Wireless World

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For Services Rendered

THERE will be general satisfaction among our readers that substantial monetary recognition has been accorded by the Royal Commission on Awards to Inventors to those who entered claims for their contributions to the initiation and development of radar. The findings were announced as we were going to press with our last issue, and elsewhere in the present number we record the awards made both to the team headed by Sir Robert Watson-Watt and to a number of workers who made claims independent of the team.

The awards will generally be taken as recognition of the foresight, ingenuity and technological competence of those who found means of putting to practical use a by-product of radio-wave propagation that had hitherto been usefully employed only for ionosphere sounding. They started with a very simple idea, but in a surprisingly short time developed it into an instrument that proved of incalculable value in war and is now proving of great value in peace. Indeed, the speed of radar development is one of its most remarkable features. Within three or four short years—and without the stimulus of self-preservation brought about by actual war—an effective weapon was évolved from the brand-new idea of using radio reflections for location of distant objects. Within ten years the same principle was in use in highly complex and refined equipment readily adaptable to peacetime use. *Wireless World* offers its congratulations to all those—whether they figured in the Commission's award list or not—who produced such spectacular results in so short a time.

One useful by-product comes from the Commission's lengthy and searching investigations. They will go some way to establish priority of "invention" in many fields of radar. Unfortunately the findings do not go all the way. The Commission did not concern itself solely, or even mainly, with "invention" in the strict and limited technical sense of that word. Equally, the published findings did not disclose the bases on which all the awards were made; it cannot be said categorically how many of the multiple claims made by some successful claimants were accepted. However, the voluminous evidence that is on record should help to settle some of the controversies that are bound to arise.

The Commission's awards do not represent the total sum received by those who contributed to the development of radar. There were, of course, similar awards to the originators of the magnetron. In addition, it has been stated that some £200,000 has been paid by the Ministry of Supply and the Admiralty. It is believed, however, that this sum is mainly accounted for by payments to industry for the use of patents as a matter of legal right and not as *ex gratia* awards.

More Reliable Valves

IN the early days nobody claimed that radio valves were reliable. They were regarded as expendable accessories, and their holders were usually mounted in accessible positions so that replacements could easily be inserted when needed. Then manufacture on more scientific lines got into its stride, and soon the pendulum swung in the other direction; valve makers began to urge that the valve was no longer an accessory but a component no more liable to failure than other components; as such, it might well be permanently wired in position, thus doing away with the (sometimes) troublesome holder. Though this line of argument has been adduced with some show of reason, it has not yet been accepted to any great extent except where sub-miniatures are concerned. In the meanwhile, we find occasional outbreaks of inconclusive recrimination as to the true reliability of valves. Inconclusive, because, as an article on another page will show, the apparently simple word "reliable" must be carefully defined when applied to such things as valves.

The present concentration of attention on valve reliability is very much to the good, especially in the sphere of industrial applications. Users of valves for such purposes naturally regard with suspicion any device with a reputation for unreliability. Valve manufacturers are alive to this, and, in the process of increasing the robustness of special-purpose types, are improving their general production.

TELEVISION GHOSTS

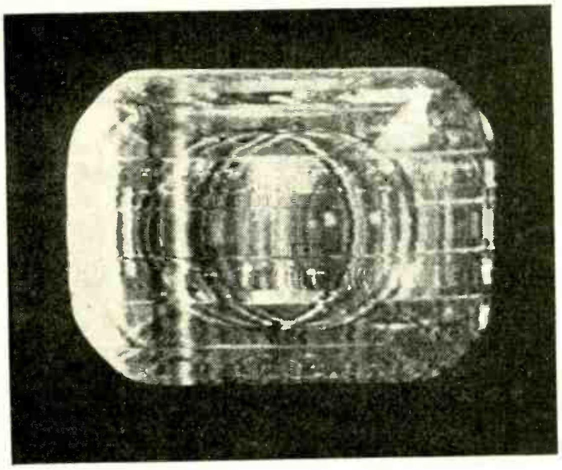
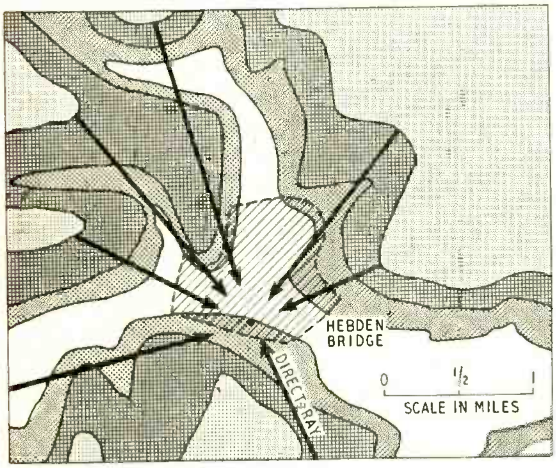
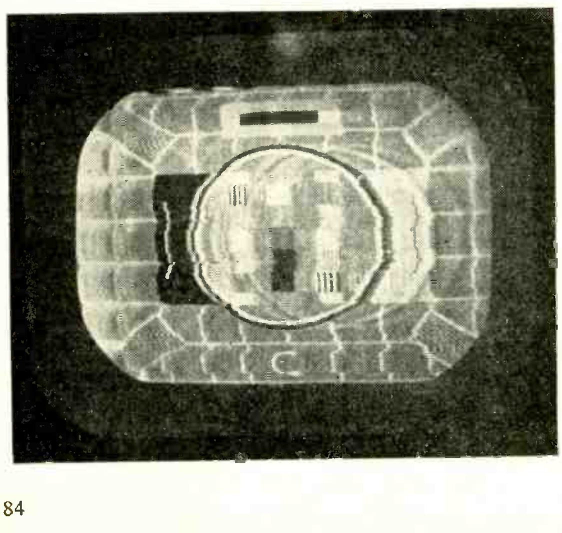


Fig. 1. A picture received with a commercial aerial at Hebden Bridge.



Above: Fig. 2

Below: Fig. 3



Effect of Multi-path Propagation in Hilly Country

By J. A. HUTTON, B.Sc.*

WHEN the television station at Holme Moss was opened, many viewers, although they were within twenty or thirty miles of the transmitter, found that signals reflected from the hills were causing very unsatisfactory reception, Fig. 1 being a typical example. On previous occasions when multipath propagation has affected television reception the reflecting objects have usually been small—such as buildings or gasholders—and the reflected signals have been of considerably lower field strength than the direct signal. It has been possible in these cases to clear the trouble with simple directional aerials, but in hilly country like that of the Pennines this is not the case, for the reasons explained in this article.

Affected Districts:—The worst conditions in the Holme Moss area occur in the valleys which lie at right angles to the direction of propagation such as the valleys of the Calder, Don, Loxley and Rivelin. Probably the most badly affected town is Hebden Bridge, although in some places, notably parts of Sheffield, the situation is aggravated by low field strength.

The topography of the districts where the effect is most serious follows a distinct pattern in which the receiver is situated on the lee side of a hill, and where neighbouring hills are fairly high and close to the receiver. In such localities the reflected ray is frequently stronger than the direct ray. This is because the direct ray is attenuated by the obstructing hill, while the incident signal on the reflecting hill is so large that, despite the poor reflection efficiency, a considerable signal is reflected. Hebden Bridge is just such a place (see Fig. 2).

It has been shown theoretically by D. I. Lawson[1] that reflecting objects which are on the side of the receiving site away from the transmitter subscribe more energy to the receiver than similar reflectors on the other side. This was checked experimentally at Luddenden, where the hills are suitably placed for such a test, using a broadside array to measure the signal reflected by each hill, and it was found here that hills to the side and rear produced fairly strong reflections, while those to the front, although much nearer to the receiver contributed very poor signals.

Throughout three weeks of intensive investigation it was noticed that strong ghost images with time

* Murphy Radio, Ltd.
[1] D. I. Lawson: *Journal I.E.E.*, Vol. 92, Part III, No. 19; September 1945.

Fig. 2. A sketch map of Hebden Bridge showing the directions from which strong reflected signals were arriving.

Fig. 3. A picture received in a radio shop at Sowerby Bridge after considerable trouble had been taken with the installation.

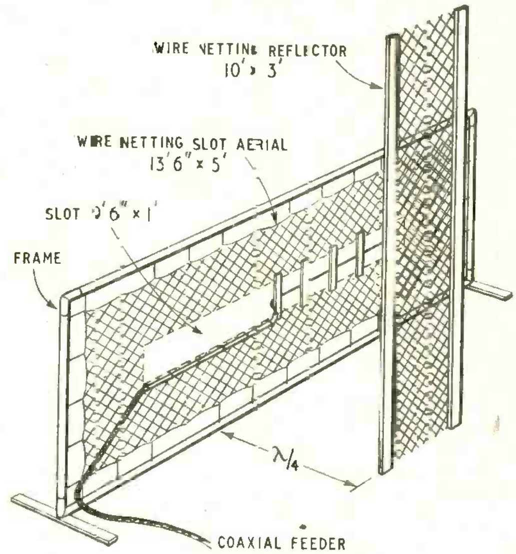
delays greater than 40 μsec were very unusual. This corresponds to hills roughly 3½ miles to the rear or seven miles to the side, and it was decided that hills which are more than five miles away can be neglected as reflectors of seriously interfering signals. A typical example of ghost images is shown in Fig. 3, in which two strong images can be seen delayed by approximately 11 μsec and 17 μsec respectively. These delays correspond to path differences of roughly two and three miles, the path difference being given by (Time Delay) × (Velocity of Propagation) where velocity = 0.186 mile per μsec.

Experiments with Different Aerials.—For the series of experiments there were used twelve aerials, of which nine were commercial types and three were constructed in the laboratory. So that we could estimate the required directivity of an aerial for the elimination of ghost images, the polar diagram of each aerial was measured under the same conditions on a stretch of open moor.

The first practical comparison of aerials took place at Hebden Bridge. All the commercial aerials gave poor pictures, the worst being illustrated in Fig. 1 and the best in Fig. 4 (a). Fig. 4 (b), (c) and (d) show the results obtained at the same place, using a slot aerial,[2] slot aerial with a reflector, and a double-H aerial respectively. The slot aerial was too large to be mounted on the mast, and was tested on the ground, whereas all the other aerials were raised 40 feet. Details of the slot aerial are given in Fig. 5.

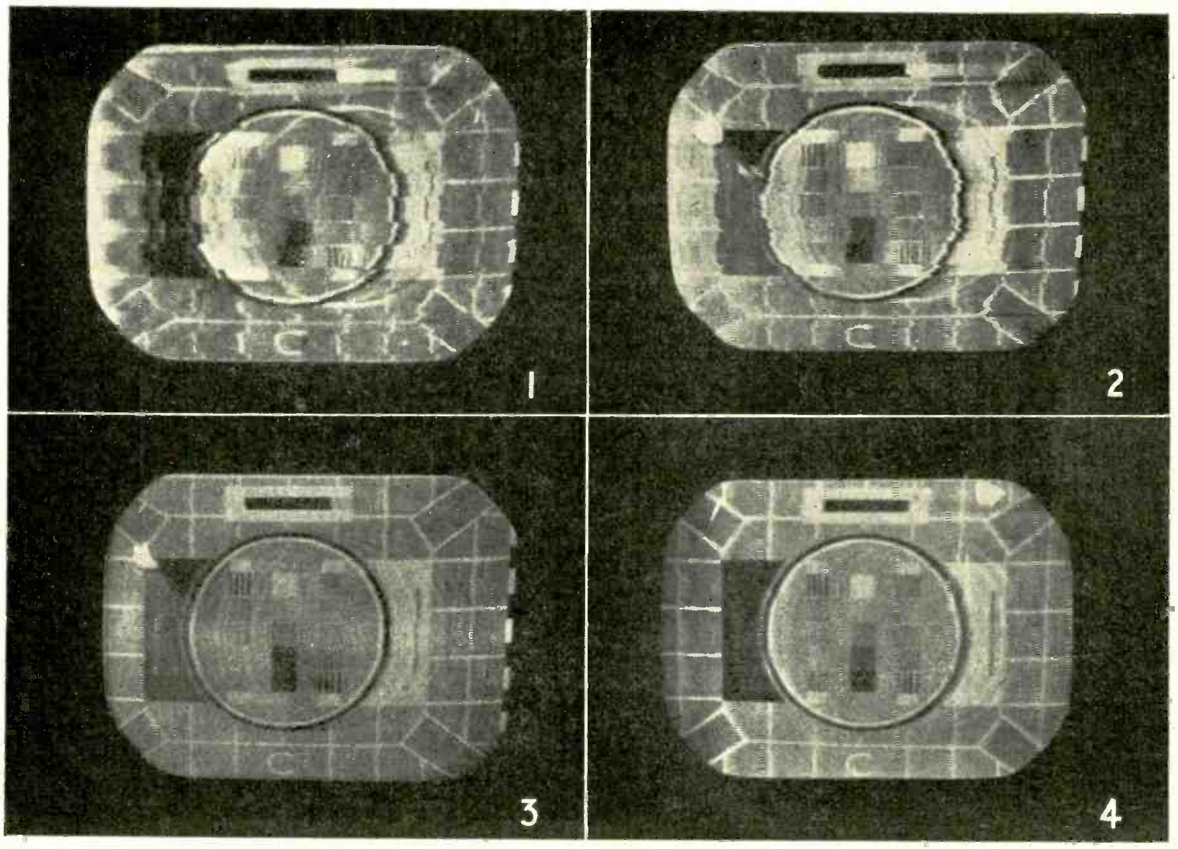
This led naturally to an experiment from which it was concluded that no significant change occurred as the height of an aerial was altered. Although this may appear surprising at first sight, it merely means that the *relative* strengths of the direct and indirect

Fig. 5. The experimental slot aerial with reflector.



[2] H. Page: *Wireless World*, May 1951, page 168.

Fig. 4. Pictures received at the same site as Fig. 1 using (a) the best of the commercial aerials available, (b) a slot aerial, (c) a slot aerial with reflector, and (d) a double-H aerial.

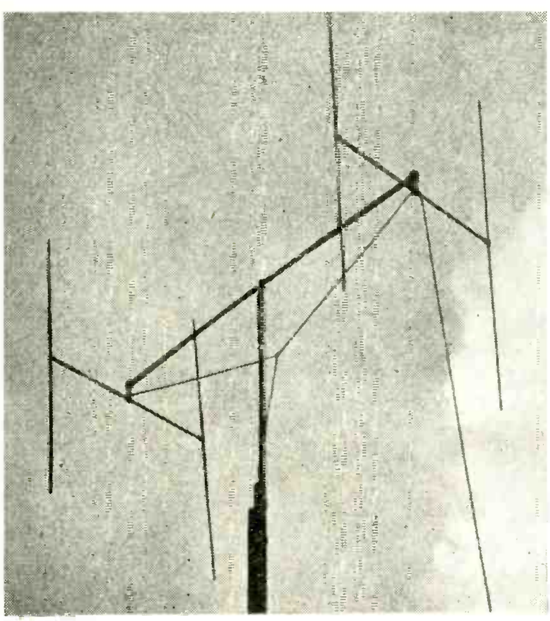


(a)

(b)

Above: Fig. 6. Pictures received at Oughtibridge using (a) the best of the commercial aerials available, and (b) the double-H aerial.

Fig. 7. Broadside array of λ/4-spaced H aerials.



signals do not change appreciably over the limited range of height which is practicably possible.

Some of the aerials were now discarded as useless under multi-path conditions, namely, those with poor front/back ratios and large side pick-up, and tests were continued at Oughtibridge in the valley of the Don, at Rivelin (west of Sheffield) and in Sheffield itself. It became clear that the double-H type was the best of the aerials available for dealing with the situation. An example of the performance of this aerial in comparison with the best of the commercial aerials tested is given by Fig. 6.

The double-H aerial (Fig. 7) consisted of a broadside array of two λ/4-spaced H aerials mounted λ/2 apart and connected (by equal lengths of feeder) in parallel. The noteworthy feature of the polar diagram of this aerial is the small sensitivity at the sides. The front/back ratio was not so large as that of some of the commercial aerials. The polar diagram requirement for an aerial which is to have general application is minimum total pick-up from back and sides.

Use of the Reflected Ray.—At two of the sites where tests were made, a reflected signal existed which was stronger than the direct signal. With an aerial directed towards the reflecting hillside the resulting picture was of poor quality, even though the direct signal was adequately attenuated. The explanation of this is that the variation of signal path caused by the immense size of the reflecting hill gave rise to very poor definition.

It was then decided to rotate the plane of the aerial in order to learn something of the form of polarization of reflected and direct signals, and to see whether any difference might form a basis for separation. The direct ray appeared to have maintained its vertical form fairly well, but the indirect signal tended towards random polarization. This implies that rotating the plane of an aerial can reject only the direct signal, leaving the reflected one. There seemed, therefore, little to be gained by using the reflected signal, although on one occasion a picture obtained in this way was considered to be superior to the one from the direct signal which was spoiled with ghost images.

Television Standing-Wave Field:—During the Hebden Bridge experiments the necessity to maintain the position of the mast with precision was discovered, otherwise the results were inconsistent. When the mobile laboratory, on which the mast was fixed in the manner of a fire-engine ladder, was moved a yard or so, the resulting picture changed considerably in character. This was clearly due to the fact that a

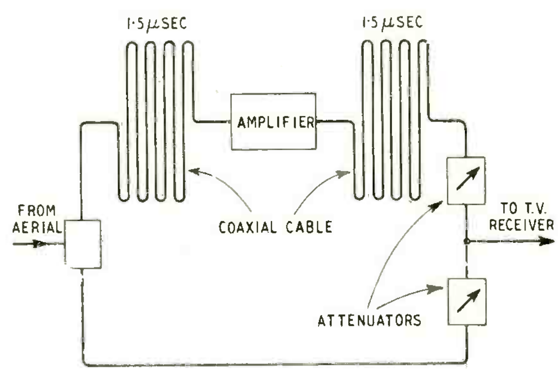


Fig. 8. A circuit for producing an artificial ghost image.

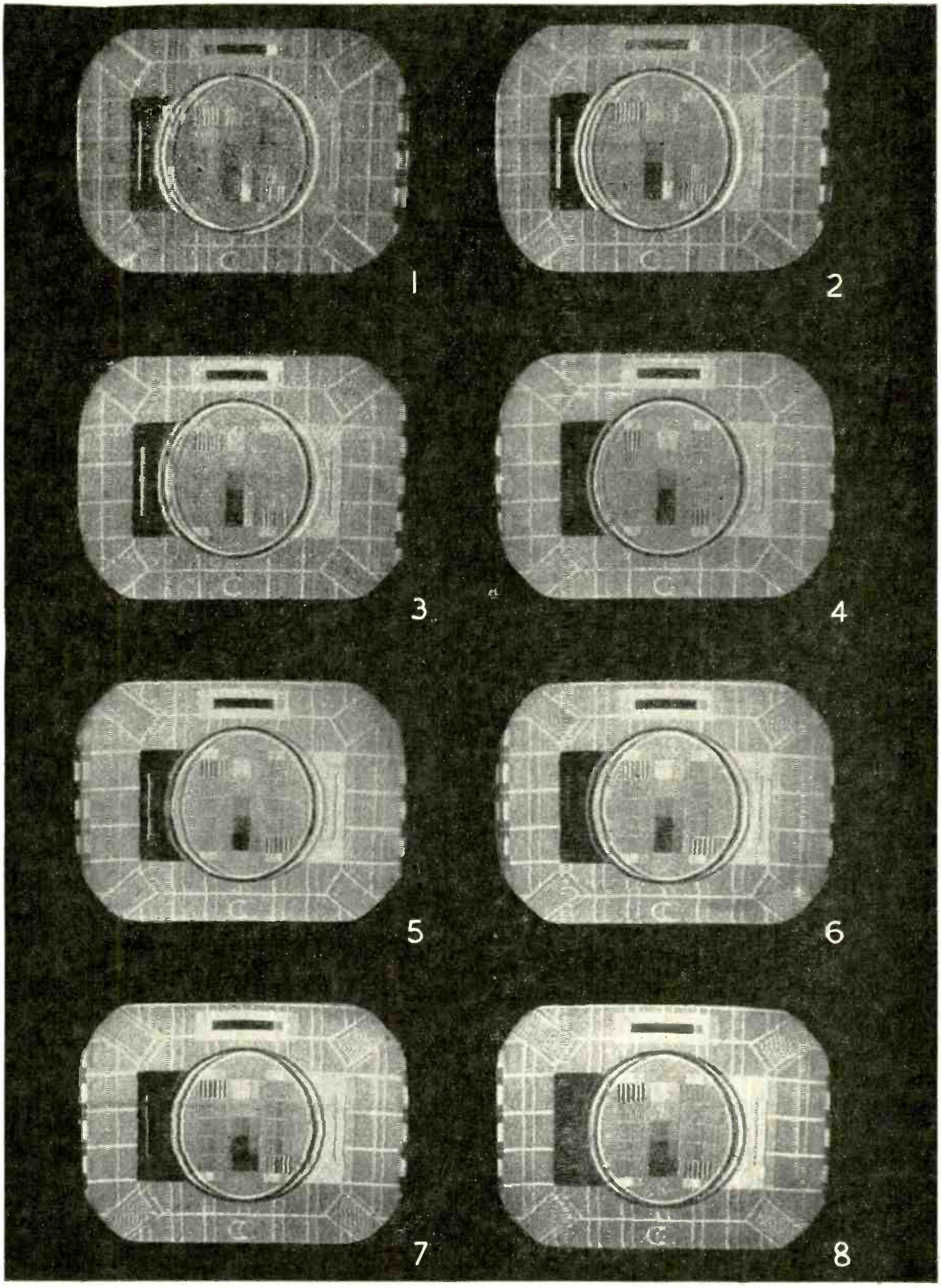


Fig. 9. The effect on the picture with variations of phase between direct and indirect signals. Photograph 1—180 deg., 2—154 deg., 3—129 deg., 4—103 deg., 5—77 deg., 6—51 deg., 7—26 deg., 8—0 deg.

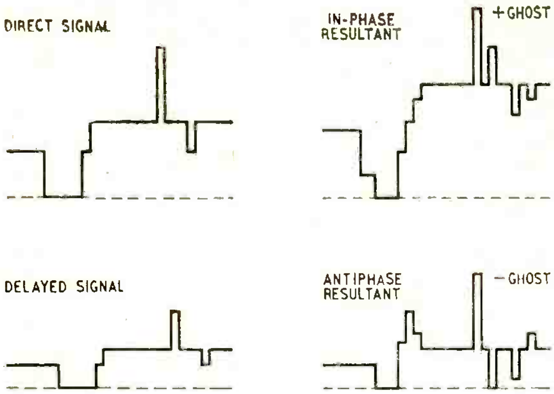
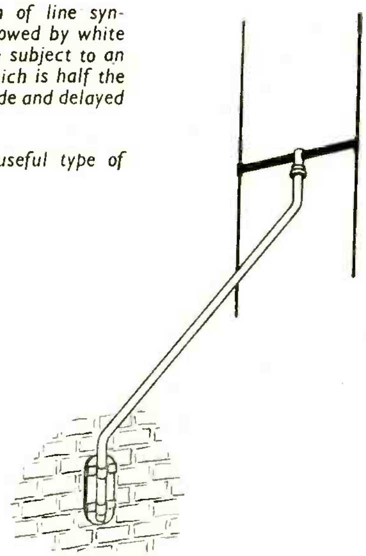


Fig. 10. Waveform of line synchronizing pulse followed by white and black bars when subject to an interfering signal which is half the direct signal amplitude and delayed 4 μsec.

Right : Fig. 11. A useful type of aerial mounting.



standing-wave field existed. The nature of this field is worthy of consideration, for it is rather different from the normal standing-wave field due to sound-modulated signals where the only factors governing the state of the field at a point are the relative phase and amplitude, and the only apparent effect is variation of signal strength between a node and antinode of the field. In a television standing-wave field, the path difference between the two signals also has an effect.

Since the reflected signal has followed a longer path than the direct signal, a particular element of picture information carried along the indirect route reaches the receiver after the same element which has arrived by the direct route. This delay means that, even though the mean amplitude of the reflected signal is less than that of the direct signal, the instantaneous amplitude may be considerably greater. For example, during a synchronizing pulse of the direct signal there is no carrier, while the reflected signal may be at maximum amplitude, conveying peak white information. A ghost image is thus formed, and its nature depends upon the phase and amplitude of the reflected signal.

If the modulus of the vector sum of the two signals exceeds the direct signal amplitude the ghost image will be positive, that is, white picture elements will be white in the ghost image. Should the modulus of the vector sum of the signals be smaller than the direct signal (e.g., at a node of the standing-wave field), a negative ghost will be obtained; i.e., white picture elements will be black in the ghost image. Stated mathematically, the condition for a positive ghost is that the phase difference, θ, is less than

$$\cos^{-1}(-e_2/2e_1)$$

where e_1 is the direct signal amplitude, and e_2 is the reflected signal amplitude, at the same instant.

Thus, when θ is less than 90 deg, or greater than 270 deg, the ghost images are always positive, but when θ is between 90 deg and 270 deg, the type of ghost image depends upon e_1 and e_2. If $e_1 = e_2$, then, statistically, one-third of the ghost images will be negative; i.e., when θ lies between 120 deg and 240 deg. With very small indirect signals roughly half the ghost images will be negative.

The form of a television signal standing-wave field, therefore, depends upon the time delay and the modulation.

In order to examine the appearance of ghost images as θ is varied, a circuit was set up as shown in Fig. 8. The delayed signal amplitude was arranged to be roughly half the direct signal amplitude, but even so an amplifier was necessary to overcome the attenuation of the delaying cable. Short lengths were removed from one of the cables in order to vary the phase difference between the signals, the resulting pictures being shown in Fig. 9. Exactly the same effect was obtained when aerials were moved in the standing-wave fields in the Pennine valleys.

It had been noticed also that when strong negative ghost images were obtained, the synchronization of the picture was poor. The explanation of this will be clear from Fig. 10. Under antiphase conditions a large white picture signal will cause a black ghost image, which may reduce the level of the resultant to below black level. This level will pass through the synchronizing pulse separator and may cause the timebase to fire at the wrong time. Modifications to the shape of the synchronizing pulses can occur with positive ghost images, but this effect was found to be much less serious.

