into obsolete, replacement and current types, while at the back of the book are base tables and an index. Eighteen British valve manufacturers are represented.

UNBIASED

By FREE GRID

Matrimonial entanglements ahead.

Vocal Evisceration

IN recent times there has been a radio development in the U.S.A. which may seem to the uninitiated to be a novelty which has sprung up overnight. Actually, however, a great deal of experimental work on it was done in the *Wireless World* laboratory nigh on a quarter of a century ago. I refer to what is known in the land of big things as functional music transmissions or functional broadcasting, hereinafter referred to as F.B.

Now I feel sure that most of my readers know all about F.B., but it has always been the policy of *Wireless World* to cater for dullards like you and me as well as for the slick, smart-Alecs of the slide-rule brigade, and so, for the benefit of you who are so sunk in abysmal insular isolationism that you do not know of the horrors of life beyond these island shores, I will endeavour to give a brief explanation.

Everybody knows, of course, that in the U.S.A. programmes are not paid for by the harassed taxpayer as they are here but by commercial firms who interlard the musical items with advertisements in the hope of making sordid profits by selling cars and caviare to soulless sybarites. Now, F.B. is nothing more than sponsored programmes with the advertising announcements muted. I am aware that this sounds like something out of "Alice in Wonderland," for it must seem, from the point of view of the programme sponsor, like paying for advertisements printed in invisible ink. If you don't want to listen to advertisements and suchlike announcements you rent a receiver incorporating a special cackle-cutting relay which is operated by supersonic strangling signals sent out by certain broadcasting stations, to which you tune the set when desiring to listen to plug-free programmes.

Func ional music.

But, as already intimated, the general idea of vocal evisceration, or cackle-cutting, is not new and it was not started in the U.S.A. There are numerous variations, not only of the *modus operandi* but also of the *raison d'être*. Some months ago a well-known British radio engineer wrote to me giving details of a method of removing, not speech, but the obnoxious noises of the B.B.C.'s studio claque and his method was quite different.

As I have already said, the fundamental idea and the pioneer experimental work was done in the far-off "twenties" when a gallant attempt was made in the *Wireless World* laboratory to produce a receiver which would automatically differentiate between music and speech. But the relatively primitive technical resources of that decade were insufficient to enable success to be achieved.

Psychrionics

I HAVE often complained in these columns about the terrible Latin and Greek hybrid words which have been thrust on us radio people by etymological Philistines. A notable example is the wretched hybrid "television" which appeared almost overnight as a descriptive word for the science of teleoptics. In this connection I am glad to see that a well-known writer has had the courage to substitute "stereoptics" for "stereovision" as the title of his new book dealing with this particular aspect of optics.

It is quite impossible to undo what has been done but we can at least take care to see that similar mistakes are not made in the future. Although I hold no brief for committees, I would nevertheless suggest that the radio industry appoint forthwith a body like the *Academie Française,* which has the power to reject or set the seal of authority on all new words.

It must be done very quickly, however, for we are, I think, not far off another major disaster in the etymological world in connection with valve developments. I think that most far-sighted men will agree with me that we shall, before very long, be entering upon the "decline and fall" period of the thermionic valve. In fifty years' time the present thermionic valve will have been replaced by its cold-cathode counterpart and that branch of physics known as thermionics will have given place to psychrionics. This is, of course, the correct word and the name for the successor of the thermionic valve should be the psychrionic valve.

I must confess, however, that I do not like these names for only the letter "r" distinguishes psychrionics from psychionics, which sounds like a scientific synonym for spookology. Similarly, the psychrionic valve might be confused with the psychionic valve, which is the sort of thing I should imagine the Madame Estelle of fifty years hence will use instead of a crystal to warn us of matrimonial entanglements ahead.

I have, therefore, been trying to think of a better word for cold-valve and the particular brand of "ionics" which will be associated with it. Can you help me before some etymological Philistine lands us with such deplorable Latin and Greek hybrids as frigidionics and frigidionic valve.

The Thermionic Coherer

RECENTLY when discussing the origin of the thermionic valve I completely overlooked the fact that de Forest produced one in 1903, in which the source of heat was a Bunsen burner. Several readers have drawn my attention to this and have sent me copies of the special issue of the American journal, *Radio-Craft* (January, 1947), in which the pioneer work of de Forest is described by himself and others.

Two electrodes, one connected to an aerial and the other to earth, were put into the flame and signals were received. The passage of r.f. oscillations apparently altered the conductivity of the hot space beween the electrodes and so controlled a local source of power. The device was, in fact, a thermionic coherer, as it acted in the manner of a coherer or amplifying valve rather than that of a crystal or diode.