One might expect that when an aerial is moved from a node to an antinode of the standing-wave field the appropriate adjustment would be receiver gain (contrast or sensitivity), whereas, as is indicated in Fig. 10, the preferable adjustment is picture brightness.

Aerial Installation:—Using the apparatus illustrated by Fig. 8, it was found necessary to attenuate all indirect signals to a level 26 db below that of the direct signals to reduce ghost images to a negligible level. Since increasing the height of the aerial did not seem to make any significant difference, it would seem to be a good idea to use the building on which the aerial is mounted as an attenuator of unwanted signals. In other words, mount the aerial on the side of the building which faces the transmitter, rather than on the chimney if no obstructions exist.

Judging from Fig. 9, a point between a node and antinode of the standing-wave field is the most desirable position for an aerial, since here the ghost image is least apparent, but the possibility of negative ghost images must be avoided, first because of the effect on synchronization, and secondly, because the resulting pictures are unpleasant.

A useful method of mounting an aerial is illustrated in Fig. 11. This form is commercially available, and enables an aerial to be fixed to a wall and then moved a few feet to avoid any negative ghost images that may appear.

The writer would like to thank Mr. R. Cook, who helped with the experiments under most trying weather conditions.

VALVE VOLTMETER

The Rectifier Section

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

Design of Input Circuits for Alternating Voltage Measurement

THE following article is a sequel to the one published in January describing a highly stable valve voltmeter for direct voltages only. The special feature of that instrument, it may be remembered, was that the addition of the valve circuitry to the moving-coil voltmeter did not necessitate any recalibration, since the output voltage of the valve unit was the same as its input, within a fraction of 1 per cent. But although this feature may not be common to valve voltmeters in general, most of them are similar in so far that the rectifier that fits them for measuring alternating voltages is organically distinct from the "d.c. amplifier" (really a resistance converter), so the principles now to be discussed have a much wider application than the particular system already described. The subject, in other words, is the left-hand unit in Fig. 1. This does not, of course, necessarily take the form of a completely detachable unit, though it is often made up as a flexibly connected probe.

Because the circuitry of this part is so very simple, consisting of a diode and one or two resistors and capacitors, it may be supposed that it calls for little consideration. But it is a good rule that anything with a rectifier in it calls for plenty of consideration. What follows does not claim to cover anything like the whole subject of how to rectify with a diode, but it may help to remove some common misunderstandings.

The first thing to consider is the "value" of the alternating voltages to be measured—peak, mean, or r.m.s.? Sometimes one is required and sometimes another, but for most purposes the r.m.s. value is the most appropriate, because it is the one from which the power can be calculated, regardless of waveform. Unless the contrary is specified, alternating voltages and currents are generally assumed to be r.m.s. Unfortunately the types of meter that respond on principle to r.m.s. values generally consume an excessive amount of power for the purposes chiefly in view, or have other limitations and inconveniences. Direct voltages can be measured, using the Fig. 1 technique, with very little disturbance of their source, so for corresponding alternating-voltage (a.v.) measurements the usual practice is to add a rectifier. If a suitable rectifier could be obtained with a natural square-law, the resulting readings would be r.m.s.; but the best that can be found is an approximation to a square-law over a very limited range. So for wide ranges of measurement the r.m.s. ideal is generally abandoned.

Instead, the aim is a "perfect" rectifier—one with zero (or at least negligible) forward resistance and infinite back resistance, like a switch. With such a rectifier connected in series with a high resistance, the average direct voltage across the resistance is equal to the average alternating voltage of the active half-cycles. If the waveform is sinusoidal, the average of a half-cycle reckoned over the period of half a

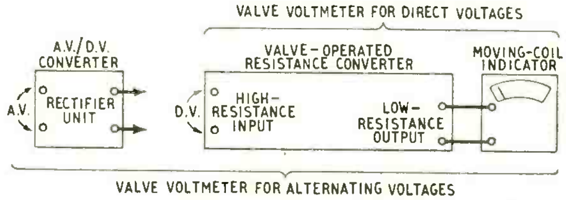
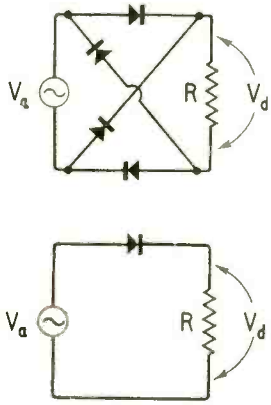
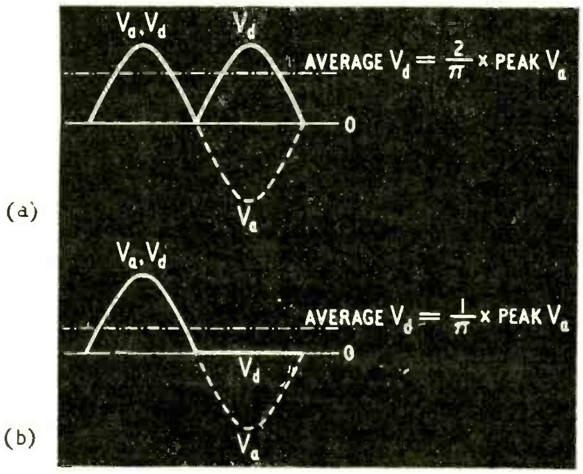


Fig. 1. Functional arrangement of the general class of valve voltmeters considered, showing inputs for direct voltage (d.v.) and alternating voltage (a.v.).

Fig. 2. Comparison of input and output voltages with (a) full-wave and (b) half-wave non-cumulative rectifier. The symbols V_a and V_d, here and in the text, do not imply any particular value—instantaneous, peak, r.m.s., or average.





cycle is $2/\pi$ or 0.637 of the peak value, so is 0.637/0.707 or nine tenths of the r.m.s. value. With full-wave rectification this ratio holds over the whole cycle (Fig. 2(a)) so if the whole voltage across the resistor is applied to a d.v. valve voltmeter and the reading multiplied by 10/9 the result should be the r.m.s. value of the alternating voltage. But if there are harmonics in the waveform the resulting errors are likely to be of the same order as the percentage of harmonics.

Using half-wave rectification (Fig. 2(b)) each half-cycle is averaged over a whole cycle, so the readings are half as much—with sine waves, less than one third of the peak value.

Not only is the reading with a simple half-wave rectifier rather low, but at very high frequencies the stray capacitance across the load resistance (R) retains sufficient charge to be appreciable during the inactive half-cycle, so causing the reading to be higher at high frequencies than at low. The way out of these difficulties is to add so much capacitance (C) across R that the charge is almost fully retained at *all* working frequencies, down to the lowest. The result is the familiar "cumulative" diode rectifier, used in most radio receivers as well as valve voltmeters. If the rectifier really were ideal and had no forward resistance, C would charge up to the full peak value during the first half-cycle. From then until the next half-cycle it would leak through R, but provided that R and C are so large that their time-constant RC is very long compared with the period of a cycle the loss is small and the reading is very nearly equal to the peak value, which with sine waves is $\sqrt{2}$ or 1.414 times the r.m.s. value.

It might seem, then, that all that need be done is to connect a suitable rectifier in series with R and C (Fig. 3) and apply 70.7 per cent. of the voltage across R to the direct-voltage instrument described in the January issue, which would then read r.m.s. values (so long as the voltages being measured were sinusoidal).

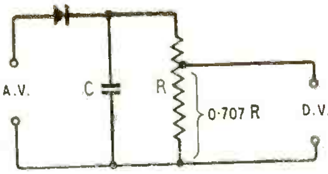


Fig. 3. Theoretical circuit of cumulative rectifier giving r.m.s. readings of sinusoidal voltages

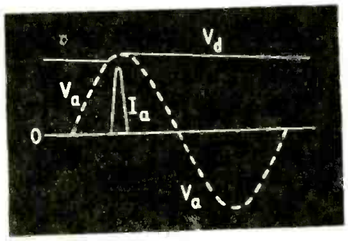


Fig. 4. Input/output diagram for cumulative rectifier, when the charging resistance (r) is much less than the discharging resistance (R).

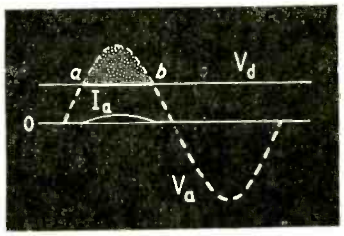


Fig. 5. If r is adjusted to reduce the output to one half, the diagram (compare Fig. 4) is altered to this.

Effective Input Resistance

In practice it is not quite so simple, however. The requirement from which all the complications spring is that the measuring system must present a very high impedance to the a.v. source. A perfect rectifier is at all times either conducting completely or not at all. Nearly all the time the charge on C biases it back so that it is not conducting, and except for any stray capacitance in parallel with the rectifier the input impedance is infinite. But at the very peak of the active half-cycle the input voltage momentarily exceeds the voltage to which C is charged (because since the last peak there has been a slight leakage through R), so the rectifier conducts and restores the charge to full peak voltage. If the forward resistance of the rectifier really were nil, the charging process would be instantaneous and the charging current infinite ; in reality, of course, charging takes an appreciable time, but as it is small compared with the whole cycle the current is correspondingly large compared with that which discharges through R (Fig. 4). For example, if the peak V_a were 10V, and R were 100kΩ, the leakage current would be nearly 0.1mA ; and if charging occupied one twentieth of the cycle the charging current would have to average $20 \times 0.1 = 2$mA over that period. So although most of the time the input impedance would be infinite, during 0.05 of each cycle it would be about $10/2 = 5$kΩ.

If one insists on a single figure for input resistance, the most reasonable reckoning is on a basis of power dissipation. The forward resistance of the rectifier being neglected, the only dissipating component is R, and the wattage is V^2_d/R. V_d being practically equal to the peak V_a, or (with sinusoidal input) $\sqrt{2}$ times the r.m.s. V_a, V^2_d/R can be taken as equal to $2V^2_{a(r.m.s.)}/R$. If the effective a.c. input resistance is denoted by R′, it must by definition be such that the dissipation is $V^2_{a(r.m.s.)}/R'$. By equating the dissipation expressed in these two different ways, R′ is seen to be equal to R/2, subject to the approximation assumed.

When the source of V_a is a sharply resonant circuit, the flywheel effect of the circuit keeps the input waveform reasonably sinusoidal, and although the damping due to the voltmeter is concentrated into a small fraction of each cycle, its effect is practically the same as that of a resistor of value R/2. In the example considered, $R' \simeq 50$kΩ, and if the dynamic resistance of the tuned circuit were also 50kΩ the effect of connecting the rectifier circuit would be to reduce V_a by one half, without causing much change of waveform. The tuned circuit is analogous to the pendulum or balance-wheel of a clock, which, though it bears a very uneven load during its cycle, has enough stored energy to maintain a smooth, regular swing.

But when the source is a non-resonant generator with internal resistance, such as the output of a valve with resistance coupling, the effect is quite different. During the active part of the cycle the source resistance (say 50kΩ) limits the charging current to an amount which clearly cannot be many times the discharge current through 100kΩ, so must spread over a considerable proportion of the cycle. Consequently the simplifying assumptions break down and calculation becomes much more difficult. At the same time practically the whole of the enlarged active peak is cut off by the voltage drop in the 50kΩ, so the waveform at the voltmeter input is highly distorted.

Fig. 5 shows in thick line this waveform when the source resistance (call it r) is adjusted to reduce the rectified voltage to one half, CR being assumed sufficiently large to maintain it very nearly steady. Current is flowing from the source during the period a to b, and since a sine wave reaches half its peak at 30° and 150° this period is 120° or one third of the whole cycle. The voltage driving this current through r is represented by the shaded area, and can be averaged over the whole cycle by measuring this area and dividing it by the length representing the cycle period. It is about 0.11 times the sine peak. The mean rectified voltage (driving the discharge current through R) having been adjusted to half the sine peak, the mean charging voltage is 0.22 times the discharging voltage. Since the mean charging and discharging currents must be equal, the ratio of r to R must be 0.22—not 0.5 as with the resonant source.*

Alternative Circuits

Experiments with an oscilloscope confirmed all the foregoing statements, and brought out very clearly that with a non-resonant source the distortion and the drop in output voltage are considerable even when r is less than 1% of R. This fact is of great importance in valve voltmeters, but before following it up the reader might note input resistance as an example of how this apparently simple circuit is commonly misunderstood. In one textbook it is stated that the input resistance (at 60 c/s) is equal to the value of series resistance required to drop the full-scale deflection to one half. Without any guidance to the contrary the reader might easily assume that input resistance found in this way (presumably with a non-resonant source) meant the same thing as input resistance calculated on a power-dissipation basis, or measured with a resonant source. If so he would be seriously misled.

This is not the end of confusion about input resistance as will soon be seen; but in the meantime it should be noted that with the Fig. 3 type of rectifier connection the source resistance r includes the forward resistance of the rectifier. So even if the source itself has no resistance, or it is allowed for by regarding the voltage to be measured as the voltage at the terminals of the instrument, there is still a loss or error due to this forward resistance. Fig. 6, which is a generalization of the half-drop example considered with Fig. 5, shows that to get the rectified voltage within 1% of the peak input it is necessary for R to be something like 2,000 times the rectifier forward resistance. Now although the forward resistance of a thermionic or a germanium diode with inputs of at least several volts may be of the order of 100 Ω, so that for the high ranges this source of error could be kept negligible by making the load resistance R no more than one megohm, at low voltages the rectifier resistance rises to thousands of ohms, so that the values of output and peak input rapidly diverge as the input is reduced, causing the well-known bend at the foot of the calibration curve. Even if one were content to put up with considerable curvature by using a 1-MΩ load resistance, one would have to face the fact that connecting the valve voltmeter would cause an appreciable drop in the voltage to be measured, even when the resistance of the source was in only the hundreds of ohms! So the oft-repeated claim for valve voltmeters in general, that they can confidently be used for measurements on high-impedance circuits, can hardly be accepted without reserve—even before starting to consider disturbance due to input capacitance. Taking this together with the fact, emphasized in the previous article, that only exceptional amplifier valves will allow more than a megohm or two in their grid circuits without appreciable drop therein due to leakage current, one sees that valve voltmeters demand a good deal of care in design if they are to come anywhere near their popular reputation.

Connecting the rectifier as in Fig. 3 has one important advantage: the output voltage is almost perfectly smooth. It is taken for granted that in order to avoid low-frequency error the time constant CR must be many times the period of one cycle; for example, if the lowest frequency to be measured is 20 c/s, the period is 1/20, and the choice of CR would be at least 0.5 and probably 1—say 10MΩ and 0.1 μF. The ripple on the output would then be so small as hardly to need additional smoothing. Fig. 3 is not unusual if the rectifier is a germanium diode, which has many advantages. But unfortunately the backward resistance of germanium diodes obtainable up till now is far too low if the load resistance is required to be of the ten-megohm order, for it is

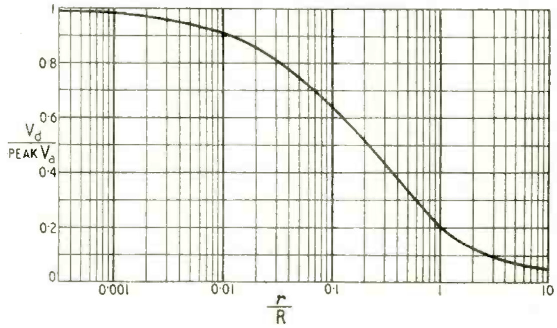


Fig. 6. Effect of the ratio r/R on rectification. (Data by D. A. Bell).

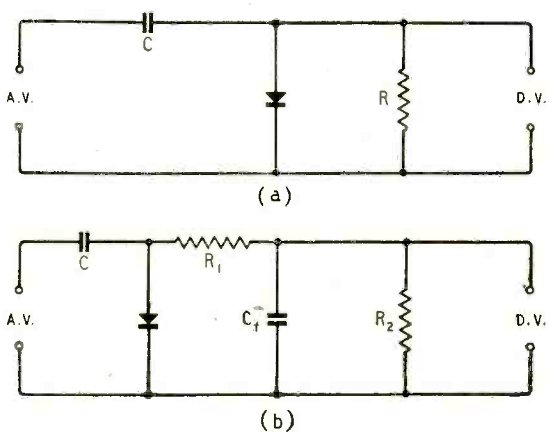


Fig. 7. Series-C modification needed when the voltage source includes a direct voltage or an open circuit. Owing to the large a.v. component passed on, a filter is desirable (b).

* This subject is discussed in greater detail by D. A. Bell in "Diode as Rectifier and Frequency-Changer," *Wireless Engineer*, Oct. 1941, pp. 395–404.

effectively in parallel. For high-impedance instruments the only kind of rectifier is the thermionic diode, hereafter to be called the diode. If it is connected as in Fig. 3, and R is many megohms, there may be undesirable effects from the heater circuit. With a carefully insulated heater winding, however, it should not be impossible to exclude such effects. Stray capacitance is harmless, for it comes across C. But with any type of rectifier the Fig. 3 arrangement is restricted to uses in which there is a highly conductive path through the source, and no direct voltage. To avoid these restrictions the circuit is usually rearranged as in Fig. 7(a). Here the d.v. output is accompanied by the full alternating component. This ought to be removed, because even if one does not measure voltages of sufficiently low frequency to make the pointer vibrate there is risk of overloading the amplifier. So some sort of filter is required. Seeing that there is (as Fig. 3 indicates) some output voltage in hand, there is the obvious possibility of using the series part of R as a filter element (Fig. 7(b)). If rectification were 100 per cent, the ratio of R_1 to R_2 to make the output equal the r.m.s. value of sinusoidal input would be $(\sqrt{2}-1):1$. With rectification less than 100 per cent (as it must be), R_1 could be reduced to compensate—if the rectification percentage would oblige by remaining constant.

Although the Fig. 7 arrangement is broadly equivalent to Fig. 3 the fact that the approximate effective input resistance (to resonant sources) is no longer R/2 is often overlooked. This can be seen in Fig. 7(a) by noting that in addition to providing the same d.c. through R as in Fig. 3, the source also has to provide an a.c. through R (the impedance of C being negligible). By the theorem of superposition these can be reckoned as if they flowed separately. So the effective input resistance is the original R/2 in parallel with R, making R/3.

But when the circuit is complicated by filtering, the input resistance is modified accordingly. Fig. 7(b) is one that might be used to fit the amplifier already described As before, input resistance is half d.c. resistance in parallel with an a.c. resistance. The d.c. resistance is $R_1 + R_2$, and a.c. resistance (C_f being large enough for its impedance to be neglected) is R_1. Input resistance is therefore $\frac{R_1(R_1+R_2)}{3R_1+R_2}$: if $R_1 = (\sqrt{2}-1)\ R_2$ it is roughly one quarter of R_2.

Some more usual arrangements are shown in Fig. 8. If it is desired to pass the whole rectified voltage to the amplifier, it can be said for (a) that the filter is not appreciably loaded, so the effectiveness of R_1 can be increased by using a higher value. But in (b), where R_1 and R_2 form a potential divider as in Fig. 7, R_3 seems to serve no useful purpose and only reduces the input resistance.

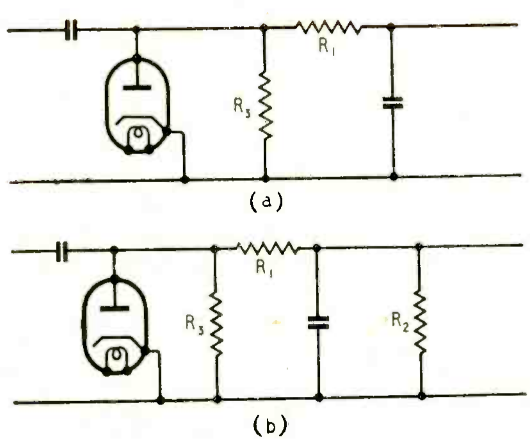


Fig. 8. Alternative load and filter circuits.

Zero Displacement

Besides having an almost infinite backward resistance and a reasonably low forward resistance (given at least several volts input), the thermionic diode has the advantage of not being easily destroyed by excessive input voltage. The usual maximum rating for suitable diodes is 420V peak inverse, which in practice means $420/2\sqrt{2}$ or 150V r.m.s. input. It is rather useful if the a.v. ranges go up to 250 to include mains voltages, and some makers of valve voltmeters apparently run the risk of exceeding the diode's rating. If the instrument is mainly for high voltages, at not more than about 10Mc/s, the type of diode used for flyback e.h.t. (such as the EY51) is very suitable, as it is quite safe up to at least 8kV peak input.

But it is the low-voltage end that is usually most important, and most difficult to arrange. For not only is there the awkward "bottom bend" but thermionic diodes have the unfortunate complication of "zero current." This is the current that flows in the anode circuit when there is no applied voltage. What matters most is the voltage, negative at the anode, that this current sets up across the load resistance. The current itself varies a good deal from one sample to another of even the same type of diode, but in any given sample depends mainly on the heater voltage. Over a considerable range it is roughly proportional to it, as shown in Fig. 9, which refers to a typical diode. Both current and voltage obviously depend also on the resistance in the anode circuit, and it is an interesting experimental fact that over a very wide range of resistance the voltage is very nearly proportional to the logarithm of the resistance, as shown in Fig. 10 for the same diode. Note that the slope of these nearly straight curves is only very slightly affected by heater voltage.

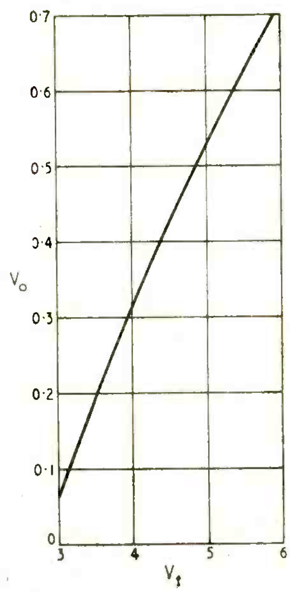
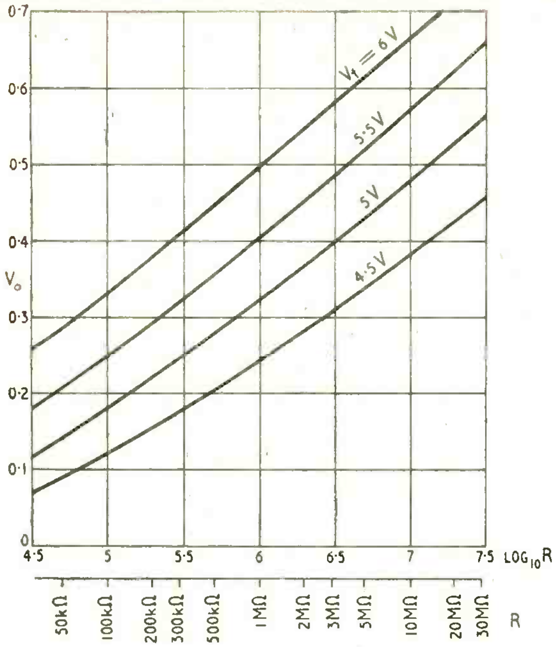
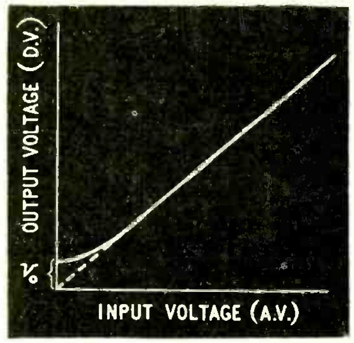


Fig. 9. Variation of "zero voltage" (Vo) with heater voltage (Vf) of typical diode, with a load resistance of 20MΩ.

Now the zero displacement resulting from this effect must obviously be corrected in some way. And since the required correction drifts so steeply with heater voltage,





Left : Fig. 10. Variation of V_o with load resistance (R), for several values of heater voltage.

Right : Fig. 11. Method of arranging for the greater part of an a.v. calibration curve to fit the d.v. scale.

the usual method is to balance it out with another diode of the same type, in conjunction with a preset adjustment to take up any initial difference between the two. This method fits very well into the instrument already described, which is symmetrical. The second diode, which can conveniently be one of the same pair as the first in a double diode, can be connected to the input of the balancing amplifier valve. Fig. 9 shows that the zero displacement voltage can be much reduced by running the heater at, say 4.5V instead of the rated 6.3V, and experiment shows that, with this type of diode at least, and with 10-20MΩ load resistance, the calibration curve is displaced bodily with hardly any change of shape; but Fig. 9 also shows that *variation* of displacement (which is what matters) is not reduced, so there is really nothing to be gained by under-running the heater.

Non-linearity at Low Voltages

And now at last it is necessary to deal with the most troublesome feature of all—the bottom bend. This, as we have seen, exists because at low input voltages the forward resistance of the diode cannot be neglected in comparison with the load resistance (in parallel with the backward resistance, if that is not infinite). One result is that even with the highest practical load resistance it is not possible to measure voltages below about 0.1 at all. Another is that up to at least several volts the curvature prevents one from using the same linear scale for all ranges. The only effective remedy is pre-diode amplification, and that calls for very skilful design to avoid drastic reduction in accuracy or frequency range or both. Even with the most modern wide-band amplifier technique one could hardly hope to cover 20c/s to 200Mc/s with good accuracy, or even at all. In any case it is a subject in itself.

An attractive way of dealing with the matter is that proposed by R. Kitai*, who deliberately arranges for a certain amount of zero displacement, v_0 in Fig. 11, so that when the curve does straighten out it will coincide with a straight line through the origin, and by suitable adjustment of the slope can be made to fit the common linear scale, at least from the point where the curve joins the straight line. Mr. Kitai places this point at 0.2V, but this seems over-optimistic, for neither the type of diode specified by him nor any other tried by the present writer has been found to approximate reasonably closely to a straight line down to such a low voltage, even with 20MΩ load resistance. Not only so, but when an accurately-drawn input/output voltage curve is examined it can be seen that there are appreciable differences in slope and zero displacement between the straight lines that best represent even the upper ranges of it. Except for rough work, then, a single preset adjustment of slope and zero displacement for all ranges is not good enough.

Scale Fitting

There are two alternatives. One is to abandon the idea of using the same linear scale for direct-reading a.v. as well as d.v., and to use a calibration curve. If you agree that almost anything is worth while to escape from a calibration curve, you will prefer the second alternative, which is so to contrive the range switching as to fit the curve as nearly as possible to the existing linear scale on all ranges. This will cause the pointer, set to zero for d.v., to move up from zero on a.v. The only range on which this matters is the lowest, because on all the others the first 30 per cent or so of the scale is better served by a lower range. The top readings on the d.v. ranges in the meter already described are 1.5, 5, 15, and 50; so the required extent of the ranges is 0–1.5, 1.5–5, 5–15, and 15–50. The rectification characteristic of a normal diode can be fitted with satisfactory accuracy to all except the first, which must be treated as if there were a still lower range by disregarding all below about 0.5 V. For these lower voltages one must either use a calibration curve or embody it in the meter by marking an extra scale.

The first step is to make as accurate calibration curves as possible for at least the first three ranges, using the Fig. 7(b) circuit with R_2 equal to what has already been chosen for the amplifier (15MΩ in the instrument already described) and R_1 equal to $\sqrt{2}-1$ times as much (6.2MΩ in that example). If the diode were a perfect rectifier, and the input were perfectly sinusoidal, all the curves would be straight lines with a 1 : 1 slope, and all the readings would be the correct r.m.s. values of the input voltage. In reality, of course,

* *Electronic Engineering*, Oct. 1950, p. 420.

the slope gradually approaches 1, and the best straight lines representing the curves over the effective parts of the ranges cut the vertical axis at different points above zero. The following are the results of a test on an EB91 :

Range, V	Slope	v_0 (Fig. 11)	Suitable value of R_1 (MΩ)
0.5—1.5	0.92	0.13	4.5
1.5—5	0.97	0.18	5.6
5—15	0.98	0.22	6.0
15—50	0.99	0.31	6.1

The slopes can be brought up to 1.00 by making the range switch reduce R_1 to the values shown in the last column. This, incidentally, varies the zero setting in two opposite ways: by varying the total zero voltage from anode to cathode (see Fig. 10) and by altering the proportion of that voltage passed to the amplifier. The net effect is small, and in any case can be taken care of by the second range-setting adjustment—that needed to provide the appropriate v_0. To do this, and at the same time retain the full compensating effect of the balancing diode, one would have to provide a complete duplicate of the first diode circuit with its range switching, plus a switched preset v_0 from some d.c. source. But fortunately a much simpler system can be devised to give results that are practically indistinguishable even with high-grade equipment.

The slope is adjusted by varying R_1, as suggested; and the appropriate v_0 for each range is derived by making the balancing diode yield just that much less than the zero voltage of the signal diode. This is done by reducing its coupling resistance, in accordance with Fig. 10. It is reduced sufficiently to meet this requirement even though (with the object of making a single untapped resistor do for each range) the whole of the voltage is passed on to the amplifier, and not only about 70 per cent of it as with the signal diode. If the curves in Fig. 10 were perfectly parallel the result would be that the balancing voltage would vary with heater voltage at a rate 40 per cent higher than the zero voltage to be balanced, but it conveniently happens that the converging of the curves towards the left just about offsets this effect over the range of resistance needed to provide v_0.

The circuitry for both diodes, designed on these lines, is shown in Fig. 12, with the adjacent parts of the direct-voltage unit sketched in lightly. Of course there are other ways of arranging the range-adjusting resistors. The values found correct in a particular case are specified as a guide. The procedure for final adjustment is rather like that for tracking a superhet. With a rheostat to provide the balancing diode load (R_b), and another for the variable part of R_1, R_b is set to the estimated value for the range, and R_1 adjusted, if necessary, to make the instrument read correctly at full scale. Then the reading at about one-third scale is checked. If it is high, the slope is not enough, and R_1 must be reduced. It is adjusted until the difference in reading at full and one-third scale is correct; R_b is then readjusted to take up any equal displacement of these points. On the lowest range the best tracking is actually obtained if the instrument reads very slightly high at these points and a similar amount low at about two-thirds scale. When the best settings have been obtained for all ranges the rheostats can be replaced by suitable fixed resistors, unless one prefers the refinement of preset components and can tolerate their bulk and expense. They need not be adjusted very precisely, especially on the upper ranges.

To check the adequacy of heater-voltage compensation with this simplified circuit, calibration was carried out very carefully over the range 0–1.5V, with the heater voltage of the EB91 double diode adjusted first to 6.0V and then to 4.5V. The difference caused by even this 25 per cent drop varied from imperceptible at the ends of the scale to barely perceptible (0.003V) at the middle. This of course is well below the probable error from other causes.

The need for the source of calibrating voltage to have a low resistance is emphasized by the fact that a perceptible drop in reading on the 50-V range occurs when 2kΩ is inserted in series, and 1 per cent with 10kΩ. Errors of several per cent can be caused by waveform distortion in a source transformer, particularly if controlled by a series primary resistance.

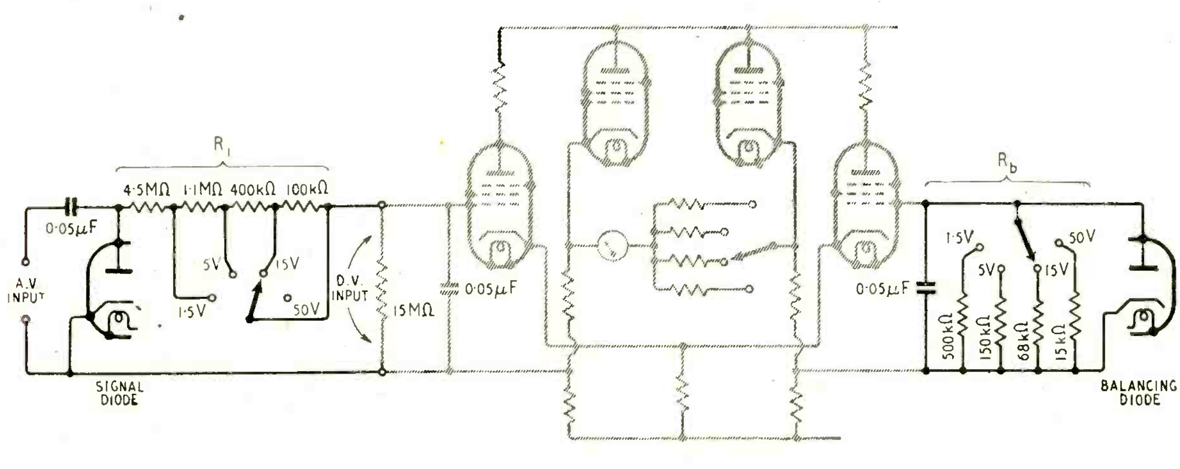


Fig. 12. Complete circuit diagram of a.v. adaptor, showing connections to the partly drawn d.v. voltmeter previously described (Jan. issue). Typical resistor values are shown for the EB91 double diode.

ORIGINS OF RADAR

Background to the Awards of the Royal Commission

This article deals only with those principles and devices that formed the subject of successful claims before the Royal Commission on Awards to Inventors for services rendered to the Nation: it is largely based on evidence given to the Commission. No attempt is made here to ascribe particular developments to individual claimants, but a list of the claimants, their claims, awards and short biographical notes is given at the end of this article.

THE speed with which Sir Robert Watson-Watt's suggestions for radio-detection of aircraft were given practical effect was probably due to the fact that he and his colleagues were familiar with cathode-ray tube techniques and with the application of these techniques to ionosphere sounding. Still earlier, they had used the techniques for the study of the waveforms of atmospherics and then for a twin-channel cathode-ray direction finder (CRDF).

Those who to-day see oscilloscopes left "on" for hours at a stretch (possibly even during a lunch-hour interval) may be interested to know that some of these early tubes cost £30 (1920 prices) and lasted for 10 hours. The trace of a transient was so faint that the observer had to stay ten minutes in pitch darkness before he could see it.

An excellent opportunity for an extension of the use of c.r.ts was given when the team studying the nature of the ionosphere under the direction of Sir Edward Appleton came to work at the Radio Research Station. At first, the frequency-change method (due to Appleton and Barnett) of measuring the equivalent height of the ionosphere was used. Later, a change was made to the "pulse" method of the Americans, Breit and Tuve, which gave much more easily interpreted indications, especially when more than one echo was present. The "display" (to use the modern term) was a Duddell oscillograph, observed on a rotating mirror and photographed on a film whose movement provided the time-scale. Watson-Watt provided a c.r.t. with a time-base, synchronized to the pulse-recurrence (the first of its kind) for monitoring the indications of the Duddell oscillograph. It was soon obvious that the monitor provided all the necessary indications and was much easier to handle than the mechanical oscillograph.

The first transmitters used in ionosphere research were based on the "squegger" circuit—now regarded as a type of blocking oscillator. Later, this was superseded by the much more efficient low-power modulation of a c.w. transmitter based on the developments of co-workers at Cambridge.

Concurrently with the development of a better transmitter, much work was done on receiver design; the characteristics required being high gain, minimum distortion of the received pulse and quick recovery from the paralysis caused by the pulse received direct from the transmitter. The development of the receiver and the display arrangements are described at length in "The C.R.O. in Radio Research" (H.M.S.O., 1933).

This was the state of knowledge at the Radio Research Station when the Government's advisers were becoming very worried about the problem of sufficient warning of air raids.

In 1934, the Director of Scientific Research, Air Ministry, wrote to Watson-Watt asking him to give his opinion on the possibility of developing a technique of destruction by radio (popularly called "death rays"). Watson-Watt replied (after making some calculations) that *radio-destruction* appeared to be quite impossible, but *radio detection* might be worth investigating.

The Defence Committee then asked Watson-Watt to expand the latter theme. In a memorandum dated February 27th, 1935, and headed "Detection and Location of Aircraft by Radio Methods" he set out in detail and with remarkable foresight the conditions necessary for an effective radar system. Among the topics discussed were: measurement of three co-ordinates (range, bearing and elevation) to give location: need for "radar frontiers" formed by a chain of stations: advantages of shorter wavelengths: IFF (Identification, friend or foe?). The need for high-power transmitters was stressed, and the possibility of radars which automatically follow a target was mentioned.

This report was written *before a single echo had been seen* by the workers at Slough. After a simple demonstration that aircraft did in fact reflect radio waves authority was given for a small team of workers to start experiments at Orfordness in Suffolk. Radar had started.

Early Days

The move was made on May 15th, 1935. The transmitter (built on steel scaffolding for flexibility) used a large Naval silica valve directly coupled to the aerial (a horizontal dipole on a 70ft mast) modulated by a transformer-coupled low-power valve. The wavelength was about 50 metres. The receiver (fed from a similar aerial) was one of the Radio Research Station's "ionosphere" receivers but with the acceptance band widened. The pulse duration was about 10 microseconds, but its shape was not particularly good. On June 16th, aircraft were being followed out to 17 miles —good progress for one month's work. A month later, the range of detection was over 40 miles.

RDF.—At about this time, the technique became officially known as RDF. The origin and intended meaning of these letters has been the subject of much speculation. The fact seems to be that the letters DF were intended to suggest that the technique was a form of direction finding. This was done to confuse a potential enemy: at that time the workers saw no solution to the problem of direction-finding pulses, and were modest enough to think that the solution would be long in coming. The first letter, R, was chosen "out of the bag." As mentioned later, the DF technique was thought of soon after RDF was so named. The (wrong) explanation followed that they stood for "Reflection Direction Finding" or "Range and Direction Finding."

An unexpected difficulty soon arose through the discovery of a reflecting layer (christened the "Z" layer) at a height of between 10 and 20 km. This set an upper limit to the detection range when using wavelengths susceptible to reflection from the layer, with aerials radiating a substantial upwards component. Accordingly, a change was made to 25 metres and, later (in 1936), at Bawdsey, wavelength was again halved to 12½ metres to avoid jamming. This became the nominal wavelength of the "Chain" stations.

DF.—Until the direction-finding problem was solved, the only possible way of locating an aircraft was to use two radar stations, measure the range from each and plot the position by triangulation. This was simple when only one aircraft was present, but two aircraft gave four possible positions and N gave N^2 positions. The system would therefore be operationally useless.

The solution came unexpectedly soon, and rather embarrassingly so in view of the would-be confusing name of "RDF." This was the use of a vertical array of crossed pairs of horizontal half-wave dipoles connected to a radio-goniometer. Success was immediate and in January, 1936, good bearings were obtained on an aircraft 25 miles away flying at 7,000ft. The first radio-goniometers, designed at Slough, were of the two-section type with two search coils, one moving in each field coil. Later, it was shown that they suffered from an inherent octantal error, and the more conventional type (with a single search coil) superseded them.

Sense.—An accompanying problem to that of d.f. was the determination of "sense" (i.e., an echo is on a North-South line: is it North or South?). In normal d.f. on vertically polarized waves, this is determined by using a vertical (all-round) aerial and comparing the phases of the signal received on it with that in the d.f. aerials. This was not possible at Orford as the polarization was horizontal. The difficulty was solved by placing dipole reflectors behind the crossed dipoles, equipped with relay-operated switches which closed and opened gaps at the centre of the reflectors.

Height-finding.—In the Watson-Watt memorandum of February, 1935, three co-ordinates were stipulated for complete location, i.e., finding the position of an aircraft in space. Height-finding (or, more correctly, angle-of-elevation finding which, in conjunction with range finding, gave the height of an aircraft) was actually achieved before direction finding. The technique was copied from that used at Slough for finding the angle of arrival of waves from transatlantic transmitters which had suffered one or more reflections from the ionosphere and the sea. A probable direction for air raids was assumed, and two horizontal dipoles were erected at right angles to this direction and spaced by a convenient distance. Echoes reached one dipole before they reached the other, and there was therefore a phase-difference between the received signals. The echoes received on one aerial were fed to the field coils of a radio-goniometer in such a way that a rotating field was produced.

The search coil picked up a voltage whose phase depended on its position, the instrument acting as a phase-shifting transformer. The signal in the search coil was compared with the echo from the second aerial, and the phase-difference thus determined.

This method of height-finding suffered from several disadvantages. (1) It gave increasingly inaccurate readings as the angle of elevation decreased; (2) it required a knowledge of the direction of the aircraft, and failed to give any reading as the direction of the aircraft approached the "end-on" direction of the dipole.

A greatly improved method, which was tried in 1936 at Bawdsey, was universally adopted on metre-wave land stations. Consider the signals received from an aircraft on two horizontal dipoles fixed at different heights on the same vertical mast. The *strength* of signals will depend on the different vertical radiation diagrams of the two aerials—different because of differing heights above the earth or sea. It can be shown that the *phase difference* between the signals is zero—a fact not recognized at the time by American workers. Because of this co-phasal property, if the amplitudes of the signals are applied directly to the field coils of a radio-goniometer, the search coil can be set to a minimum, and the position of the search coil will give an indication of the angle of elevation of the downcoming waves. Under certain circumstances there will be an ambiguity of indication: the angle of the search coil will correspond to more than one angle of elevation. This ambiguity is resolved by changing from one of the dipoles to another at yet a third height.

Transmitters.—The two main requirements for radar transmitters—shorter pulses and higher power—were first tackled.

The problem of higher power was attacked by obtaining large (1-kW) silica valves whose design was a speciality of the Navy's Signal School at Portsmouth. As these valves would only be conducting for a short time (10 microseconds), followed by a rest period of 1990 microseconds (corresponding to a recurrence rate of 50 pulses per second), thermal effects were negligible. It was therefore possible to overrun them considerably, and peak powers of sixty times the rated figure were obtained. By using silica valves specially designed for radar much higher power was subsequently obtained. In 1939 silica tetrodes were developed.

Transmitter Monitor.—During the early days much effort was expended in getting "lots of power" into the aerial. The problems of frequency variation during the pulse and of reasonably square pulse shape were of secondary importance. The need for a pulsed-transmitter monitor was recognized, and provided. It allowed observation of the pulse shape, and, in conjunction with a variable-frequency oscillator, showed up any signs of frequency variation during the pulse. This device cast so much light on the design of the early pulse transmitters, and taught the workers so much, that it was not needed in later models.

Coupling to the Aerial.—During the early experiments, working into a single dipole with fairly short transmission lines, the problem of matching the transmitter to the lines was not too difficult. With increasing lengths of lines and more elaborate arrays, this direct coupling became impracticable, and an isolating or "buffer" stage had to be interposed between the oscillator and the open-wire lines.

Transmitting Aerials.—The first transmitting aerial was a single horizontal half-wave dipole slung between two 70ft masts. Later, metal-covered hollow wooden spars, threaded through the structure of 240ft wooden towers, were used. In the final CH (Chain) stations curtain arrays, suspended from cantilevers fixed to 360ft steel towers took their place. Owing to the effect of the ground, the vertical radiation pattern consisted of several lobes. An aircraft would be lost to the radar observer if it flew into the minimum region between two lobes. The technique called gap filling, which consisted of using alternative aerial arrays at different heights, overcame this difficulty.

Receiving Aerials.—The first receiving aerial was exactly like the transmitting aerial. The next design, using the hollow wooden spars, was used subsequently for all CH aerials. The receiver aerials were necessarily more complicated, as they had to give direction-finding facilities (crossed dipoles), height finding and gap filling (sets of dipoles) at different heights.

Lines.—For satisfactory d.f. it was essential that there should be no coupling between the lines from the aerials to the receivers. As no suitable low-loss concentric lines were available at the time, these were made locally by threading copper wire, carrying triangular ceramic spacers, into copper tube.

Receivers.—In the early days the ideal receiver characteristics were not obvious, and so it was decided to make an i.f. amplifier lavishly equipped with adjustments. The assistance of the Radio Department of the N.P.L. at Teddington was called in. Later, a receiver was developed with ganged adjustments for gain and for bandwidth. This became the prototype for the CH receivers made by a commercial firm. The r.f. amplifier used two stages of push-pull amplification and was followed by (usually) five stages of i.f. amplification at 2 Mc/s. All possible precautions known at that time were taken to ensure stability, such as separate screened boxes for each stage, "binocular" intervalve transformers and filtered heater supplies to each stage. Grid bias was supplied from tappings on a dry battery, as any voltage-dividing circuit (necessarily associated with r.f. bypass capacitors) seriously delayed recovery from the effect of the very powerful transmitted pulse.

Display.—This consisted at first of a c.r. tube with a sine-wave time base fed through a bridge-type phase-changing network from the 50-c/s mains which also controlled the timing of the pulse. The sufficiently linear part of the sine wave around zero volts was used, the range scale derived from a 15-kc/s oscillator being marked on the surface of the c.r. tube. Later, conventional time-base circuits were employed.

Anti-jamming.—Any new military device is likely to be confronted by a corresponding new "anti-device." In 1937 steps were therefore taken to explore the possibilities of and protection against jamming. The former were brought forcibly to the notice of Bawdsey, when someone turned on a metre-wave radio-therapy device using a spark generator and brought all the radar development work to a standstill. It was thought that c.w. interference should be guarded against, and attention was given to rejector circuits with their "Q" artificially increased by positive-feedback valves. It seemed natural to put these circuits in the r.f. amplifier, as early as possible, to prevent overloading the early stages. Success was only reached when the circuit was inserted in the i.f. amplifier, and the IFRU (intermediate-frequency rejection unit) came into being.

Another suggestion for combating jamming (of the "noise" type) was the use of a long-persistence c.r.t. screen.

Permanent Echo Suppressor.—An example of the application of a little science to an unusual problem is given in the way in which trouble due to radar echoes from an important balloon barrage were overcome. It was at first thought that it would be necessary to move a complete radar station, as these echoes put it completely out of operation. One of the Bawdsey team who was consulted installed in the direction of the barrage an aerial fed with a suitably phased fraction of the transmitter output. The cure was completely successful and the station once more became operational.

Identification : Friend or Foe ?

Watson-Watt, in his 1935 memorandum, had recognized the need for some form of identification of the sources of echoes. The satisfaction of this need was called IFF (Identification: Friend or Foe?). He suggested the use of keyed radiators, on friendly craft, which would cause the echoes to change abruptly in time in accordance with a prearranged code. In order to increase the difference of radiation caused by keying the radiator, tests were also made with dipoles whose Q was reduced by valve circuits using positive feedback. Success was obtained when experiments were carried out on these lines, but the results were too dependent on the attitude of the craft. A remarkably successful experimental flight was carried out to test the following principle.

A super-regenerative receiver was fed from a dipole. When the r.f. pulse impinged on the dipole, the receiver greatly amplified the effect, and the amplified oscillations were re-radiated from the dipole and received at the ground station. This principle, with modifications, has been since used in many IFF systems. It was necessary that the receiver be tuned to the radar frequency in order that it should respond to a number of different radar frequencies; and to allow for drift in its own tuning and in that of the radar transmitter, a slow frequency sweep was applied by a motor-driven capacitor. The frequency sweep, which caused the "blip" to appear intermittently on the radar, permitted a simple form of coding.

PPI.—The Plan Position Indicator has been described so often that details will not be given here. The principle was suggested at Orfordness as early as October, 1935, but radar technique was hardly ready for it. The PPI for its proper development needed a more-or-less directional aerial system; the comparatively long wavelengths (50 and 25 metres) in use at that time prevented the use of the requisite directional array. PPI, though used with "metre" radar (3m and 1½m), did not come fully into its own until centimetre radar became possible with the invention of the magnetron. Without PPI the positions of aircraft had to be plotted manually by reading the range on an "A" (range-amplitude display) and the bearing on the goniometer scale. At a later date, a mechanical computor was designed, but was superseded by a very effective electrical computor (named the "fruit machine") based on automatic telephone practice.

Increased Accuracy.—The team at Orfordness were, at first, not concerned with accuracy of range or bearing: they were only interested in extending the range of detection and in plotting the positions of raiders sufficiently accurately to enable fighters to be directed towards them. When radar was being developed for directing guns, there was a need for greater accuracy in range and bearing. Two developments, dealing respectively with these two problems, will now be mentioned.

Bearing Accuracy.—Whereas the CH stations used a goniometer to obtain bearings, the shorter wavelength used in the gun-laying (GL) sets made this technique less easy: further, there was the ultimate aim of making the GL sets follow the target automatically, a condition for which goniometer operation is not suitable. The simplest way of obtaining a bearing was to rotate an array until the signal was a minimum. This has two grave disadvantages, the "minimum" direction is vague and, if the target bearing alters, the direction of change is not at once obvious.

To overcome these two difficulties, the system known as "split" was devised. In this, the axis of the beam could be switched rapidly from one direction to another a few degrees away. If the size of the echo remained constant, the target lay on the bisector of the angle between these two directions. If the direction of the target altered, the two echoes became different in size. It was necessary to distinguish which echo was produced with which direction. In one scheme a rotating disc synchronized with the aerial switch with red and green sectors moved in front of the c.r. tube, the echoes there were distinguished by colour. Another scheme (which gave the technique its name) was based on applying a small horizontal shift to the time base: the echoes appeared to have "split" into two echoes side-by-side—hence the name. (Confusion was later caused by the transfer of the term "split" from the echo to the beam, and the term "split beam" gained currency. As the two beams exist in succession and not simultaneously this usage is clearly wrong, and the term "switched beam" is now recommended.)

Range Accuracy.—The early radar displays used a range scale marked on the face of the c.r. tube. The accuracy of reading was low, as the whole range (perhaps 20 miles) was included in a length of about four inches, and parallax errors (due to the thickness of the glass envelope) were in evidence. Further, if the voltages applied to the c.r. tube changed, serious "zero" errors could occur. Two solutions to the problem were produced: (a) the potentiometer method, and (b) the "goniometer" method.

Potentiometer.—In the first of these, a time base was expanded to many times the diameter of the c.r. tube screen, only a small portion, therefore, being visible. The range was read by applying a horizontal shift to the trace until the echo was brought to coincidence with a line marked on the screen. The shift voltage was supplied from an accurate potential divider (potentiometer) connected across the h.t. supply to the c.r. tube. This artifice compensated for variations in the h.t. since an increase of h.t. voltage both *reduced* the c.r. tube deflectional sensitivity and *increased* the shift voltage available in the same ratio.

"Goniometer" Method.—The second method is usually referred to as the "goniometer" method because in some cases it made use of a radio-goniometer (part of a Naval Bellini-Tosi d.f. set) as a phase-shifting transformer. In this system there appear two traces on the screen. The upper one is a normal "A" display, the lower consists of calibrating pips from an accurate oscillator. If these pips correspond to ranges of thousands of yards, the range can be estimated by eye by noting the relative positions of the echo and the nearest two pips. If, now, a phase-shifting transformer is inserted between the oscillator and the pip-generating device, and the spindle of the transformer is turned steadily through 360 degrees, the pips will all move along the trace until each takes the place of its neighbour, i.e., moves 1,000 yards on the range scale, so that 1 degree on the phase-shifting transformer corresponds to 1,000/360 or 1.8 yards. If the phase-shifting transformer is adjusted so that the echo coincides with one of the pips, the range can now be measured to a high degree of accuracy.

Airborne Radar

Metre-Wave AI.—We now turn to another branch of radar—the use of radar in the air. In 1935 it was suggested that a half-way solution to the problem of airborne radar might be found: an airborne receiver only, receiving echoes from an aircraft as the result of transmissions from a *ground* transmitter. (This was called RDF $1\frac{1}{2}$, RDF 1 being all ground radar and RDF 2 the future all-airborne radar—but the name soon disappeared.) In comparison with CH the requirements for the all-airborne set were: reduction in size and weight; reduction in wavelength (this would reduce aerial size) to 1 or 2 metres; reduction of pulse duration one or two microseconds to give sufficient range discrimination at short ranges; development of a suitable display of beaming, range and elevation to be indicated directly without turning knobs.

It was rightly anticipated that severe difficulty would be caused by the closeness of the transmitter to the receiver. A start was made on a receiver on 6.7 metres; this was completed in six months. At the end of 1936 trials of RDF $1\frac{1}{2}$ were carried out, resulting in detection ranges of 8 miles. The co-operation of a powerful ground transmitter was responsible for a greater range being attained than on all other AI radar during the war. In early 1937 an airborne transmitter was designed and tested with negative results against aircraft. Ground objects and ships were detected. This was the start of ASV (Air to Surface Vessel), described later.

By December, 1937, a complete airborne set was in existence working on $1\frac{1}{2}$ metres. The peak power was 100 watts. The maximum range of detection was 5,000 feet. The set could only measure range. In mid-1939 it was possible to judge bearing and elevation; for this purpose two c.r. tubes were used. This set became AI (Air Interception) Marks 1, 2 and 3. AI Mark 4 followed in the winter 1940/41. This was the last of the metre AI sets.

ASV (Metre).—As mentioned above the 6.7 metre trials showed that echoes could be received from objects on the ground and from ships. In the autumn of 1937, a range of 5 miles was obtained at $1\frac{1}{2}$ metres. This led to the development of ASV Marks 1 and 2. The problems were easier than that of AI because the minimum range need not be so short and there is no need to measure elevation.

In 1940 large numbers of these sets were fitted by the Navy in escort vessels under the designation Type 286. Part of this apparatus was also used on the searchlight patrol set (SLC or "Elsie").

AI (Centimetre).—Suggestions for the use of much shorter waves which would allow narrow beams to be employed were made in 1940, but development had to wait for the magnetron and centimetre waves. The first centimetre AI sets were flown in early 1941 as AI Mark 7.

ASV (Centimetre).—As in the "metre" sets, the AI technique was applied to ASV. Here it had an important operational success. The Germans were beginning to fit their submarines with listening sets for detecting the approach of aircraft fitted with metre ASV. When we changed to centimetre waves they were puzzled and lost confidence in their sets.

H_2S.—The discovery (mentioned above) that objects on the ground could be distinguished by their echoes led to the development of H_2S—there are so many explanations of the reason for the name that it is inadvisable to mention any—for blind bombing. The development was held up because it was for a long time considered inadvisable to risk a magnetron falling into German hands, but in July, 1942, permission was given. The display is a plan position indicator.

AWARDS TO RADAR PIONEERS

Successful Claimants and Their Claims

AFTER A LONG and highly detailed investigation of claims, the Royal Commission on Awards to Inventors recommended that an *ex gratia* award be paid to Sir Robert Watson-Watt "in respect of his initiation of radar and his contribution to the development of radar installations." Sir Robert made a joint claim on behalf of a team of ten but the Commission has recommended individual awards to each member and also to eleven other claimants for their "contribution to the development of radar installations."

We give below a list of the successful claimants—twenty-one in all—with their claims and awards.

Sir Robert Watson-Watt (£50,000): RADAR.

At the time when Sir Robert Watson-Watt began his *magnum opus* as leader of the team that developed the means of using radio reflections for aircraft location, he was Superintendent of the Radio Dept. of the National Physical Laboratory (incorporating the Radio Research Station at Slough, where the initial experiments were made). In 1938 he became Director of Communications Development, Air Ministry, and from 1942-46 was Vice-Controller of Communications Equipment, Ministry of Aircraft Production. He received his knighthood (C.B.) in 1942. In 1946 Sir Robert left M.A.P. to set up a private company of technical consultants but continued as scientific adviser on telecommunications to a number of Ministries. He is a Fellow of the Royal Society.

Dr. E. G. Bowen* (£12,000): Development of single-station radar systems; metre-wave and centimetre-wave AI; metre-wave and centimetre-wave ASV; PPI; GCI; discrimination of ground targets (as used in H_2S); radar blind bombing (as used in H_2S); h.f. engine-driven alternators.

Dr. Bowen went to the Radio Dept., N.P.L., in 1935 as a junior scientific officer. He worked under Sir Robert Watson-Watt on the first airborne radar equipment. In 1940 he was a member of the Tizard Mission sent to the United States to disclose details of radar techniques to the American Chiefs of Staff. For nearly two years from 1942 (when he received the O.B.E.) he was British Liaison Officer at the Radiation Laboratory, Massachusetts Institute of Technology. In 1944 he went to the Australian Commonwealth Scientific and Industrial Research Organization as Deputy Chief of the Radiophysics Division of which he is now Chief.

A. F. Wilkins* (£12,000): Method of height measurement in single-station radar; gap-filling in single-station radar; sense-finding device for use with crossed-aerial d.f. system; IFF apparatus and aircraft aerials for use with IFF; device for reduction of effect of permanent echoes at CH stations.

Mr. Wilkins, who undertook research in radio at both the Manchester College of Technology and Cambridge University, was engaged in work on v.h.f. propagation and direction finding during most of his service (1930-36) at the D.S.I.R. radio research station. In May, 1935, he went to Orfordness as one of the Watson-Watt team, being mainly concerned with the design of transmitting and receiving aerials. From 1936-41 he was successively scientific officer and senior scientific officer at the Bawdsey research station where he was concerned with the design of the original CH stations. During 1942-45 Mr. Wilkins was officer-in-charge of the Operational Research Sections at Fighter Command and later at Air Command Headquarters in Ceylon. He returned to the radio research station (Slough) in 1946 as senior principal scientific officer (which position he still holds) and is concerned with the propagation of h.f. at oblique incidence and the maintenance of the overseas ionospheric observatories of D.S.I.R.

L. H. Bainbridge-Bell* (£2,400): Radar transmitter and receivers; optical converter.

Mr. Bainbridge-Bell, whose absorbing personal interest is the presentation of technical information (on which he has contributed to *Wireless World*), has been at the Admiralty Signal and Radar Establishment since 1939. From 1927 to 1936 he was at the Slough radio station developing the c.r. direction finder for atmospherics and ionosphere-sounding apparatus. During this period he was co-author with Watson-Watt and Herd of "The Cathode-Ray Oscillograph in Radio Research." Prior to joining the research staff at Slough he was for six years with the Radio Communication Company developing the Robinson system of d.f. for ships.

H. Larnder* (£2,400): Radar countermeasures; afterglow of c.r. tubes; pulse analysis and monitoring; measurement of transmitter power; measuring standing waves on transmission lines.

Before joining the Watson-Watt team at Bawdsey in 1936, Mr. Larnder was for some months in the transmitter laboratory of the Plessey Co. He is now superintendent of Weapons Assessment, Armament Development Establishment, Ministry of Supply.

Geoffrey A. Roberts* (£2,400): Electrical calculators.

Prior to joining the Bawdsey research station in 1937 Mr. Roberts was for seven years with Standard Telephones and Cables, where his experience in automatic telephony contributed largely towards his designing the electrical calculator for which he received the award. He became a M.B.E. in 1946.

Dr. Denis Taylor* (£2,400): GCI.

After graduation in 1931 Dr. Taylor became a research assistant at University College, Hull. For two years prior

* Members of the Watson-Watt team.

to joining T.R.E. in 1939 he was senior lecturer in physics and radio engineering at the Polytechnic, Croydon. During his five years at T.R.E., first at Bawdsey and later at Dundee, Swanage and finally Malvern, he was concerned with ground radar. He was subsequently on counter-measures against "flying bombs" and V2s. From 1944-46 Dr. Taylor was Superintendent, T.R.E. (Far East), and has, since then, been head of the Electronics and Instrumentation Division, Atomic Energy Research Establishment (Harwell). He is author of "Principles of Radar" and "Measurement of Radio Isotopes."

Dr. A. G. Touch* (£2,400): Metre-wave AI and ASV.

Dr. Touch, who, since 1947, has been Superintendent of the Blind Landing Experimental Unit, joined the Civil Service in 1936 as a junior scientific officer at the Air Ministry research station, where he worked with Dr. Bowen on the development of AI and ASV. In 1940 he went to the Royal Aircraft Establishment, Farnborough, on the development of airborne radar, and in the following year was appointed to the British Air Commission, Washington, where he assisted in the development and production of airborne radar and navigational aids in N. America.

R. Hanbury Brown* (£1,200): Metre-wave AI and ASV.

Mr. Brown, who has, since 1949, been at the Jodrell Bank research station of Manchester University as I.C.I. Research Fellow, working on radio noise from the galaxy, joined the Bawdsey research station in 1936, where he participated in the early experimental flying with night-fighter equipment (AI) and ship and submarine-detection equipment. With Dr. Bowen he detected the first submarine by radar in 1939. From 1942-45 he was in the Naval Research Laboratory, Washington, D.C., as assistant head of the combined research group working on the development of radar equipment. For two years from 1945 he was principal scientific officer at the T.R.E., Malvern, after which he undertook radar consulting until going to Manchester University.

W. A. S. Butement (£1,200): "Split" method of d.f.; developments leading to CHL, CD/CHL, CDU and GCI sets; fire control system using echoes from shell splashes.

Mr. Butement, who for the past few years has been chief scientist in the Australian Government's Department of Supply, was assistant director of scientific research in the British Ministry of Supply during the latter part of the war. He was appointed an O.B.E. in 1946.

P. E. Pollard (£1,200): Radar ranging systems; radar beacons.

The whole of Mr. Pollard's working career has been in the Scientific Civil Service, and he is at present chief superintendent, Radar Research and Development Establishment of the Ministry of Supply. His technical training as a physicist was at King's College, London, under Sir Edward Appleton. He was appointed an O.B.E. for his part in the development of radar.

R. H. A. Carter* (£750): IFF.

Mr. Carter, who was at the Slough radio research station in the early '30s, was one of the team at Orfordness and Bawdsey and later went to Malvern, where he is now senior experimental officer at T.R.E.

H. Dewhurst (£750): 4-metre receivers; gap-filling arrays; sense-finding array; PPI type display; phasing dipole array; transmission line feeds; mobile receiver RM1; intermediate CH chain.

Mr. Dewhurst is now head of the Photographic Division and Film Unit, T.R.E. His researches while in the Research Pools of the Ministries of Air, Aircraft Production and Supply include work on h.f. filters, mobile radar, a supersonic impedance bridge and aircraft microphones.

S. Jefferson (£750): Intermediate frequency rejector unit; frequency measurement using IFRU.

Before joining the radio research station, Slough, in 1936, Mr. Jefferson spent five years in industry (Siemens, Murphy and the Gramophone Co.). From Slough he went to Orfordness and Bawdsey. In 1947 he was a technical adviser to Sir Stanley Angwin at the Atlantic City Conference. He went to T.R.E. the same year and was engaged on industrial applications of electronics, and since 1951 has been at A.E.R.E. (Harwell) working on the industrial applications of radio isotopes.

Dr. J. H. Mitchell (£750): Beam techniques; use of spark gaps, etc.; Yagi aerials.

Dr. Mitchell, now controller of research at Ericsson Telephones, Ltd., joined the Air Ministry Scientific Pool in 1936 and after a few months went to Bawdsey research station for work on radar. He returned to the Royal Aircraft Establishment, Farnborough, in 1937 to take part in research on v.h.f. communication and in 1939 took charge of radio aids to navigation. After working on general electronic problems he joined Ericsson Telephones in 1947.

B. Newsam (£750): Crystal-controlled calibrator used on GL1, GL2, GL3 and CD; controlled squegg modulator used on GL1, GL2, CHL and CD; improvements on Pollard's time-base used on GL1 and GL2; "strobe" circuits and gating circuits; "spiral" time-base used on CD; "fine" and "coarse" time-bases used on GL3.

After graduation in 1932, Mr. Newsam was with E.M.I. and Standard Telephones and Cables before joining the staff at the Bawdsey research station in 1938. While with S.T.C. he worked on cathode-ray oscillography, particularly on the time-base circuit now known by its American name of "Bootstrap Circuit" (British Patent No. 493,843). At Bawdsey he developed the equipment which is the subject of the Award, and applied it to army radar during the early years of the war. Later he was in charge of the Group responsible for microwave test gear. Since the war Mr. Newsam has been working on the fundamental Theory of Information.

E. J. Dickie and Dr. B. J. O'Kane (£500 jointly): North-seeking PPI.

As liaison officer between T.R.E. and Bomber Command R.A.F., Wing Commander Dickie participated in the early flight trials of H2S with Dr. O'Kane in 1941. He also assisted in operational trials of "Gee." Since 1946 he has been operations officer at the Ministry of Civil Aviation where he has been associated with the introduction of the "Airways" system.

Dr. O'Kane, who is at present chief engineer of International Aeradio, was in the G.E.C. Research Laboratory, Wembley (1935-40), before transferring to T.R.E., Malvern. He returned to G.E.C in 1945 and joined International Aeradio in 1947.

P. A. Marchant (£250): Aerial switching equipment; computors 60a and 60b.

Although a telecommunications engineer, Mr. Marchant became associated with radar in 1938 as a member of the Post Office sub-committee for air defence communications. From 1939 onwards he was in charge of a small group of design engineers responsible for the provision of telecommunications for radar; control devices for switching power into radar transmitting aerials; plotting, recording and sending equipment; and computors. He is at present a senior executive engineer in the E-in-C's office, G.P.O.

D. A. Weir and P. A. Marchant (£250 jointly): Electrical calculator.

For nine years prior to joining T.R.E. in 1939, Mr. Weir was with the Automatic Telephone & Electric Co. At T.R.E. he was concerned with the development of the electrical calculator, colloquially called the "Fruit Machine." He was also associated with the development of GCI and OBOE. In 1946 he joined Standard Telecommunication Laboratories.

R. V. Whelpton (£250): High-power multi-stage transmitters; mobile radar sets; hand-made CHL stations.

Mr. Whelpton joined the Research Dept. of Metropolitan-Vickers in 1928. While there he worked on the development of the high-voltage c.r. oscillograph and the high-voltage electron microscope. He went to the Air Ministry research station at Orfordness in May, 1936, and to Bawdsey later that year. In 1940 he went to R.A.E., Farnborough, and became deputy head of the Radio Dept. in 1946. He has been assistant director in charge of research and development of airborne and ground radar and radar aids to navigation at the Ministry of Supply's Directorate of Communications Development since 1949.

WORLD OF WIRELESS

Organizational, Industrial and Personal Notes and News

News in Morse

IT is many months since we published a schedule of transmissions of news in Morse in the London Press Service and, as a new timetable was introduced early in February, we give below the revised details. The bulletins, which are radiated by the Post Office stations, are transmitted at 20-27 w.p.m. In addition to the bulletins scheduled there are a large number of Hellschreiber transmissions.

G.M.T.	Call	Freq. (Mc/s)	Area
0015—0230 *w**	GAC	6.945	1
0030—0230 *M*	GAC	6.945	1
0030—0230 *M*	GAD6	7.355	2
0130—0220 *w**	GAD6	7.355	2
0130—0300 *w*	GDC	4.125	3
	GDI	7.780	4
0130—0300 *d*	GCX	8.920	5
0945—1045 *w*	GPF	16.190	6
1100—1200 *w*	GPF	16.190	6
1215—1315 *w*	GPA	20.100	5
	GIA	19.640	7
1600—1700 *w*	GPA	20.100	5
	GDT	8.925	6
1600—1800 *w*	GPT	9.270	7
1815—1930 *d*	GAH	8.065	6
	MLJ	7.447	7
1845—1945 *w*	GDG	6.912	3
	GCX	8.920	4
1945—2215 *w*	GAH	8.065	6
	GDB2	6.795	7
2000—0015 *w*	GIH	10.650	2
2045—2200 *S*	GAH	8.065	6
	GDB2	6.795	7
2100—2200 *w*	GAN	10.805	5
2245—0015 *w*	GAC	6.945	1
2330—0030 *S*	GAN	10.805	5

d daily. *S* Sundays.
M Mondays. *w* weekdays.
*w** weekdays except Mondays.

The number in the fourth column of the table denotes the area to which the transmission is beamed: 1, N. America; 2, S. America; 3, Distant Europe; 4, Middle East; 5, Africa; 6, N.E. Asia, Australia and New Zealand; 7, S.E. Asia.

There is no restriction on the reception and use of these bulletins outside the United Kingdom.

Hospital Radio

"FREE Grid's reference to the deplorable state of the radio installation in many hospitals has prompted a reader to draw our attention to the recent appeal by the *Cambridge Daily News* for funds for new radio equipment for Addenbrooke's Hospital, Cambridge. The scheme, for which £7,000 was subscribed within three weeks, provides for a selection of three or four programmes at each bed, with volume control, selection switch and Pillophone for each patient. The technical adviser to the Appeal Committee is G. E. Middleton, Secretary of the Cambridge Radio Group, I.E.E.

Standard Frequencies

STARTING with the March issue, our associated journal *Wireless Engineer* is publishing regularly the results of measurements made daily by the National Physical Laboratory on the standard frequency transmissions of MSF Rugby on 60 kc/s. Figures for Droitwich, 200 kc/s, are also given. The results are presented in the form of the deviations in "parts in 10^8" from the nominal frequency; the results for January appear in the March issue and so on regularly.

Television Convention

DETAILS of the convention on "The British Contribution to Television," which the I.E.E. is organizing for April 28th to May 3rd, are now available, together with registration forms, from the Institution. The registration fee for non-members is 30s. Sessions covering various aspects of television—from the studio to the viewer—will be held at Savoy Place. In addition, there are to be visits to research and industrial establishments.

Solar Eclipse

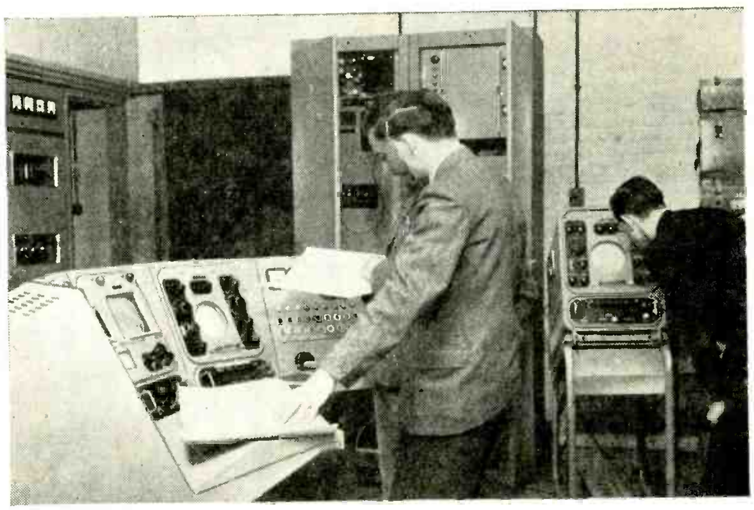
TWO ionospherists have been sent by the D.S.I.R. to sounding stations in the tropics in order to carry out continuous observations over a period including that of the solar eclipse (February 25th). They will use equipment installed by the D.S.I.R. at the University Colleges at Ibadan (Nigeria) and Khartoum (Sudan) for regularly sounding the ionosphere. W. R. Piggott, who is principal scientific officer at Slough, has gone to Ibadan, and C. M. Minnis, a scientific officer at Slough, is in Khartoum.

PERSONALITIES

Sir Edward Appleton, F.R.S., has been elected an Honorary Member of the I.E.E. "for his distinguished work in the field of pure and applied physics and his researches into the characteristics of the ionosphere." Sir Edward, who has been Principal and Vice-Chancellor of Edinburgh University since 1948, was for ten years Secretary (Administrative Head) of D.S.I.R. He was awarded the Nobel physics prize in 1947.

Sir Arthur Fleming, D.Eng., has also been elected an Hon. M.I.E.E. "for his distinguished work in electrical engineering, in particular in the field of technical education." Sir Arthur, who has been with Metropolitan-Vickers and its associated companies since 1902, is a member of the Government Technical Personnel Committee.

J. D. McGee, Ph.D., M.Sc., A.M.I.E.E., a senior scientist with E.M.I. Research Laboratories, has been appointed an Officer of the Order of the British Empire (O.B.E.). Australian born, he graduated B.Sc. in mathematics and physics from Sydney University, where, continuing with physics research, he took his M.Sc. degree (1928) and was awarded the University Medal in Physics. He was also awarded a research scholarship to Clare College, Cambridge, where he worked from 1928-1931 on atomic physics in the Cavendish Laboratory under the late Lord Rutherford. In 1932 he joined



SCOTTISH TELEVISION. Engineers testing the 5-kW Marconi vision transmitter at Kirk O'Shotts preparatory to the opening of the Scottish television service using initially this stand-by equipment on March 14th. Test Card C will be transmitted from 10-12 on weekdays and the London programme at normal times.

E.M.I., where he has worked mainly on the development of Emitron camera tubes.

H. L. Kirke, C.B.E., M.I.E.E., Asst. Chief Engineer, B.B.C., has been elected vice-president of the American Institute of Radio Engineers for 1952. Before joining the B.B.C. in 1924 he was for four years with Marconi's at their experimental station at Writtle, near Chelmsford. Unfortunately, owing to ill health, he has been absent from the B.B.C. for some months.

E. G. Rowe, M.Sc., M.I.E.E., contributor of the article "'Trustworthy' Valves," studied at the City & Guilds Engineering College, where he obtained his degree in engineering. He joined the M.O. Valve Co. in 1933, where, for fifteen years, he was engaged in the design and development of valves, being successively superintendent of receiving valve staff and chief design engineer. In 1948 he went to the Brimar valve division of Standard Telephones & Cables and is now chief engineer.

J. Alan Hutton, who contributes the article "Television Ghosts," graduated from Sheffield University. He subsequently worked in Pye's Research Dept., where he was in charge of the e.h.f. and aerial section. He left in 1949 to join Murphy's Research Dept.

IN BRIEF

Receiving Licences.—Approximately 12,547,700 broadcast receiving licences, including 1,181,200 for television, were current in Great Britain and Northern Ireland at the end of 1951. The increase in television licences during December was 67,300.

R.S.G.B. Officers.—The new president of the R.S.G.B. is F. Charman (G6CJ) and L. Cooper (G5LC) is acting vice-president. Jack Hum (G5UM), editor of *Murphy News*, was elected Hon. Editor. The following were elected members of the committee: C. H. L. Edwards (G8TL), H. A. Bartlett (G5QA), T. L. Herdman (G6HD), P. W. Winsford (G4DC), H. McConnell (GM2ACQ), F. G. Lambeth (G2AIW) and R. Walker (G6QI).

R.C.E.E.A. Council.—At the annual general meeting of the Radio Communication and Electronic Engineering Association the following member firms were re-elected to form the Council. The representative's name is in brackets. B.T.H. (V. M. Roberts), E.M.I. (J. S. Carr), G.E.C. (M. M. Macqueen), Kelvin & Hughes (C. G. White, vice-chairman), Marconi's (F. S. Mockford), Metro-Vick (L. H. J. Phillips), Mullard (T. E. Goldup), Murphy (K. S. Davies, chairman), Plessey (P. D. Canning), Pye (C. O. Stanley), Rediffon (B. St. J. Sadler), and S.T.C. (L. T. Hinton).

Scottish Section of the Brit. I.R.E. is holding a conference and exhibition in Glasgow on March 14th and 15th to mark the opening of the Kirk O' Shotts television transmitter. Papers on many aspects of television will be presented at the conference and a display of receivers, aerials, test gear and other items of television equipment will be provided by manufacturers. Full details of the conference, attendance at which is not limited to members of the Institution, are obtainable from R. H. Garner, 66, Buchanan Drive, Cambuslang, Lanarkshire. Registration fee is 7s 6d.

Technical Writing.—A series of ten lectures on "The Technique of Technical Writing" will be given at Norwood Technical College, Knight's Hill, West Norwood, London, S.E.27, on Tuesday evenings at 7.0, commencing March 18th. The fee for the complete course, which will be given by Geoffrey Parr, former editor of *Electronic Engineering*, is 15s.

Dr. J. D. McGEE
(See "Personalities")

"Microphones."—The price of this new *Wireless World* book by the staff of the Engineering Training Dept., B.B.C., was misquoted in our note in last month's issue. It costs 15s (postage 5d).

MEETINGS

Institution of Electrical Engineers

London Meeting.—"Electronic Telephone Exchanges" by T. H. Flowers, M.B.E., B.Sc., at 5.30 on March 13th.

Radio Section.—"The Slot Aerial and its Application to Aircraft" and "A Survey of External and Suppressed Aircraft Aerials for Use in the High-Frequency Band" by R. H. J. Cary at 5.30 on March 12th.

"Radio-controlled Models" by P. A. Cummins at 5.30 on March 24th.

London Students' Section. — "Industrial Electronics" by R. A. Jones at 7.0 on March 19th.

The above meetings will be held at the I.E.E., Savoy Place, London, W.C.2.

Cambridge Radio Group.—"An Investigation into the Mechanism of Magnetic-Tape Recording" by P. E. Axon, O.B.E., M.Sc., at 8.15 on March 11th at the Cavendish Laboratory, Cambridge.

Mersey & North Wales Centre.—Faraday Lecture on "Sound Recording—Home, Professional, Industrial and Scientific Applications" by G. F. Dutton, Ph.D., B.Sc.(Eng.), at 6.45 on March 17th at the Philharmonic Hall, Liverpool.

North-Eastern Centre.—Faraday Lecture (see above) at 7.0 on March 11th at the City Hall, Newcastle-upon-Tyne.

North Midland Centre.—Faraday Lecture (see above) at 7.0 on March 13th at the Town Hall, Leeds.

Northern Ireland Centre.—Faraday Lecture (see above) at 6.45 on March 20th at the Sir William Whitla Hall, Belfast.

Scottish Centre.—"Instruments for use in the Microwave Band" by A. F. Harvey, D.Phil., B.Sc.(Eng.), at 7.0 on March 5th at the Heriot-Watt College, Edinburgh.

South Midland Radio Group.—"Stereophonic Sound Reproduction" by J. Moir and J. A. Leslie, B.Sc., at 6.0 on March 24th at the James Watt Memorial Institute, Great Charles Street, Birmingham.

Irish Branch. — "Modulation — Some Fundamental Considerations" by T. P. Allen, M.Sc., at 6.0 on March 20th at Trinity College, Dublin.

Norwich District.—"The Nervous System as a Communication Network" by J. A. V. Bates, M.A., M.B., B.Chir., at 7.30 on March 31st at the Royal Hotel, Norwich.

British Institution of Radio Engineers

London Section.—"The Application of Magnetic Amplifiers to Industrial Measurement and Control" by H. M. Gale, B.Sc., at 6.30 on March 27th at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

South Midlands Section.—Above paper, by H. M. Gale, B.Sc., at 7.15 on March 19th at the Exhibition Gallery, Public Library, Rugby.

Scottish Section.—"Radar as an Aid to Navigation" by N. J. Donald, B.Sc., at 7.0 on March 13th at the Natural Philosophy Department, The University, Edinburgh.

"The Future of Broadcasting," by Paul Adorian, at 7.0 on March 14th at the Institute of Engineers and Shipbuilders, Glasgow.

British Sound Recording Association

London.—"Recording Characteristics" by P. E. A. R. Terry at 7.0 on March 14th at the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.

Portsmouth Centre.—"Crystal Pick-up Devices" by S. Kelly at 7.30 on March 6th at the Central Library, Guildhall Square, Portsmouth.

Television Society

London.—Fleming Memorial Lecture by Prof. H. M. Barlow, Ph.D. (University College) at 6.30 on March 20th at University College, Gower Street, London, W.C.1.

"Some Mechanisms of Signal Generation in Stage-type Television Camera Tubes," by Dr. R. Theile (Pye, Ltd.), at 7.0 on March 28th at the Cinematograph Exhibitors' Association, 164, Shaftesbury Avenue, London, W.C.2.

Leicester Centre.—"The Design and Application of Television Gear" by R. Freeman and E. D. Groom (Waveforms, Ltd.) at 7.0 on March 31st at the Leicester College of Technology, The Newarkes, Leicester.

Institution of Electronics

North Western Branch—"Electro-encephalography" by W. Heaton, B.Sc. (Ferranti) at 7.0 on March 19th at the College of Technology, Manchester.

Radio Society of Great Britain

"Microphone Acoustics for the Radio Amateur" by H. A. M. Clark (G6OT) at 6.30 on March 28th at the I.E.E., Savoy Place, London, W.C.2.

Institute of Practical Radio Engineers

Thames Valley Branch.—"The Alignment of Television Receivers" by M. Molem (Cossor) at 8.0 on March 4th at the Wheatsheaf Hotel, Kingston Market Place, Kingston-on-Thames, Surrey.

LETTERS TO THE EDITOR

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

I.F. Interference

WHILE in full agreement with Richard Donald, G3DJD (February), I do not think he goes far enough. The transmitting amateur operates within the framework of national and international law, and so long as he emits no energy on frequencies outside amateur bands recognized by his licensing administration, he is then surely as authentically licensed as Holme Moss!

If this is so (and surely it is his moral right, or why take his licence money?), we should not have to plead with designers and constructors to choose their i.f. They would simply have to "carry their own can back" if they didn't.

Where a dealer, maybe a self-styled "expert" with a pitiable lack of technical knowledge, sells a set to a purchaser who will take his word rather than that of an amateur (simply because the semi-literate confuse the words "amateur" and "novice"), then the can is surely for one of these to carry and is not the concern of the transmitting amateur, whose knowledge of radio technology sometimes far exceeds that of the dealer!

Some time ago I asked the G.P.O. engineers to check a complaint of television interference from my transmitter. They handled the matter admirably, but the viewer was amazed to learn his unselective receiver was the cause. His dealer had told him to *expect* interference caused by me! The fault is blamed on the amateur always by the public and often by the dealer, who finds it a Heaven-sent "alibi" for all kinds of troubles.

It is noteworthy that the G.P.O. require greater harmonic suppression from amateurs than the international regulations require from government and commercial stations.

We ought to be upheld by all concerned in taking the stand that if no emission takes place outside the licensed frequency limits, we are beyond reproach. By all means let my neighbours buy or build sets which stand up and beg for interference, but why should I have to concern myself about it, after I have spent a good deal of time and money to ensure that I am abiding by the regulations in my licence?

H. S. CHADWICK, G8ON.

Short Weight in Energy?

"CATHODE RAY," in his article on "Energy" (January issue), touches a sore point when he states "The electrical people might assume that their pressure was, on the average, constant, too, and install meters taking account of current and time only, but fortunately for us in these days, when the variations are always downward, they don't."

He misses one class of electricity consumer out; i.e., those like myself connected to a d.c. supply with meters taking account of current and time only. Mine records energy supplied based on the assumption of a constant voltage of 240 volts. I have on several occasions measured my supply voltage and it is, on the average, between 210 and 220 volts. I have only known it to rise to 240 volts at about midnight, when all the other consumers are in bed.

It would be interesting to know whether the B.E.A. are prepared to reimburse such electricity consumers as myself for electricity recorded but not actually consumed.

S. YARROW.

London, N.16.

Avoiding Hum in Pickup Transformers

I HAVE found the following tip useful in avoiding hum pick-up in the coupling transformer of a low-impedance gramophone pickup. If the first a.f. valve has a top-cap grid the transformer can be conveniently mounted on the top of the valve screening can. This gives a short grid lead and direct earthing through the can and at least one degree of freedom in rotating the transformer to find zero hum.

Thornton Heath, Surrey. S. HEATH.

Critique of Colour Coding

I KNOW, from the fact that statistics state that one male in every six suffers from colour blindness, that I can expect at least 17 per cent of your readers to agree with the contents of this letter.

How pleasant it is to handle a piece of radio equipment made on the Continent and find that all the small components are plainly marked with values and tolerances! No wondering whether a dot or a band is yellow or orange, brown or red or even green!

As for the use of such colours as blue and violet, well, I have even heard women, who do not normally suffer from colour blindness arguing about these.

I believe that a case cannot be made out to justify the continued use of colour coding. If it is claimed that it is cheaper to code than print, I should like to know how much is involved, for I find it difficult to believe that all the manufacturers in the world who print the values are functioning uneconomically. I contend that when a resistor is old and charred it is easier to read a printed number, especially if this appears in more than one place on the body, than to determine whether a spot is, say, yellow or orange.

Now, in case I am accused of being entirely destructive and having nothing new to offer, I should like to propose for the consideration of your readers and the resistor manufacturers a scheme which, to my mind, embodies the advantages of the two aforementioned methods.

Resistors should be body-colour coded in groups as follows:—

0—100Ω	black
101—1,000Ω	red
1,001—10kΩ	yellow
10,001—100kΩ	green
100,001—1MΩ	blue
1,000,001—∞	white

The depth of colouring to be so chosen that the higher-value groups should reflect more light than the lower ones, thus enabling a completely colour-blind person to assess the group to which a component belongs, i.e., dark red and light blue should be used in all cases.

Tolerance (for 10% and better).—Gold, silver, etc., tips.

Wattage (necessary because with the new high-rating resistors it is impossible to assess their durability by examination).—Designated by a number of bands of any colour distinctive to base. I suggest for black bodies use white and for all other colours use black.

1 watt	1 band
½ ,, ...	2 bands
¼ ,, ...	3 ,,
⅛ ,, ...	4 ,,

Lower wattages not coded. Higher wattages plainly marked.

The value printing should be impressed at 90 deg intervals around the resistor and be at one or both ends (heat is less at the ends). For smaller resistors, which are normally used in "powerless" circuits, values could be printed centrally. Very small resistors would probably have to be colour-coded as at present.

Capacitors might also be colour-coded in groups as already mentioned, with the addition of the value, tolerance, etc., printed on *both* sides if of flat construction. D.C. working voltage might be spot- or band-coded.

L. G. WOOLLETT.

Petts Wood, Kent.

LOCATING TELEVISION PIRATES

Post Office Detection System

IN its new campaign against unlicensed television viewers, the General Post Office is employing vans fitted with apparatus which can detect any ordinary television set in operation within a radius of about 100ft. The van carries three horizontal loop aerials on its roof; they are fitted one at the front and two at the rear at the three corners of an "L."

By means of a switch a sensitive receiver can be connected to any one of the aerials and the receiver output operates a meter and a loudspeaker.

A normal television receiver, using electromagnetic deflection, necessarily produces a strong magnetic field varying at line and frame scanning frequencies. It is impracticable to confine this entirely within the receiver, but it falls off quite rapidly as the distance from it increases.

In the detection equipment it is the line-scanning field which is utilized and the receiver is tuned to the second harmonic, 20.25 kc/s.

In operation the receiver is normally connected to the front aerial and the van cruises until a signal is heard. The van then slows up and the receiver is switched backwards and forwards between the front aerial and the rear one immediately behind it. The aerial nearer the television set gives the stronger signal and the signals from the two only reach equality when the bisector of the line joining the aerials passes through the television set. When they are equal the van is stopped. It is then known that the television set is in a house alongside the van.

To determine on which side of the road this house is the receiver is switched to the third aerial, and since this must be either nearer to or farther from the television set it immediately reveals the side of the van on which the set lies by an increase or decrease of signal. Reference to a list of licence-holders then shows whether or not the television set which has been detected is being used legitimately or by a pirate.

The apparatus is claimed to be capable of locating the position of a television set when the van is within 100ft of it. In addition to its primary object of locating pirates the van has an obvious secondary use in that in a rapid cruise round a given area it would be possible quite quickly to determine how many television sets were in use at a given time. By comparing this figure with the known number of television sets obtained from the records of licence-holders, the percentage of viewers using their sets at a given time could be obtained. This information would presumably be of value to the B.B.C. as evidence of viewers' reaction to programmes. This use is perhaps one to which the vans will be put when they have fulfilled their primary job, and there are no more pirates for them to detect.

The fact that television sets provide a field which makes them so easily detectable may serve to bring home to users the possibilities of their interfering with other broadcast receivers. The second harmonic of the line-scanning frequency is used for their detection, but the twentieth harmonic is quite strong near the set, and its frequency is very close indeed to that of Droitwich. It is quite strong enough for serious interference with a broadcast receiver on the other side of a party wall.

This was pointed out in *Wireless World** some time ago. In fact, broadcast interference is probably more usually due to the electric field than the magnetic and set makers minimize it by screening. Sometimes the line-scanning circuits are enclosed in a metal box and quite often the inside of the cabinet is "painted" with colloidal graphite to form a screen. Such screening is relatively ineffective on the magnetic field, and in any case complete screening of a television set is impossible until someone invents a transparent material which is also a good conductor. One must be able to see the tube face!

The fact that a television set gives away its presence and so enables pirates to be traced thus cannot be regarded as an entirely unmixed blessing by law-abiding citizens. The very fact that it does so means that it is liable to interfere with nearby broadcast listeners. If it were possible completely to remove this possibility of interference, then the possibility of detecting pirates would also vanish.

This is a unique case in which the Post Office might well be tempted to aim at less than perfection in the suppression of interference!

View of the van showing the three aerials.

* "Interference from Television Receivers," by M. G. Scroggie, *Wireless World*, April 1950, p. 126.

"Trustworthy" Valves

Greater Reliability Achieved by Improved Mechanical Design

By E. G. ROWE,* M.Sc., A.C.G.I., D.I.C.

MANUFACTURE of valves for domestic receivers is controlled primarily by the need to produce them at minimum cost, and despite this limitation it has been possible to maintain a low failure rate during the normal life of sets. This fact was particularly noticeable during the war, when it was clear that even with the most antiquated receivers valve troubles were much less frequent than those of other components. However, the rapid increase in the number of television sets, with their average complement of twenty valves against the sound receiver's five, has revealed that the failure risk can be embarrassing, and so manufacturers have been steadily improving their quality within the close confines set by economics.

The fact that valves in domestic receivers have a very long life is partly because the mechanical shocks to which they are subjected are very mild. Over the last fifteen years, however, there has been a growing enthusiasm for electronics in the industrial field, and here the conditions of operation are more severe. The military uses of radio received a strong impetus during the war and we have now reached a point where the whole tactics of attack and defence are greatly dependent on the electronic equipment used. Moreover, since the war many of the devices developed for destruction have been adapted to peacetime uses and the safety of the traveller now depends very much on them.

The use of valves in industrial applications is, of course, a very different matter from their use in domestic receivers. Industrial use frequently involves conditions of extreme vibration and shock, extreme ranges of temperature and humidity and so on. Further, the failure of a valve in a domestic receiver simply means that one loses a certain amount of pleasure until the valve is replaced, whereas in industry a valve failure can cause a catastrophe with serious loss of life, while in war it may perhaps result in defeat in a vital conflict.

The unsuitability of the ordinary radio valve for such vital applications becomes very obvious, and while the valve-maker has been very much aware of this, the great expense of a programme of reliable valve development has been prohibitive, except for types used in certain specialized equipment such as deep-sea repeater cables.

In this article the name "Trustworthy" is used to describe a type of valve that is perhaps more generally known as "reliable". In America, the term "ruggedized" has much the same meaning. "Reliable" valves are generally improved (and more costly) versions of existing commercial types; the electrical characteristics are kept the same but the mechanical structure is redesigned to give a better performance under conditions of vibration and shock. Moreover, the description "reliable" usually denotes a very definite standard of reliability. This is expressed in terms of the percentage of failures in a batch of samples tested over a certain time (usually 1,000 hours), and is generally less than one per cent. Reliability does not necessarily *mean long life, although in practice it often does. The valves in a guided missile, for example, must have extremely good reliability for the short while they are in existence but there is obviously no requirement for long operating life.*

An engineer interested in the subject of "reliable" valves very quickly realizes that any attempt to give an accurate definition of reliability depends very much on the application in which the valve is used. For example, a valve may be considered reliable if it operates for a long time in a normal circuit without giving trouble; alternatively, its reliability may necessitate that it performs with negligible changes in certain essential parameters throughout life. Again, another user would consider reliability attained if he could have a guaranteed short term of life without early failures, whilst still another would be satisfied with an extremely short guaranteed operational life following immediately after an undefined shelf life. Finally, there is the well-known requirement for trouble-free performance under conditions of extreme vibration and/or shock.

One of the best general definitions is that a "reliable" valve is characterized by having a very high probability that it will operate normally when taken from stock and installed in equipment for which it was intended, and an extremely low probability that it will fail during subsequent operation in that equipment for some definite period of time.

It is quite possible to make "reliable" valves that will achieve any or all of the above requirements, but this article is concerned only with valves to be manufactured in large quantities and required to operate reliably up to one or two thousand hours, under conditions where extremes of ambient temperature may be encountered, either in storage or in operation, and where the valve and equipment may be subject to considerable mechanical shock or vibration. To be still more specific, the immediate objective is to achieve valve types having characteristics corresponding to existing designs but with a failure risk of the order of 1 per cent in 1,000 hours.

The subject of valve reliability has been exhaustively investigated in the United States, where various military and civil authorities have quoted the valve as being responsible for more than 50 per cent of the equipment breakdowns. An analysis was

* Brimar Valve Division, Standard Telephones & Cables Ltd.

Some of the information in this article has been taken from a paper by the same author in the November, 1951, issue of the *Journal of The British Institute of Radio Engineers.*

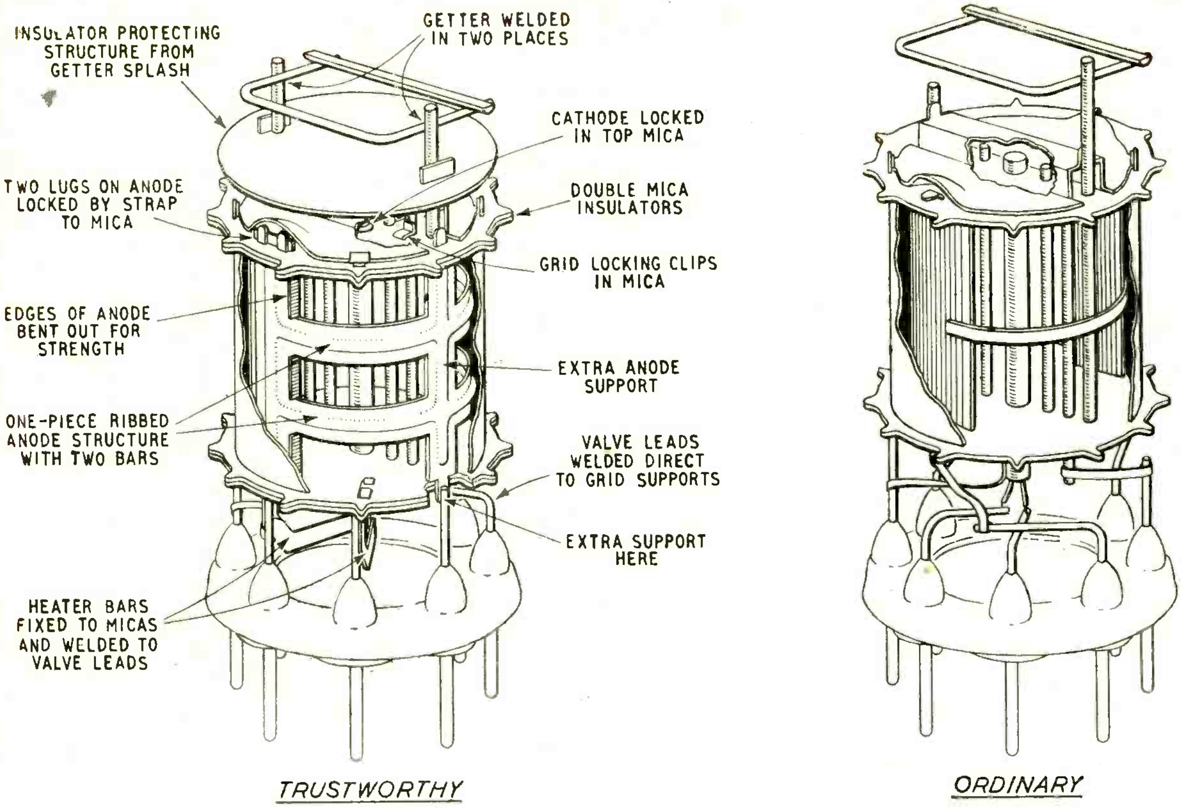
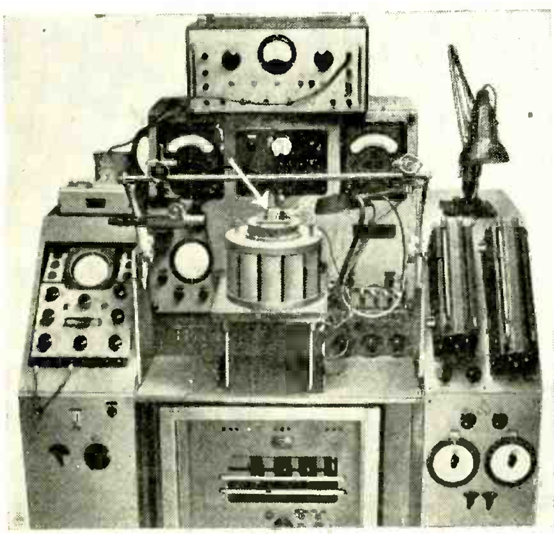


Fig. 1. Showing some of the ways in which the "Trustworthy" valve differs from its "ordinary" counterpart. This does not represent any particular valve type but is merely a general illustration of the technique.

Fig. 2. Equipment for studying valve noise caused by vibration. The valve (indicated by arrow), working under Class A conditions, is mounted on a moving-coil vibrator and its output is displayed on the oscilloscope. A small calibrating signal is applied to the grid so that the noise level can be measured against it. The equipment has a telescope and stroboscopic lamp to enable a vibrating part to be studied when it is in resonance.



made of valve failures in civil aviation and the information obtained was used to improve the design of the particular types concerned. It is claimed that they are now at least 10 times as reliable as they were. Work in this country has been centred on valve types in the Services Preferred List and mainly on miniatures and sub-miniatures. The author's company has concentrated on miniatures and novals.

A valve is basically a mechanical structure having electrical properties that must be maintained throughout its life. Because it is built up from metal, mica and glass, it is subject to the failures common to all structures made of these materials, such as breakage, distortion, loosening of component parts, etc. In addition, mechanical weaknesses can directly affect electrical and chemical properties.

Complete analysis of many large groups of standard commercial valves returned as failures from operational equipment has shown that the faults occurring are as follows:—

(a) Electrical failures such as noise, instability.
(b) Mechanical failures of the assembly giving short-circuits and open-circuited elements.
(c) Mechanical failures of the heater structure.
(d) Glass faults.

Group (a) is caused by vibration and is a preliminary to group (b), so there are really three main sources of trouble: mechanical faults, often aggravated by vibration; heater faults; and glass faults.

It was fairly obvious that re-design efforts had to be directed towards shorter and more rigid structures that would be more stable under vibration, and what has been done can be seen from Fig. 1. The modified structures have the following main features:—

(a) Tight mica holes for the grids and double micas of optimum thickness.

(b) Locking straps in the micas to hold the grids.
(c) Locking of the bottom insulator to the stem in as many positions as possible.
(d) Straps welded across the anode lugs to lock the anodes into the micas.
(e) General changes giving greater strength to the anodes and improved location and fixing methods.
(f) Shorter valve mount made possible by increased-diameter cathodes.
(g) Minimum number of welds throughout the structure.

By applying many of these modifications it is possible to reduce the valve noise due to vibration to a very low general level as shown in Fig. 3, although there are still a few sharp peaks in the region above 1,000 c/s. These latter resonances are in general much lower in height than those of the original valve but usually occur at the same frequencies, indicating that they are fundamental resonances of components and can only be removed by a complete change of design technique. As the immediate aim is to produce valves of similar electrical properties (including capacitances) to an existing range, complete re-design is generally out of the question.

Heater failures resulting in open-circuits and short-circuits have been due to three causes:

(a) Excessive core temperature.
(b) Movement of the heater inside the cathode under vibration conditions and consequent damage to the heater coating at the cathode ends.
(c) Incipient fracturing of the core wire at any sharp bends.

While the operating temperature was satisfactory for normal receiving valves, it was thought advisable to reduce it for the "Trustworthy" types by the use of thicker core wires. This necessitated a longer length of heater wire, which meant extra loops, giving a tighter fit into the cathode. The improvement was not as much as was expected, as the heaters still had sharp bends that led to breakage, so the reverse helical heater has now been adopted, permitting the use of a large wire size and having no sharp bends to cause incipient failure. This design of heater is now being used for most of the "Trustworthy" valves and it has been found that the core temperature can be kept down to a safe figure. The heater is flexible with no sharp bends, and it fits the round cathode sleeves exceedingly well and is easy to insert into the cathode without damage to itself.

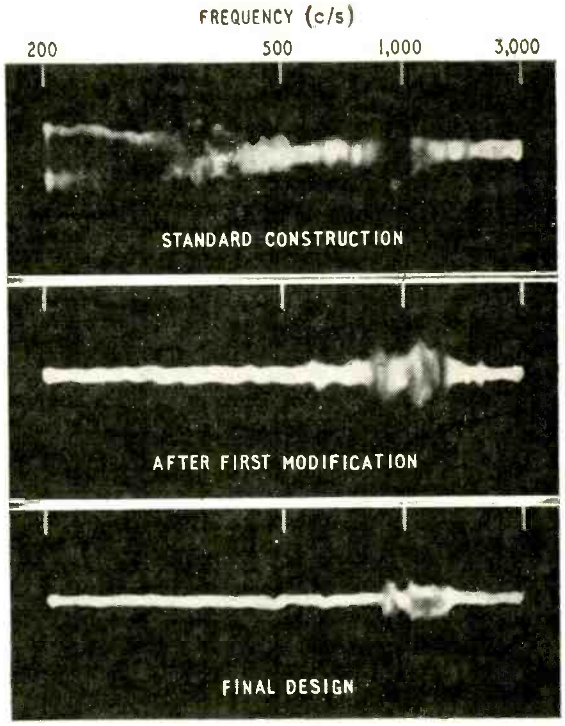


Fig. 3. Records from the vibration test equipment in Fig. 2, showing the noise output from a "Trustworthy" valve at three stages in its development. The peaks at the higher frequencies are mechanical resonances in the grid and cathode, while the general noise level at the low-frequency end is caused by looseness of the structure.

List of "Trustworthy" Valves and their "ordinary" Counterparts

"Trustworthy" Type	Commercial Equivalent	Description
13D2	6SN7GT	Double triode
5749	6BA6	Variable-mu r.f. pentode
5750	6BE6	Heptode frequency changer
6042	25SN7GT	Double triode
6057	12AX7	Double triode
6058	6AL5	Double diode, separate cathodes
6059	6BR7	Low-noise amplifier, pentode
6060	12AT7	High-slope double triode
6061	6BW6	Output pentode, 6V6 characteristics
6062	5763	R.F. amplifier, pentode
6063	6X4	Full-wave rectifier
6064	8D3	High-slope r.f. pentode
6065	9D6	Variable-mu r.f. pentode
6066	6AT6	Double-diode triode
6067	12AU7	Double triode
6132	6CH6	Video output pentode
6157	R17	Half-wave rectifier
6158	13D3	Double triode

A further design feature was the use of heater bars that lock into the bottom mica and project below the cathode (see Fig. 1). The heater can then be inserted into the sub-assembly and welded to the heater bars before the sub-assembly is mounted on the glass base and the working space is restricted. Thus we have ensured good heater welds which can be adequately inspected before the final mount is put on to the stem. Furthermore, the stem wires can be welded to the thick heater bars near the mica periphery, giving valuable support to the lower mica and at the same time enabling this weld to be performed away from the congested inner section of the mount.

For the glasswork of "Trustworthy" valves the usual methods are still employed, but the controls are very much tighter, with rigid rejection limits and complete batch rejection if the limits are exceeded. As an envelope material, glass has the advantage of transparency, chemical inertness, electrical insulation, hardness and the ability to be welded by flame heating, but it is a brittle rather than a tough material and therefore requires a considerable number of refinements in technique to ensure freedom from cracking in service.

Glass is strong in compression and relatively weak

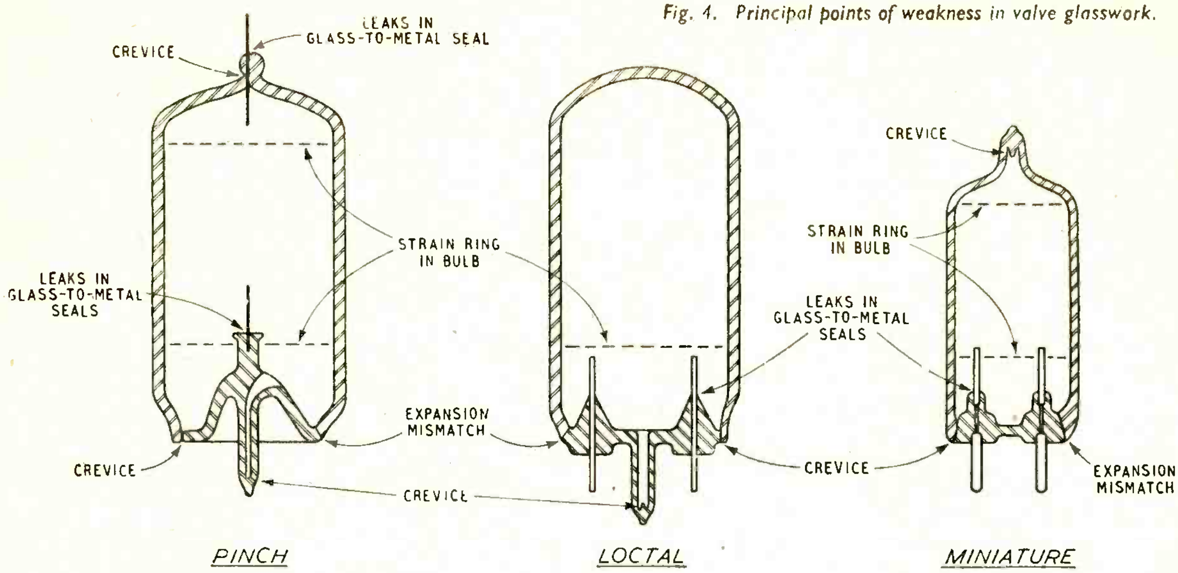


Fig. 4. Principal points of weakness in valve glasswork.

in tension, and small surface scratches and any crevices are likely to become cracks under quite small stresses. In addition, residual stresses can lead to ultimate failure of glass structures; the two best known are "mis-match stress" arising from the differential contraction of two glasses welded together and "thermal strain" due to the differential contraction of glass near to a weld relative to the glass farther away from the weld. There are also the problems of glass-to-metal seals that are an inevitable consequence of leading metal conductors through the glass. Fig. 4 shows some of the weak points which have to be carefully watched.

During the process of manufacture the valves undergo very stringent testing. There are two main groups of tests. Those in the first group are to ensure that the valves are uniform and line up with the design specification and these tests are applied to every valve that comes off the production line. They include inspection of the mounts and glasswork, a thermal shock test, short-circuit tests, a heater test, tests for characteristics and a 10-hour life run under Class A conditions. The tests in the second group are made on samples at various stages in manufacture and ensure that the original quality is being maintained. They are largely mechanical and include vibration tests, a resonance test, a shock test and a fatigue test, with a 2,000-hour life test at the end.

In conclusion, evidence so far obtained shows that early-life failures, which are the cause of most of the heartburnings, are due almost entirely to mechanical and glass troubles. If these are eliminated by attention to design and manufacturing methods, together with a short life run, there is a great hope that for at least 1,000 hours the failures will be negligible.

It is a hazardous thing to prophesy, but within five years the reliability of the valve can be such that the present criticisms will then be directed towards other components. As reliability work must inevitably take considerable time, adequate pressure should be maintained on manufacturers of other components to ensure that all the constituent parts of an equipment keep in step.

CLUB NEWS

Bath.—We are asked by the new secretary of the Admiralty Electronics Society, G3BPU, to announce that, whilst membership of the society is primarily for civilian and service members of the Admiralty, members of other Government Departments are admitted at the discretion of the Committee. Workshop facilities are available, including test equipment, at the headquarters, Electrical Engineering Dept., Admiralty, Bath. Sec.: W. J. Green, G3FBA, Room 110A, Block "A," Admiralty Offices, Bath.

Cleckheaton.—F. E. Henderson of the General Electric Company will speak on "The Development and Application of the Germanium Crystal Valve" at the meeting of the Spen Valley Radio & Television Society on March 26th at 7.30 at the Temperance Hall, Cleckheaton. Sec.: N. Pride, 100, Raikes Lane, Birstall, Nr. Leeds.

Coventry.—At the March meetings of the Coventry Amateur Radio Society W. Grimbaldeston, G6WH, will speak on "Frequency Modulation" (3rd) and L. W. Gardner, G5GR, "25 Years of Amateur Radio" (17th). Meetings are held at 7.30 on alternate Mondays at the Y.W.C.A., Queen's Road, Coventry. Sec.: K. G. Lines, G3FOH, 142, Shorncliffe Road, Coventry.

Downham.—Meetings of the radio class run in conjunction with the Downham Men's Institute, are held on Wednesdays at 8.0 at Durham Hill School, Downham, Kent. The class is linked with the Ravensbourne Amateur Radio Club (G3HEV) of which W. H. F. Wilshaw, 4, Station Road, Bromley, Kent, is secretary.

Exeter.—The meeting of the Exeter Radio and Television Club on March 13th, at which P. W. Crouch (Post Office) will talk on "Broadcast Interference," will be open to the public. The club meets each Thursday at 7.30 at the Hobbies Association Hut, Haldon Road, Exeter. Sec.: L. R. Jenkin, 16, South Avenue, Exeter.

Manchester.—The South Manchester Radio Club (G3FVA) has acquired new premises at Ladybarn House, Mauldeth Road, Manchester, 14, where meetings are held on alternate Fridays at 7.30. Sec.: F. H. Hudson, 21, Ashbourne Road, Stretford, Manchester.

Speech Reinforcement in St. Paul's Cathedral

(*Concluded from page 57 of the previous issue*)

Details of the Equipment and Results of Tests

By P. H. PARKIN,* B.Sc., A.M.I.E.E., and P. H. TAYLOR,† A.M.I.E.E.

WE have so far been concerned mainly with the directionality in the vertical plane, but directionality in the horizontal plane may also be desirable. For example, the columns to be used in the dome area of St. Paul's were required to cover a horizontal area in front of them of about 60 degrees on either side of the axis; but radiation to the back was not required and would only have decreased α and increased β in equation (3) of the previous issue.

Kalusche[6] has described two arrangements for obtaining directionality in the horizontal plane, one of which will be briefly described here. Consider a loudspeaker mounted in an "open-backed" baffle of cross-section as shown in Fig. 5(a), employing a certain quantity of packing material. At the front of the loudspeaker there is a pressure p_f, emitted directly, plus a pressure p_b from the back of the loudspeaker which has been diffracted round the baffle. At a given frequency, the vector diagram, Fig. 5(b), illustrates the behaviour; p_b is 180 degrees behind p_f, but is additionally delayed by an angle corresponding to the the path length from back to front, l, and also by an angle corresponding to the time taken, A, to pass through the packing material, the velocity of sound in which is lower than in air. Fig. 5(c) illustrates the behaviour at the back of the loudspeaker; the pressure p_f' from the front is delayed by an angle corresponding to the path difference l and the pressure p_b' from the back, already 180 degrees out of phase with the front, is in addition delayed by an angle corresponding to A. If A is adjusted so that these two angles are the same, then the resultant pressure R is zero providing the intensities of p_f' and p_b' are equal.

If for the packing we use a material in which the velocity of sound is independent of frequency, then the angle corresponding to A can be equal to l at all frequencies. Now at a certain low frequency the attenuation through the packing material can be such that p_b' is attenuated as much as p_f' is attenuated by diffraction. With increasing frequency, p_f' is more attenuated by diffraction and thus the material must have an attenuation which increases with frequency at the same rate; the resultant pressure at the back will then always be zero.

In the front of the loudspeaker at this certain low frequency, p_b will be attenuated by diffraction and by passage through the material; the resultant pressure is given by R in Fig. 5(b). As the frequency increases, the angle corresponding to l plus A increases so that p_b is coming closer in phase to p_f, and R increases; eventually p_b would be more than 360 degrees behind p_f and R would begin to decrease. However, the intensity of p_b is being decreased by diffraction and by attenuation through the material, so that in practice p_b becomes negligible compared with p_f before this stage is reached.

Kalusche describes a design of this type using "packwatte" (which appears to be cotton waste) as the material; at 200 c/s the emission to the back is about 20 db lower than that to the front.

The requirements for the loudspeaker columns for the dome area of St. Paul's have been discussed above in general terms. The length of the low-frequency section was required to be 11 feet; eleven 10-inch (nominal) loudspeakers were mounted as closely together as possible in a cabinet. The high-frequency section (2ft 9in long) was made up of nine 3½-in loudspeakers; the cross-over network was a half-section operating at 1,000 c/s. Each section of the column was tapered in intensity from the centre toward each end by inserting T-attenuators between each loudspeaker and a load resistance equal to the nominal impedance of the speaker; in this way all the speakers in each section could be connected in series, thus providing a convenient impedance for the cross-over network while keeping reasonable damping across each speaker. The back of the cabinet was left open, and cotton waste was used for the attenuation material. Accurate free-field measurements on this column were

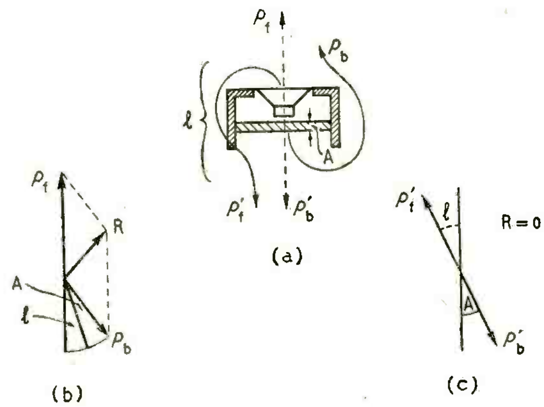


Fig. 5. Principle of directionality in the horizontal plane.

* Building Research Station, Department of Scientific and Industrial Research.

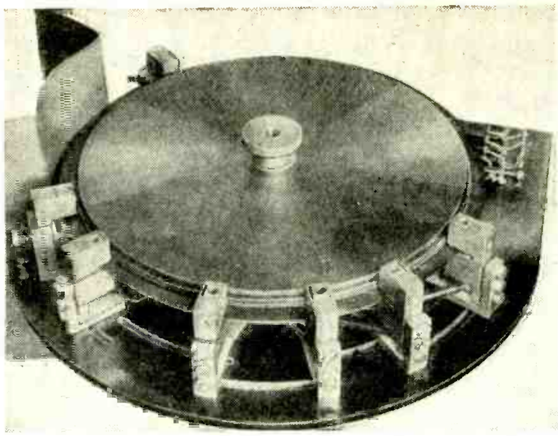
† Pamphonic Reproducers, Ltd.

6 Kalusche, H., *Zeitschrift für Angewandte Physik*, 1950, 2, (10) pp. 411-415. (Available in English from Building Research Station as Library Communication No. 565.)

not possible as it was too big for an echo-free chamber, but some approximate measurements made in the open air, although confused to a certain extent by reflections, did indicate that the directional characteristics in the vertical plane had been realized (Fig. 6).

The frequency response on the axis measured at 30-ft distances showed that the output of the $3\frac{1}{2}$-in loudspeakers was on the average 3 db lower than the 10-in loudspeakers. A 3-db attenuator in the low-frequency section equalized the response. (The gain factor, k, of a line source, defined as the ratio of the sound pressure of the line source on the axis to the sound pressure of a single radiator of the same power,[4] is given by $k=0.73\sqrt{f\,l}$, where f is in kc/s and l is in feet. This formula predicts a frequency response rising 3 db per octave for a given value of l. No such rise was noticed in the measured frequency characteristic, but this may have been because each section of the column covered only two octaves and because the output from the individual loudspeakers may have been falling.)

The speech in the nave area was reinforced using loudspeaker columns mounted on the sides of piers away from the pulpit (Fig. 1). Their design followed the general principles outlined above, but as they each had a much shorter distance to cover (about 35ft) it was not necessary to make them as long as the dome columns. A length of 6ft appeared to be the best compromise between height above ear level and directionality; their low-frequency sections reached the permissible limit of directionality at about 1,400 c/s and the cross-over was therefore designed for this frequency. The length of the high-frequency section was about 2ft. It was thought that the size of the piers



Time delay mechanism for the nave loudspeaker columns, using a disc of magnetic recording material and adjustable playback heads.

they were mounted on provided sufficient directionality in the horizontal plane, so the directional arrangement using cotton waste backing was not employed.

Time Delays.—A previous article[7] has described the use of time delays to preserve realism, and this technique was employed in the Cathedral. The first pair of nave loudspeaker columns (Fig. 1) was delayed by a time interval corresponding to the path difference between the pulpit column and the nave columns, plus 5 msec. The second and third pairs were delayed correspondingly, but plus 10 msec and 15 msec respectively. The amplitude of these nave columns was also reduced, and the Haas effect ensured that all the sound appeared to be coming from the pulpit.

The time delay mechanism consisted of a turntable carrying an 11-inch diameter disc of plastic magnetic recording material. This disc extended beyond the periphery of the turntable[8] and provided an annulus supported only at its inner radius. Recording, playback and erase heads were mounted on the deck of the unit in such a way that the underside of the annulus was in contact with the pole pieces of the heads. Small felted weights carried in slides over each head maintained contact between the annulus and the pole pieces.

The recording head was permanently fixed and the playback heads were attached to radius arms which allowed them to be moved and clamped at any position on the circumference of the annulus. A graduated scale, marked off in feet and milliseconds, facilitated the setting-up of the heads to give the required delay times. The maximum overall delay obtainable on this unit corresponded to a distance of 200 yards, the peripheral speed of the annulus being 30in per second. The

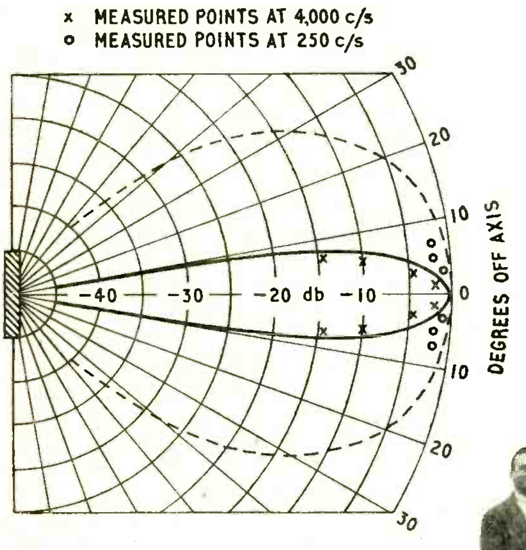
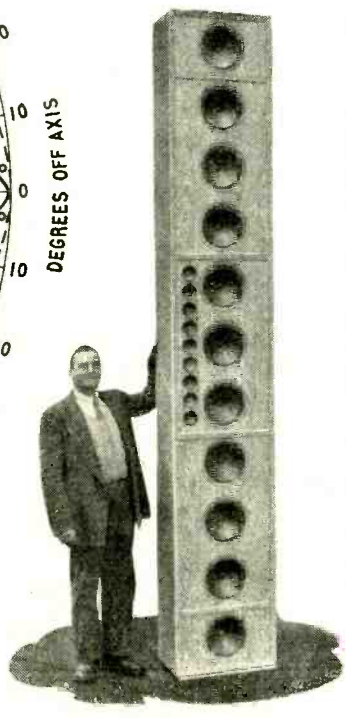


Fig. 6. Directionality in the vertical plane of 11-ft column. The full line is for 1,000 c/s in the l.f. section and 4,000 c/s in the h.f. section; dotted line, 250 c/s in l.f. section and 1,000 c/s in h.f. section.



Loudspeaker column for the dome area of St. Paul's consisting of eleven 10-inch (nominal) units for low frequencies and nine $3\frac{1}{2}$-in high-frequency units. The cross-over filter is centred at 1,000 c/s.

[4] Meyer, E., Building Research Congress Report, 1951, Division 3, Part 1, pp. 43-48.

[7] Parkin, P. H., and Scholes, W. E., "Recent Developments in Speech Reinforcement Systems," *Wireless World*, 1951, 57, (2), pp. 44-50.

[8] Patent Application (Pamphonic Reproducers, Ltd.), No. 22237/1951.

minimum delay between adjacent playback heads corresponded to a distance of 20ft.

Erasure of the recorded sound took place at each revolution of the turntable just in advance of the recording head. In an installation of this sort it is essential to guard against failure of the erasing mechanism; should this happen the recorded sound is continually repeated from the loudspeakers. To cover such an eventuality, the recording was first erased by permanent magnets and then again by a supersonic head. Although the permanent magnets removed the recorded sound the residual noise level was high, and this was removed by the supersonic head.

The recording and playback amplifiers were conventional in design. The main power amplifiers were standard 25-watt public address amplifiers feeding the loudspeaker columns at 100 volts.

Power Requirements.—The tapered columns as designed for St. Paul's are inefficient electrically since nearly all of the acoustic power is radiated from the centre loudspeakers while the electrical power is distributed equally between all the loudspeakers. This could be avoided in a final design, e.g., by use of a tapped transformer, but the loss of power is not important when, as in St. Paul's, the columns are used for speech only and the total acoustic power required is only of the order of milliwatts.

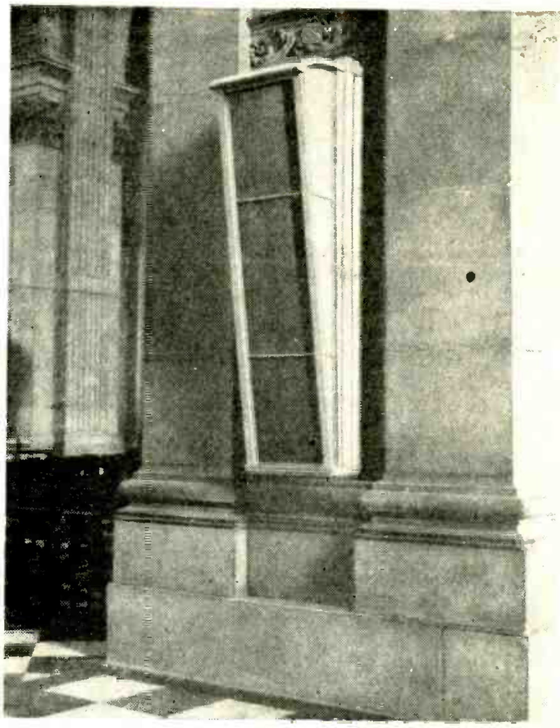
However, another important use of this type of loudspeaker arrangement is to cover large numbers of people, as, for example, at sport stadiums; in these cases the acoustic power required may be considerable, particularly when music has also to be amplified. The loss of electrical power must then be avoided, and in any case it is probably better to use a uniform line source; the secondary lobes are still small compared with the main lobe, and the directivity of the line source results in a saving of power. Thus the gain factor, $k=0.73\sqrt{fl}$ for an 11-ft column at 1,000 c/s is 8.03, or 18 db. Meyer[1] quotes the example of a 3-metre column with a total electrical power of 75 watts, producing a sound pressure level of +94 db relative to 0.0002-dynes/cm^2 at a distance of 100 metres.

At the time of writing several details of the St. Paul's installation remain to be settled, but they concern this particular installation only and are not of general interest. For example, there is a requirement for speech at the altar to be amplified while maintaining the illusion that the sound is coming from the altar. This will probably be done by installing another column out of sight near the altar and then delaying the dome and lectern columns.

Using the pulpit column plus the six nave columns, the word intelligibility was measured in the empty Cathedral at the six positions indicated in Fig. 1 of the previous instalment, with and without the delays, but otherwise with the system unchanged. It was mentioned in a previous article[7] that time delays would probably improve intelligibility and this is, in fact, the case as is shown by Table I. It is seen that even in the empty Cathedral the intelligibility is high, and from equation (7) we can expect it to be better still when the congregation is present.

TABLE I

Position	Word Intelligibility		Corresponding Sentence Intelligibility	
	Delayed	Un-delayed	Delayed	Un-delayed
1	99	92	100	97
2	95	93	98	97
3	92	89	97	97
4	93	85	97	96
5	85	61	96	85
6	85	52	96	78



One of the 6-ft loudspeaker columns mounted on the piers in the nave in St. Paul's.

However, the main advantage of the columns plus the time delays is the naturalness of the reinforced speech, a quality which is difficult to measure. With the new system, the illusion that all the sound is coming from the pulpit is maintained over the seating area except, not surprisingly, for the few small areas behind the pillars in which the pulpit is screened acoustically and visually. More important, probably, is the apparent lack of reverberation when the column system is used.

Acknowledgments.—This work is part of the research programme of the Building Research Board of the Department of Scientific and Industrial Research. Thanks are due to the Dean and Chapter and the officials of the Cathedral for help freely given at all times.

TWO-COLOUR P.V.C. WIRES

WIRES with two-colour P.V.C. covering have recently been introduced by Tenaplas Ltd. of Upper Basildon, Pangbourne, Berks, to provide greater possibilities in colour coding without departing from the small basic range of strongly contrasting colours which are in common use. This is done by superimposing a spiral of coloured lacquer on the P.V.C. covering, so that any number of code variations are made possible by the use of different spiral colours, while the basic identifying colour can be kept the same.

ECONOMICAL METERING

Using a Single Meter to the Best Advantage

By H. B. DENT

FOR some years past there has been a plentiful supply of reasonably cheap single-range meters in the surplus market and one acquired a habit of using them fairly lavishly in all kinds of radio equipment. In many cases built-in meters are nothing more than a luxury, a very convenient luxury it must be admitted, but there are some equipments in which the inclusion of meters of one kind or another is an indispensable necessity.

The supply of these cheap meters is now beginning to show signs of drying up and thus it has become necessary to consider ways and means of being a little more sparing in their use, but at the same time retaining all the essential monitoring facilities hitherto available. The pressing questions that arise from this are; how best can a single meter be employed? how much can it usefully do? and should it or should it not be permanently wired into the apparatus?

Only the individual user can find the right answers to these questions since there are so many unknown factors involved, but a little guidance might possibly be given in the light of recent experience and after studying the various ways of utilizing a single meter to the best advantage.

One way is to employ a series of jacks distributed throughout the equipment and plug the meter in each as required. It has the advantage of releasing the meter for other purposes, but as the currents required to be measured will most likely vary widely, a multi-range instrument is necessary. This entails first converting the single-range meter into one to cover the range of currents involved, but this is not a difficult matter.

A single-range meter can be made to answer most requirements if suitable shunts are joined across each jack and they are easily made up from a few inches of resistance wire. When the current to be measured is within the range of the meter these jacks are left unshunted. Fig. 1 shows a circuit in which an unshunted jack is used, this being a type in which there is a middle spring (a) normally in contact with the spring (b) and wired externally to the frame (c), so that when the plug is withdrawn the two "live" contacts (b) and (c) are short-circuited.

Shunted Jacks

In order to avoid even a momentary break in the circuit, which in audio equipment can give rise to quite shattering crashes in the loudspeaker, a resistor of 100 ohms or so ($\frac{1}{4}$-watt will suffice) can be joined across (b) and (c). It is never in circuit for more than a fraction of a second (unless the plug is only partially inserted) so it is not additive to any other resistance, such as a bias resistor, which may be included in the same lead.

When shunted jacks are employed the single type as shown in the circuit of Fig. 2 will meet requirements as the shunt R maintains circuit continuity with the plug out. The resistance of R will rarely be more than an ohm or two, so that it has a negligible effect on the circuit resistance. Inserting and withdrawing the plug will produce no objectional noises in the loudspeaker.

One advantage of wiring the meter shunts across the jacks is that it provides a simple, but most reliable, protection to a low-reading meter and it becomes impossible under normal conditions to burn it out, or bend its pointer, by plugging the meter into a 50-mA circuit when set on its 5-mA range, or whatever the equivalent might be.

Duplication of resistance shunts becomes inevitable with this scheme, but the amount of resistance wire needed is so small as to be of little consequence.

Jacks have the disadvantage of being rather cumbersome and sometimes awkward to accommodate in accessible positions, while in the ordinary variety the frame and fixing bush form one of its contacts. This restricts the jack to use in circuits where the frame can be at the same potential as the chassis, usually h.t. negative, otherwise it must either be mounted on an insulating plate or a type used that has both its contacts fully insulated from the body of the jack. For example, insulated jacks would have to be used if the metering points were anywhere on the h.t. positive side of the valves, as in a small transmitter where it is generally required to know the values of anode, screen and grid currents separately and not lumped together as would be the case if the jack were fitted in the

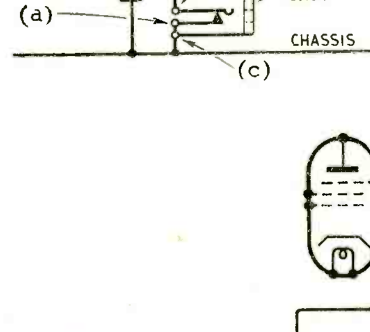


Fig. 1. Self-shorting jack wired into the cathode circuit of a valve.

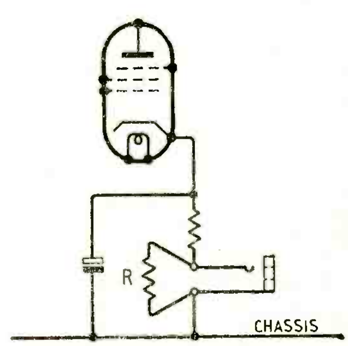


Fig. 2. With a meter shunt R permanently joined across the jack it is not usually necessary to employ the self-shorting type.

cathode lead with its frame "earthy."

A scheme which avoids many of the aforementioned difficulties, yet which provides all the safeguards of individually shunted jacks, is to have just one insulated jack for the meter and a rotary, or wafer, switch to connect the meter across appropriate shunts wired into the circuit at points where current measurements are required. A variation of this scheme is to include the meter in the actual equipment, and while it means tying up a meter permanently for every piece of apparatus fitted with metering facilities, the small 2¼-in type are not yet so scarce nor so expensive that it makes this idea impracticable. Moreover, the meter, and the right one at that, is always where it is wanted at the time it is needed, and by merely rotating a switch the operating condition in several valve stages can be seen at a glance.

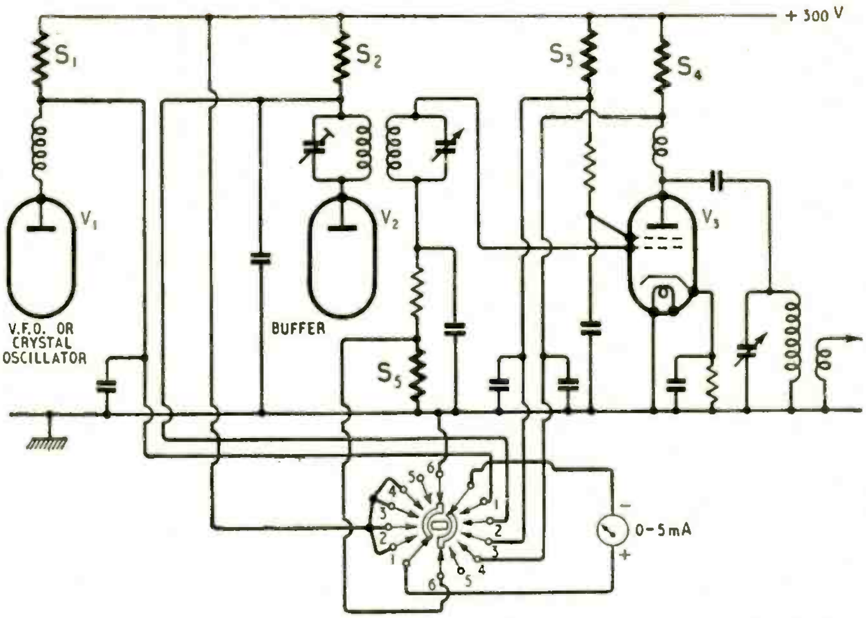


Fig. 3. Skeleton circuit of a small transmitter showing positions in which meter shunts are required for routine checking and tuning of the equipment.

In a transmitter current readings often serve as a guide for tuning and for keeping a check on current consumption of valves, which may be operating very close to their maximum limiting conditions.

Fig. 3 shows a skeleton circuit of a small 10-watt transmitter in which the monitoring scheme discussed here is employed. The transmitter covers the amateur "top-band" only (1.715-2 Mc/s), includes a v.f.o. (variable frequency oscillator) and a band-pass coupling between the buffer stage V_2 and the power amplified V_3, thus minimising the amount of retuning for any change in frequency.

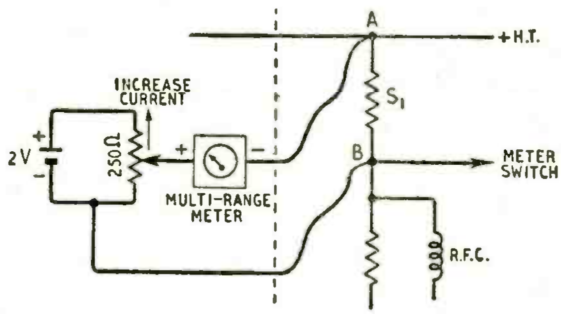
As used in Fig. 3 provision is made to measure the combined anode and screen currents of V_1, the v.f.o. and of V_2, the buffer, but the anode, screen and grid currents of V_3, the power amplifier, are measured separately. Incidentally the first two valves are VR91s (EF50), and the final a VT501 (TT11).

Grid current of V_3 is measured by switching the meter across the shunt S_5, which is not a shunt in the sense that $S_1 - S_4$ are, as it does not modify the meter's reading: it is a 150-ohm resistor and merely serves as a point across which to connect the meter for reading over its normal range of 0-5 mA.

It was convenient to make the shunts S_1, S_2 and S_3 of such value that the meter reads full scale with 25 mA flowing, thus applying a multiplying factor of 5 to the existing scale. Shunt S_4 was adjusted to give a full-scale deflection with 50 mA, the multiplying factor being 10.

The actual amount of resistance required for S_1, S_2 and S_3 depends on the internal resistance of the meter. The small 2¼-in 0-5 mA moving coil meters the writer has used have internal resistances ranging from about 13 to 15 ohms, so that for 0-25 mA conversion shunts S_1, S_2 and S_3 each require to be about 3.3 ohms and S_4 about 1.5 ohms. When the meter resistance is known exactly, and means are available for measuring low values of resistance accurately, the shunts can be made to calculated values and measured before fitting into the circuit. The following simple formula gives the value of the shunt in each case:—

Fig. 4. Set-up of the apparatus used for adjusting the meter shunts and described in the text. That on the left of the broken line is external to the set.



$$R_s = \frac{R_m}{n-1} \text{ ohms}$$

where R_s = resistance of shunt
R_m = resistance of meter
n = scale multiplying factor.

Where no such facilities are available a very simple test rig will enable the shunts to be adjusted by the trial and error method.

The set-up used for the purpose is shown in Fig. 4 and consists of a 2-V accumulator (a 1½-V dry cell could be used instead), a 250-ohm potentiometer and a multi-range meter. These are connected up as shown and joined to the two points A and B across which points is joined also the length of resistance wire to be adjusted to form S_1. Points A and B are already wired up to the meter shunt switch and to the

0-5 mA meter in the transmitter. About 36in of No. 28 s.w.g. (silk or enamel covered) Eureka resistance wire is used to commence with and progressively shortened until the potentiometer can be moved to register 25 mA on the multi-range meter and 5 mA on the built-in meter. In all cases about ½in is allowed for connecting and the length of wire wound on a bakelite rod which is then fixed to the chassis. Two more identical shunts are made for S_2 and S_3. S_4 is made by starting with 18in of wire and adjusting to give full-scale deflection on the 0-5-mA meter with 50 mA registered on the multi-range meter. This shunt is finished off as already described, one method adopted by the writer being shown in Fig. 5. The former measures 1¾in × ½in × ¼in. The two pegs are ½in apart.

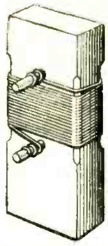


Fig. 5. Constructional details of the shunts are shown in this drawing.

Although there are only five points in the circuit of Fig. 3 where measurements were required it was necessary to use a 2-pole 6-way switch, shown diagramatically as a single-plate wafer, but it could take any convenient form. A blank position (No. 5 in this case) must be allowed at the point of change-over from anode-current to grid-current measurement so as completely to isolate the meter from all circuit wiring during the change-over from the h.t. line to the earth line.

In other types of equipment where there is no such transition from a high- to a low-voltage circuit, switching sequences can be continuous, but if any change is made which results in the meter being switched to entirely different parts of a circuit, as illustrated in Fig. 3, then a blank contact must be allowed at each transition.

Decade Multivibrator Design

Method of Stabilizing Frequency Division from a Crystal Drive

By J. E. ATTEW

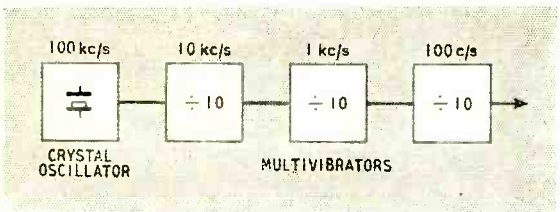


Fig. 1. Schematic diagram of crystal-controlled multivibrator chain.

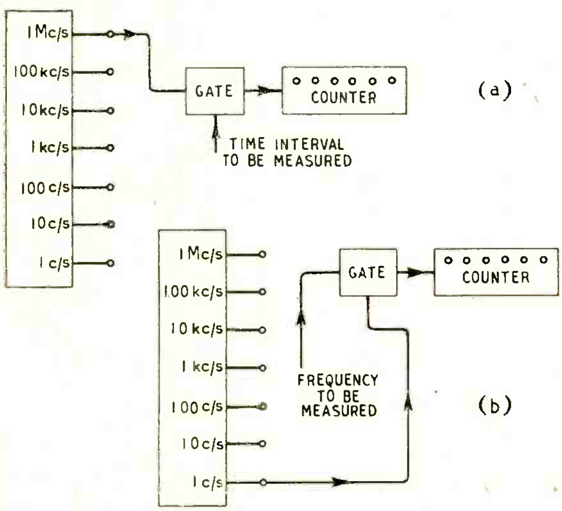


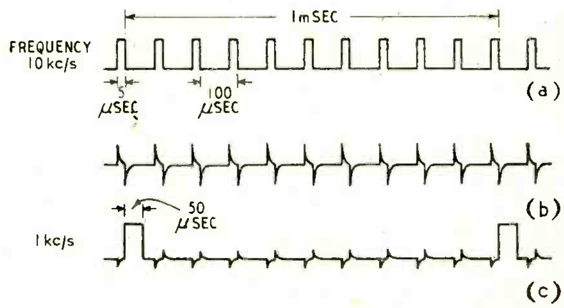
Fig. 2. Use of decade multivibrator and counter (a) for time measurement, when the gate is opened for the time interval to be measured (b) for frequency measurement, when the gate is opened for exactly one second.

It is well known that a crystal oscillator controlling a chain of decade multivibrators (Fig. 1) can provide a very accurate source of frequencies. Such a system has been used for controlling clocks, frequency checking, time interval measurement, etc.

The writer had occasion to investigate such systems for accurate frequency and time interval measurements, in conjunction with a commercial electronic counter capable of registering counts up to 10^6 (See Fig. 2).

Various multivibrators were investigated but all suffered to some degree from a particular fault, which unfortunately causes large errors when the multivibrator is used for the purpose mentioned. This fault is the effect of the multivibrator momentarily jumping to the next lower ratio of division (in this case ÷9), although synchronizing was injected to discriminate

Fig. 3. Details of synchronizing pulse waveforms. (a) Output of 10-kc/s multivibrator. (b) After differentiation by circuit with time constant approximately 1/5 pulse time. (c) Anode waveform of 1-kc/s multivibrator showing timed locking. The synchronizing pulses are inverted after passing through the circuit of Fig. 4.



for even division. This effect is very spasmodic in nature, causing an increase in the number of pulses counted over a given time period. It is thought to be due to an increase in amplitude of the injected synchronizing voltage (due to heater or h.t. voltage changes), causing the multivibrator frequency to be "drawn" towards the synchronizing frequency. The multivibrator was never found to "jump" to a higher ratio of division.

It was found that if a pulse of opposite polarity were inserted just before the true synchronizing pulse, this would prevent the multivibrator triggering if it was about to trigger early, so holding it off until the true synchronizing pulse arrives (see Fig. 3).

This method of synchronizing is most economically carried out with an asymmetrical multivibrator which gives a short pulse out. The basic circuit is shown in Fig. 4, using a double triode. The oscillator gives a positive pulse out of first anode and requires a negative synchronizing pulse, as shown.

The final circuit (Fig. 5) shows that each frequency is available via a cathode follower, all with positive-going pulses and synchronized to a 100 kc/s crystal.

The anode circuit of the modified Colpitts crystal oscillator is over-compensated by L_2 causing a large positive overshoot which is differentiated and shaped by the cathode-follower circuit.

The 1-Mc/s circuit consists of various shaping circuits (L_1 and C_R resonating at 1 Mc/s), producing a $\frac{1}{3}$ μsec positive pulse at the output.

The synchronizing condenser between each multivibrator is adjusted to give the correct differentiation for each preceding value of pulse which, the synchronizing being largely independent of injected pulse amplitude.

The unit is supplied from a stabilized h.t. supply, as shown in Fig. 5.

Setting up presents no difficulties if a double-beam

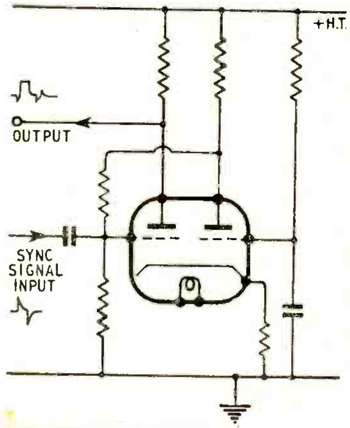
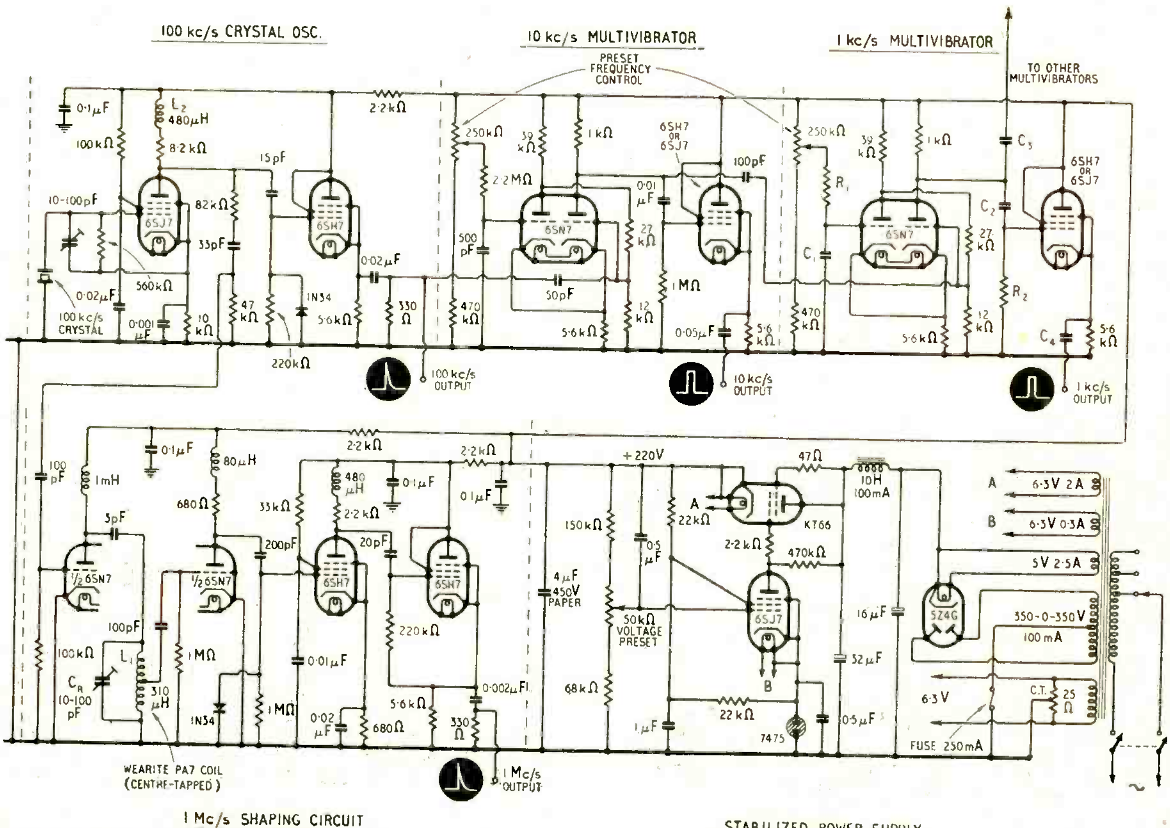


Fig. 4. Basic multivibrator circuit. A negative synchronizing pulse is normally required.

COMPONENT VALUES FOR OTHER MULTIVIBRATORS

f	R_1	R_2	C_1	C_2	C_3	C_4
1 kc/s	2·2 MΩ	1 MΩ	0·005 μF	0·05 μF	500 pF	0·1 μF
100 c/s	2·2 MΩ	1 MΩ	0·05 μF	0·25 μF	0·005 μF	1 μF
10 c/s	3·3 MΩ	2·2 MΩ	0·5 μF	0·5 μF	0·05 μF	2 μF
1 c/s	6·8 MΩ	4·7 MΩ	2 μF	0·5 μF	—	DIRECT

Fig. 5. Complete circuit diagram of stable decade multivibrator source. Component values for decade frequencies of 1 kc/s and below are shown in the table.



oscilloscope is used. After setting the crystal to a standard (or by means of beats between the B.B.C. Light Programme on the long-wave band (200 kc/s) and the second harmonic of the crystal), the crystal output is applied to one beam, and the oscilloscope time base is synchronized to display ten pulses (one at least will be observed in the flyback). The next lower multivibrator is then applied to the second beam and its frequency adjusted until one pulse is apparent, the process being repeated downwards. The 1 c/s pulse was timed in conjunction with the electronic counter.

The original unit has been in continuous use for a period of more than six months, and during this time it has not required resetting, nor has any ratio-jumping been observed.

BUSINESS RADIO

Some New Applications

DURING the latter half of last year there was a tremendous increase in the number of stations licenced by the Post Office for mobile radio services (business radio). According to figures quoted at the annual meeting of the Radio Communication & Electronic Engineering Association fixed stations increased by some 50 per cent and mobile stations by over 70 per cent. The total number of stations at the end of the year—excluding equipment issued to police and public utilities—was nearly 2,800.

The most recent application is the equipping of a number of the large ocean-going tankers delivering crude oil to the new refinery at Fawley, Hants. The operating company, Esso, has found the tests carried out with three tankers since September so successful that the whole fleet is ultimately to be fitted. Initially 37 are being equipped.

The problem facing the authorities was how to organize the arrival of tankers so as to maintain a steady supply of oil without causing congestion. It is only when the tankers have reached the Solent that the Marine Superintendent at Fawley can estimate the volume of traffic, but advice and instructions cannot be given by radio to the ships' masters on the normal shipping wavebands because of the wireless silence imposed. As there is, however, no such ban on the use of v.h.f. business radio, the obvious solution was to use this means of communication, which, it was found, provided complete coverage of the Solent and its approaches.

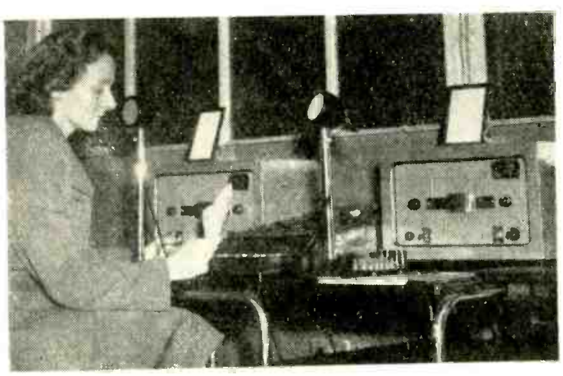
Unlike other mobile stations which, being usually in cars or vans, have to depend on batteries for their power supplies, the tankers' sets can be operated by the ships' mains. It has been possible, therefore, to employ heavier and more powerful equipment.

Another special application of business radio is that of British Field Products, Ltd., at Walsingham, Norfolk, which has the largest grass-drying plant in the country and is now producing much-needed animal foodstuffs from fresh grass, lucerne and other green crops. To obtain the maximum protein value the greenstuffs must be cut at the appropriate time, transported and dried within a few hours.

As the area from which crops are obtained extends to some 15 miles from the factory, the problem facing the originators of the scheme was how to ensure a steady delivery of freshly cut crops. This involves reports by cropping managers and analysts and the passing of instructions to field managers and even to drivers of tractors. Business radio provided the solution and the company now has a 15-watt fixed station and a number of 5-watt mobile sets in use.

Another company using business radio is the Pressed Steel Co., manufacturers of refrigerating plant. Having installed over 13,000 refrigerators, some in hospitals and laboratories for the preservation and freeze-drying of valuable substances such as blood-plasma, penicillin, streptomycin and certain vaccines and viruses as well as for special foodstuffs, the problem was, how to ensure prompt attention in the event of a breakdown in any such plant. The company has thirty service vans engaged mainly on routine visits in the Greater London area and v.h.f. radio-telephone equipment has been installed in twenty-two of them. So as to cover the whole area served by the vans two transmitters have been used, one at Richmond and the other at Highgate, both being operated by remote control from the company's service depot at Gunnersbury. The fixed stations are Pye PTC 704's and the vans have PTC 113's.

(Right) Pye PTC 704 transmitter-receiver installed by Rees Mace in a tanker. (Below) The control equipment (with microphone and receiver for each fixed station) at the service depot of the Pressed Steel Co.



TOTAL POWER

How to Find It When Several Currents Flow in the Same Circuit

By "CATHODE RAY"

HAS any wisecracker ever remarked that the obvious is seldom true? If not, I will; in spite of the grave risk that some well-meaning but literal-minded person will write me several learned pages to show where the proposition breaks down. But I am sure I can count on the support of readers of detective fiction, and probably also of the more experienced and disillusioned students and experimenters. What, after all, is the obvious? "Something one learnt yesterday" might be the cynic's answer. Or is it often something we haven't bothered to think about very thoroughly?

For instance, suppose G_1 and G_2 in Fig. 1 are two a.c. generators. When G_1 is working alone it develops 10 watts in the circuit. And when G_2 is working alone it develops 2 watts in the same circuit, at some higher frequency—say four times that of G_1. If now G_2 is started up when G_1 is working, its current, i, will be a harmonic ripple on the G_1 current, I; and isn't it obvious that the total power cannot possibly be 12 watts, for, as Fig. 2 confirms, i subtracts from I just as much and as often as it adds to it? What is gained on the swings is lost on the roundabouts; Q.E.D., and all that.

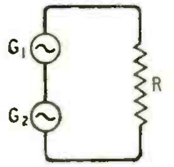
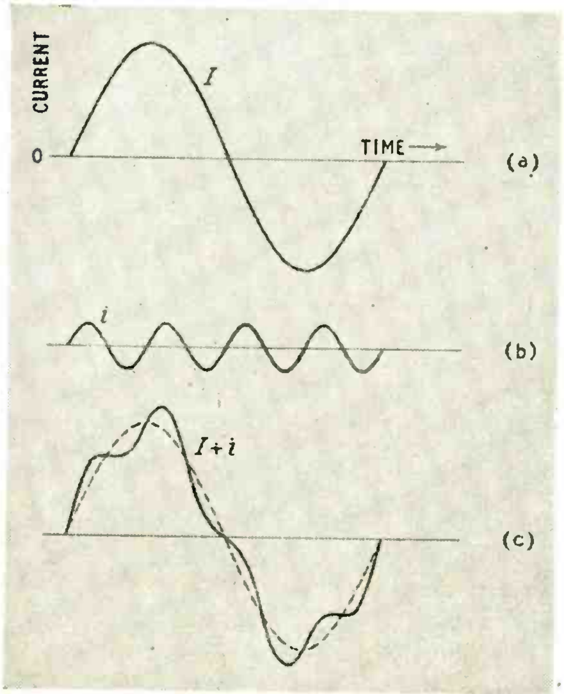


Fig. 1. *If two generators are driving currents through the same circuit, what is the total power in terms of the power of the separate currents?*

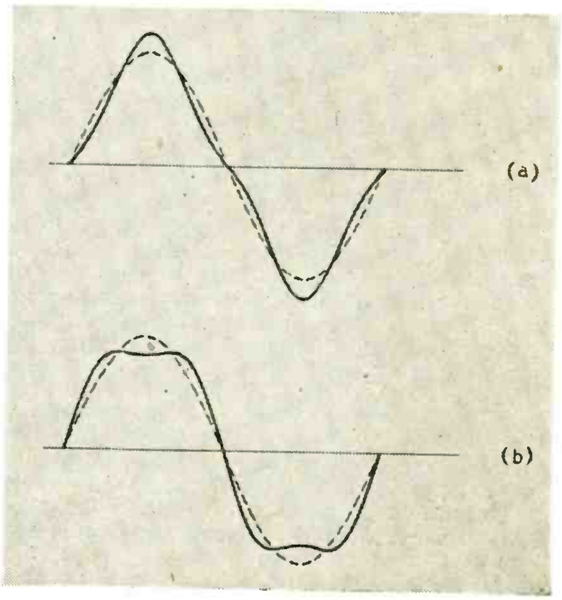
Fig. 2. *(a) and (b) represent what might be the currents from G_1 and G_2 in Fig. 1. The total current, plotted by adding (a) and (b), is shown as (c), in which I is repeated in dotted line to show more clearly how i alternately strengthens and weakens it.*



If anybody liked to be particularly awkward he might point out that if G_2 happened to generate a third harmonic it would reduce the effect of G_1 twice as often per cycle as it increased it (Fig. 3(a)), so what then? Or if the phase slipped a little the proportions would be reversed (b). It is obvious then, is it not, that calculating the total power of a number of different alternating currents flowing in the same circuit must be a complicated business?

There are two other cases that might be thrown into the collection before trying to sort it out. One is when the two currents are of the same frequency. If they happen also to be of the same amplitude, and opposite phase, they cancel out and there is no current and so no power. If they are in the same phase there is double current. This, surely, helps to confirm the

Fig. 3. *In this case i has three times (instead of four times) the frequency of I. The effect of adding it to I is shown for two different phase relations.*



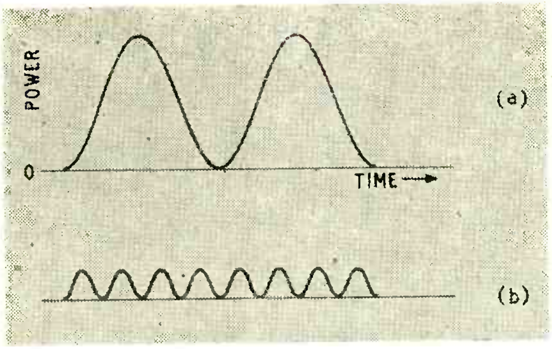
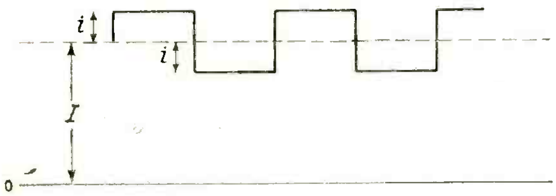


Fig. 4. Here at (a) is shown the power graph corresponding to Fig. 2(a), obtained by plotting the square of the current; and (b) corresponds to Fig. 2(b). What corresponds to Fig. 2(c)?

Fig. 5. A combination of currents (d.c. and square-wave a.c.) that lends itself to easy calculation of separate and combined power.



impression one gains from Fig. 3, that the power in the circuit depends on the relative phases of the currents?

The other case is a.c. superimposed on d.c., which concerns us all, because it happens in every valve. There can be no doubt that adding a ripple of a.c. to a larger d.c. makes no difference to the average current reckoned over any number of complete cycles. A milliammeter in the anode circuit of a Class A power amplifier reads the same whether or not the valve is delivering signal power—or at least it would if the valve were a perfectly linear one. Yet in one event power is not going into the load, and in the other it is.

Adding Currents

I have now assembled an exceptionally fine collection of red herrings. Have you succeeded in clearly identifying them all? If so, there is perhaps not much point in pursuing the matter. But if you have accepted all the foregoing obvious things as true, or perhaps suspected there was something wrong but were not quite sure where, or are not satisfied with what the books say and prove mathematically if they seem to contradict the evidence of your eyes, then it may be some help to read on.

First, there is no catch about the way we have been adding the currents due to the separate generators. What is usually called the Superposition Theorem says that the total current due to two or more e.m.fs acting in the same circuit is the sum of the currents due to each e.m.f. separately. In other words, you just add up the separate currents, taking account of their direction—a current in the reverse direction must, of course, be given a minus sign. And there is one important proviso—the circuit must be linear; that is to say, current must be exactly proportional to voltage as in Ohm's Law, so that their graph is a straight line passing through the origin. Strictly, that rules out all circuits containing valves and iron-cored coils; but under favourable conditions and within certain limits these can sometimes be reckoned as approximately linear. To keep things simple, non-linear circuits are excluded from the present discussion. So the current-adding method used in Figs. 2 and 3 is quite correct.

Another basic principle we can take for granted is that the *average* value of any alternating current (or voltage), reckoned over a complete cycle, or any number of complete cycles, is nil. In fact, an alternating current could almost be defined as one of which that is true. If any current is found to have an average value, then that much of it is d.c. In a waveform graph, such as Figs. 2 and 3, average value is represented by average height above the base-line, and is equal to area above the base-line divided by horizontal distance. In the graph of one cycle of any purely alternating current the areas above and below the line are equal and cancel out. So it is perfectly correct to say that adding i in Fig. 2 has no effect on the average value of the current. It is zero in every case shown. (True enough, one sometimes reads that the average value of a.c. is 0.64 times the peak value; but that is when it is averaged over *half* a cycle.)

While it is easy to see that the positive and negative half-cycles cancel out everywhere in Fig. 2, there may be a flicker of hestitation about Fig. 3, because of the third harmonic strengthening the fundamental twice as often per cycle as it weakens it (or vice versa). The answer to this, of course, is that although the third harmonic (unlike the fourth harmonic in Fig. 2) admittedly alters the average value of the fundamental-frequency half-cycle, it alters both half-cycles equally, so they still cancel one another out.

So much for average values of currents. How about their power? It is proportional not only to the current but also to the voltage, and since the voltage across a linear resistance is proportional to the current, the power is proportional to current-squared. And the square of a number is positive, no matter whether the number is positive or negative. So the graph of a.c. power in a purely resistive circuit never falls below the base-line. In an electric lamp or heater the negative half-cycle is just as useful as the positive. The power graph of I in Fig. 2(a) is as shown in Fig. 4(a), and that for i as in Fig. 4(b). Presumably, then, the power of the combined currents is shown by the result of adding (a) and (b) in Fig. 4, and is equal to the powers of the separate currents added together? But how can this be, seeing that there is no doubt (Fig. 2(c)) that i reduces I as often and as much as it increases it?

The short answer is that although the net result of adding and subtracting an equal amount is nil, that is not true of the square. Adding 20 to 100 gives 120 and subtracting 20 from 100 gives 80, and the average of 120 and 80 is 100—the same as before. But 120 squared is 14,400 and 80 squared is 6,400—4,400 up but only 3,600 down, so the average is 10,400, which is the square of 100 *plus* the square of 20.

Fig. 5 shows more clearly how this principle applies to electrical power. It represents the simplest case I can think of—square-wave a.c. added to d.c. Throughout the positive half-cycle the current is $I+i$, and throughout the negative half it is $I-i$. If for simplicity we suppose the resistance is 1 ohm, the power is $(I+i)^2$ and $(I-i)^2$ respectively. To find the average power we have to add these together and divide by 2:—

$$(I+i)^2 = I^2+2Ii+i^2$$
$$(I-i)^2 = I^2-2Ii+i^2$$
$$\therefore \frac{(I+i)^2+(I-i)^2}{2} = \frac{2I^2+2i^2}{2} = I^2+i^2$$

So the power when both currents are flowing is the sum of the separate powers. The same applies with a circuit of any resistance R, as can be seen by doing the same little bit of algebra with that factor included. It is because power increases more rapidly than the current that the increase in power during the positive half-cycle more than outweighs the decrease during the negative half. The algebra simply demonstrates the general truth of what we found with the particular numbers 100 and 20.

"Brick-built" Waveforms

The proper way of demonstrating the principle more generally still, for all waveforms and any number of simultaneous currents, is by the integral calculus. But I am writing for those who either lack the calculus or who, while accepting its proofs, like to "see" them as well. I sympathize with this desire, for I am never really happy about a conclusion that has only an involved chain of mathematical manipulation to link it with familiar territory. So, assuming that the case of Fig. 5 has been clearly seen and accepted, let us see how we can extend its application. It would make no difference to the principle if the amplitudes of the a.c. cycles were varied, say by modulating them. It would merely vary the value of i, which can be anything. Nor would the principle be affected if batches of positive half-cycles were lumped together, and likewise their negative partners, so long as the averaging process embraced both. Fig. 6 shows how this amplitude-varying and rearranging process can be used to make a batch of 15 square-wave cycles into a rough approximation to a single sine-wave cycle. It could be made as good an approximation as one wished—still without affecting the power-addition principle—by using a large enough number of sufficiently high-frequency square waves. So it is reasonable to conclude that what we have proved for a square wave holds good for any a.c. waveform.

Although i in Fig. 2 is added to another a.c., the same line of reasoning that we have used for d.c. can be applied to that case too, because Fig. 2(c) is so symmetrical. At every point in the I cycle where the effect of i is to increase the total current, one can find another point where I has the same amplitude and i decreases the current by the same amount. Thus the fourth half-cycle of i can be set off, bit by bit, against the first; the third against the second; and so on.

Fig 3 is not quite so easy. But the apparent inconsistency—that the "ups" are twice (or half) as numerous as the "downs"—disappears when one realises than an "up" from an already large current has more effect on power than one from a smaller current. The power increases of the added current is, in fact, proportional to the amplitude of the current to which it is added. So in Fig. 3(a) the effect of the positive half-cycle of i at the peak of I is matched by *two* negative half-cycles centred on 30° and 150°, where I is *half* its peak amplitude. If you are sufficiently interested you might like to try extending the algebra to cover this case, averaging $(I+i)^2$ and $2\,(I/2-i)^2$ (and remembering to divide by 3 because there are 1+2 half-cycles of i).

Even if I did try it on, I could hardly expect to get away with the bluff that I have proved the case for Fig. 3. Somebody would be sure to point out that the half-cycles of i are not concentrated exclusively at the 30°, 90°, and 150° points of I, and that the matching of equal-amplitude points that worked with Fig. 2 won't with Fig. 3. And that—unless someone can think of a dodge for extending the "building brick" technique to include combinations of a.c. such as those in Fig. 3—is regrettably true. But at least we can see, as we may not have done at the start, that (a) and (b) are at least roughly equal as regards total power, and that the more elegant mathematical demonstrations which prove exact equality are not so hard to believe as they might have been at first.

One red herring waiting to be disposed of is the power of a combination of currents of the *same* frequency. Obviously (and it really is true this time!)

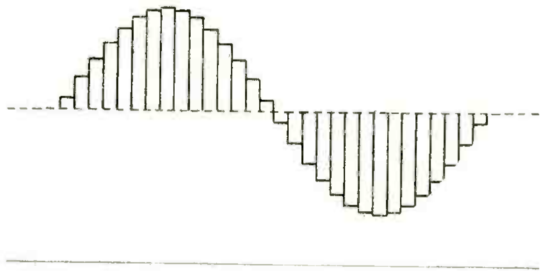
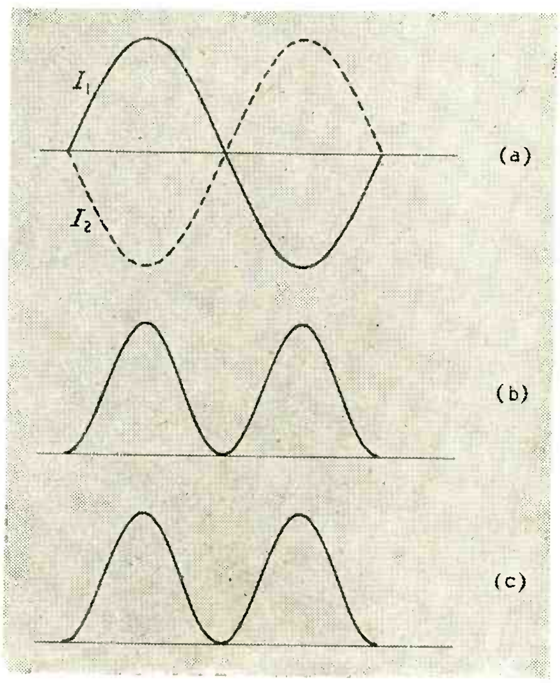


Fig. 6. *How the principle established for Fig. 5 can be extended to cover other waveforms.*

Fig. 7. *I_1 and I_2 are equal and opposite a.c. of the same frequency. Their power curves, (b) and (c) respectively, are identical. Yet the combined current, and its power, are zero.*



it is possible to add two powerful currents together and get no power. If they are equal and opposite they just cancel out. Suppose I_1 in Fig. 7(a) represents one of the currents. Its instantaneous power graph, obtained as before by plotting current-squared, is shown at (b). I_2 is the equal and opposite current, which would cancel I_1 out and leave no current or power. Its individual power graph (c) is an exact duplicate of (b). So in this case at least it is glaringly untrue to arrive at the total power by adding the separate powers. This method having been discredited once, how can it be trusted at all? Well, if what I said about Fig. 4 led anybody to believe that adding the separate power graphs was in any way a proof of the power-adding principle, then I apologize for one more little leg-pull. (I did say "presumably," and presumptions are often wrong, as this one is!) This is an example of the logical fallacy called (for no obvious reason) begging the question. The fault lies in assuming the truth of what one is ostensibly setting out to prove. It is quite true that (with certain qualifications) the power of any combination of currents is equal to the sum of their powers when flowing separately. But in general it is not true that if you draw the graphs of power against waveform for the individual currents and then add them together the result will be the power graph of them all flowing at once. We have seen one case (Fig. 7) where it is quite clearly untrue. And even when the frequencies are different it is quite possible for the two separate currents occasionally to have equal and opposite amplitudes, and at such moments the total power is less than that of either current separately.

What this amounts to is that our power-addition principle does not apply to *instantaneous* power, such as is shown by a waveform graph. It applies only to the power averaged over a suitable period. And now we are really getting to the heart of the matter.

Period for Averaging

When reckoning the power of a single current there is no doubt about the suitable period; it is one whole cycle. It could be averaged over any number of whole cycles, but one is the minimum. Often (as in Fig. 7) it could be averaged over half a cycle with correct results, but that cannot be safely relied upon for all waveforms. In the two-current combinations of Figs. 2 and 3, one whole cycle of the lower frequency is enough, because it includes a whole number of cycles of the other. After that the whole sequence repeats, so the average power for each successive period would be the same. But if the frequencies of I and i were in the ratio of 3 to 5 it would be necessary to sit through three cycles of the lower frequency to see the whole programme, and that would be the minimum averaging period.

In case the necessity for averaging over a whole "programme" is not quite clear, suppose two equal currents have almost exactly the same frequency. If they start off precisely in antiphase, the power of the combination will begin by being zero. Quite a large number of cycles will have to elapse before this state of affairs alters appreciably; and when it does the power will rise very slowly. After very many cycles the currents will arrive in phase, making the total current twice that of each separately, and the power *four* times. And then it will wane slowly to zero. That happens when one current has gained one whole cycle on the other. In such a case it is easy to see that the power would have to be averaged over the entire slow beat to get a fair figure. That figure—yes, you have guessed it!—is twice the power of each current separately. The minimum period for averaging is that which includes an exact whole number of cycles of both—or all—component currents.

The case in which both currents are of exactly the same frequency still seems to stick out as an exception to this rule. A single cycle contains a whole number of cycles (one) of each current, but we have already seen that the power-addition principle fails to apply over this period. If you have what is supposed to be the typically British mind, unperturbed by arbitrary and illogical rulings so long as they work, you will just accept this as one of those things. But if you insist on tidy regularity you will talk this exception into the rule by arguing that the logical conclusion to considering pairs of currents of progressively more nearly equal frequency, requiring progressively longer periods for averaging the power, is to say that an equal-frequency pair of currents requires an infinitely long period of time. After all, unless one extends the time to infinity, how can one be certain that their frequency really is identical and that there is not an enormously slow beat, which in the (very) long run would make the power-addition rule apply?

But perhaps we had better descend from this rarified theoretical atmosphere to some ground-level practice. What happens when one measures an audio output power with the usual "output meter," consisting of a metal rectifier voltmeter across a known resistance? It is scaled to read watts by making use of the fact that the wattage is equal to voltage-squared divided by the resistance. But there is a catch—the meter responds to the *average* value of the rectified a.c. And we can see that the average value of the combined current in Fig. 3(a), for instance, is less than that of the single low-frequency current, which in turn is less than that of the (b) combination, though that has the same power as the (a) combination. So this type of meter is apt to be misleading, at least with the odder waveforms. It is wildly inaccurate with narrow pulses, which have considerable r.m.s value but little straight average. So for this kind of thing one ought to have an indicator that responds to r.m.s. values, such as a moving-iron or thermo-junction meter, or a valve voltmeter of the rather inconvenient type that works over a selected slice of bottom bend. Noise has a peaky kind of waveform, so signal/noise measurements in particular are the better for being performed with an r.m.s (square-law) meter.

But how about the programme-repetition rule in this connection? The characteristic feature of noise is that it is *not* regularly periodic. And there is no strict regularity about the waveform of, say, a broadcast performance. True enough, and the theory becomes too complicated to embark on at this stage; sufficient to say that the power fluctuates, and so will the meter reading, but the chance of the total power differing appreciably from the sum of the separate powers (unless some of their frequencies are equal) is small.

All this may seem to have been a lot of to-do about one small by-way of theory. But unless one goes into the matter closely it does seem rather incredible that when a lot of signal currents of different frequencies are flowing together, with so much mutual cancelling out, their individual powers nevertheless add up by simple arithmetic to give the total. And even if one knew that already, this discussion goes to show, does it not, that even small and apparently straightforward by-ways have some curious twists?

Ionosphere Review: 1951

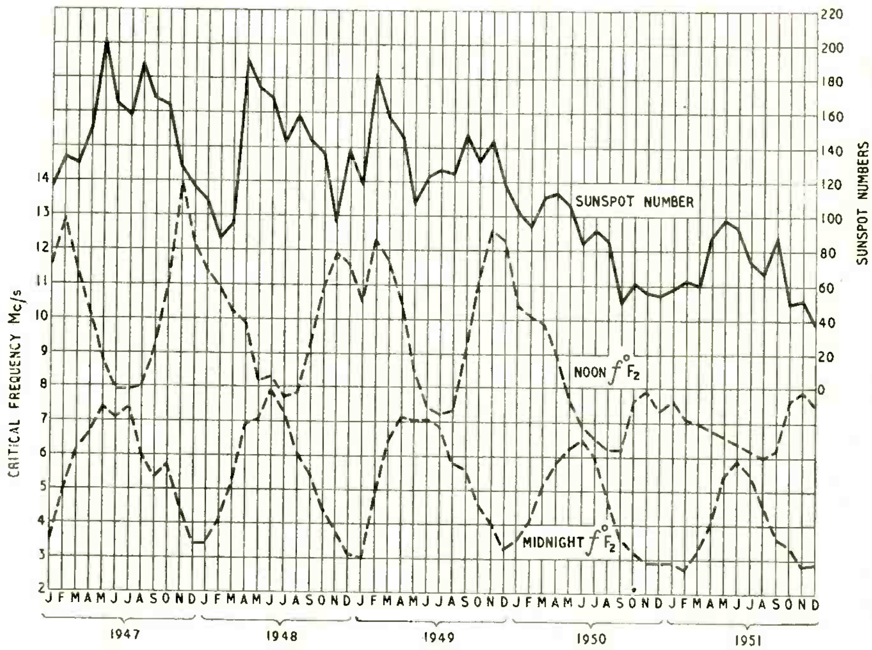
Greatly Reduced Rate of Decrease in Sunspot Activity and M.U.Fs

By T. W. BENNINGTON*

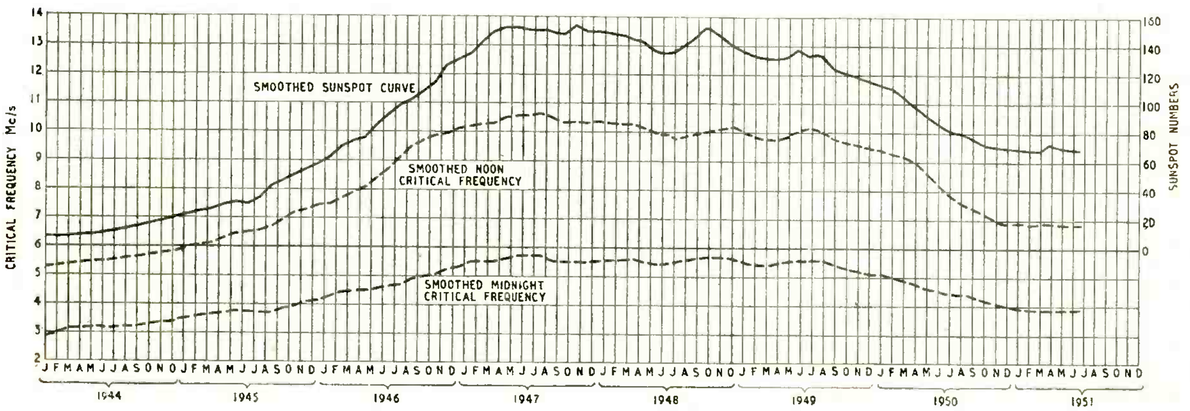
DURING the latter part of 1950 sunspot activity had undergone a large and rapid decrease, and there had been a corresponding large decrease in the maximum usable frequencies for short-wave transmission. These variations were dealt with in *Wireless World* for March 1951, where it was mentioned that it would not be surprising if, during 1951, sunspot activity were to remain relatively constant, or even to rise somewhat. If the current sunspot cycle was to run anything like a normal course this seemed a likely thing to happen.

In Fig. 1 the full line curve gives the monthly mean value of the sunspot relative number for each month since the last sunspot maximum, whilst the two dashed line curves give the monthly mean of the F_2 layer critical frequencies for noon and midnight respectively, as measured at the Slough station of the D.S.I.R. In April 1951 there was a considerable increase in sunspot activity, which was maintained for several months, and, in fact, for the greater part of 1951 the activity was higher than it had been during the last few months of 1950. The effect of this upon the ionosphere is shown by the behaviour of the noon critical frequency. This decreased towards its summer minimum much more slowly than is usual, this being due, no doubt, to the temporary increase in the solar activity which started in April. In fact, the lowest monthly value recorded for the year

* Engineering Division B.B.C.



Right: *Fig. 1. Monthly mean sunspot numbers and noon and midnight F_2 critical frequencies since the last sunspot maximum.*



Below: *Fig. 2. Twelve month running averages of sunspot numbers and noon and midnight F_2 layer critical frequencies since the last sunspot minimum.*

(for August) was very little lower than the lowest monthly value for 1950, whilst the winter values for 1951 were no lower than those for 1950.

The arrestment of the fall in both sunspot activity and critical frequencies during 1951 is well brought out in Fig. 2, which gives the 12-month running means of sunspot numbers and Slough critical frequencies since the last sunspot minimum. By taking such means the short term variations in these quantities are smoothed out, and the long-period variations are more clearly seen. The curves, it is thought, speak for themselves, and, as to the variations during the past ten months, they have been very small, and such as to maintain in the ionosphere, and for short-wave propagation, a condition of little change. Propagation conditions at the end of 1951 were thus not very different from what they were at the end of 1950; m.u.fs. being very slightly lower, both by day and night.

It is, of course, impossible to be in any way certain about the variations in solar activity likely to occur during 1952, but it is likely that it will begin to decrease again, but to do so at a slow rate, so that by the end of the year the running-average sunspot number may have fallen to about 48. This would imply that, during 1952 the frequencies of use for long distance communication will also decrease slowly, so that, by the end of the year, the m.u.fs. for these latitudes will be about 4 Mc/s lower by day, and about 1 Mc/s lower by night than what they are at present. Frequencies of use for short-wave communication will therefore be somewhat lower on all circuits than those which have been usable this year. This will mean somewhat less use of the higher daytime broadcasting frequencies—like 21 Mc/s for southerly and 17 Mc/s for westerly circuits—and more use of those bands of somewhat lower frequency. At night 11 and 9 Mc/s bands will probably remain usuable during the summer, but next winter the situation is likely to be even more difficult than at present, with 6 Mc/s the only usable frequency over some circuits. At that time a lower frequency than any now available for short-wave broadcasting to North America would seem to be desirable in order to maintain good service at night.

INTERNATIONAL EXCHANGE OF STUDENTS

NUMERICALLY and geographically the work of the International Association for the Exchange of Students for Technical Experience (I.A.E.S.T.E.) has extended during the past year. In the annual report of the association it is recorded that the number of students sent abroad during last summer for experience in industry increased by 761, bringing the total to 2,433. The normal period for which students are employed is eight weeks, although in some instances it is longer.

The students came from 16 countries. So far as this country is concerned, we sent 422 students overseas for technical experience and received 457 from other countries, compared with 353 and 368, respectively, the previous year. More U.K. students went to Sweden (106) than to any other individual country, the next highest being received by France (68). The arrangement is, of course, reciprocal and the intake of overseas students into this country was proportional—from Sweden, 85; France, 79 and Holland, 63.

It is not known how many of the students went into the radio and electronic industries in the various countries but it can be assumed from the few radio concerns listed among the organizations participating in the scheme that the number was comparatively small.

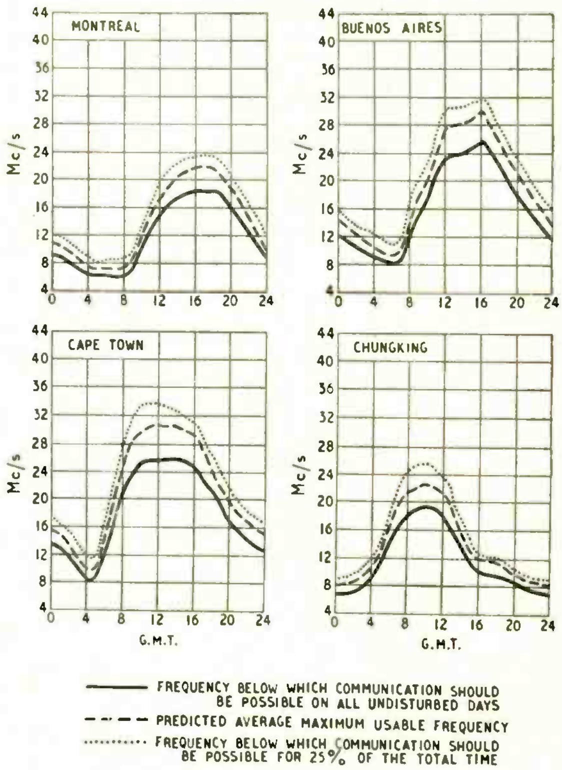
Details of the scheme, which was started in 1948, are available from J. Newby, I.A.E.S.T.E., Imperial College, London. S.W.7.

Short-wave Conditions

Predictions for March

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

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



MASS AND ENERGY

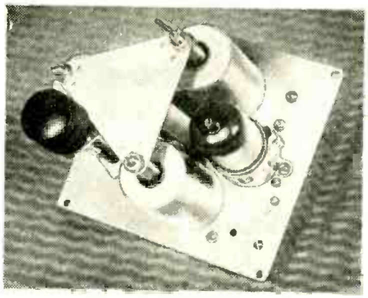
ORDINARY chemical explosions are just the same as atomic explosions, so far as the principle of the mass-to-energy exchange is concerned, and "Cathode Ray" asks us to convey his apologies for having, in "Energy" (January issue), misled readers into thinking there was a difference between the two because of the greater loss of mass in atomic explosions. Although the loss of mass in a chemical explosion is too small actually to measure, theory indicates that a very small loss should take place. In fact, the mass/energy rate of exchange he quoted, $E = c^2m$, holds for *all* energy changes. So the distinction he drew between the two kinds of explosion is really only one of degree, not principle.

Manufacturers' Products

EW EQUIPMENT AND ACCESSORIES FOR RADIO AND ELECTRONICS

Television Tuner

ALL five B.B.C. television frequencies can be received on a television set with the aid of the permeability-tuned television tuner recently introduced by The Plessey

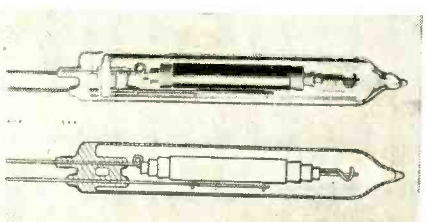


Plessey television tuner

Company of Ilford. It comprises a tuned r.f. stage, covering the frequency band 40-70 Mc/s, and a mechanically-ganged system of three coils—r.f. grid, r.f. anode and oscillator. The oscillator valve is not mounted on the unit. A calibrated scale is provided to facilitate tuning, while good tracking is achieved by the use of padding coils. When the oscillator is working below signal frequency the auxiliary padding coils are connected in parallel with the r.f. circuits and when it is above signal frequency the oscillator coil itself is shunted. The r.f. grid-circuit padding coil is mounted outside the ganged r.f. coil and serves also as an aerial coupling coil. Electrical stability is achieved by the use of temperature-compensated tuning capacitors in the oscillator circuit, and attention has been given to the tuning coils to make them mechanically stable.

Corona Stabilizer

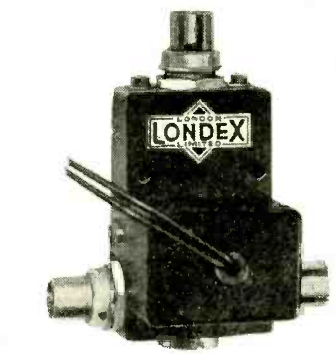
NEARLY twenty years ago it was found that voltages could be stabilized by a corona discharge between coaxial cylinders in gas, but only recently has the principle been utilized commercially. A British tube is now being produced by Nucleonic & Radiological Developments, Ltd., of 77, King's Road, London, S.W.3. This is used in the same way as a neon stabilizer, with a series resistor, but works at a much higher voltage and is distinguished by having a positive a.c. resistance. Because the current consumption is only of the order of microamps the stabilizer is particularly suitable for high-voltage low-current e.h.t. supplies. For a 500-V tube the striking voltage is 550 V, the current range for regulation is 1 μA to 100 μA (the extinction current being below 1 μA) and the a.c. resistance is about 75 kΩ. If the load is very small, a 10-MΩ resistor in series will give a regulation of 1 per cent. Types are available for voltages between 500 V and 1.3 kV in steps of 100V.



N.R.D. corona stabilizer.

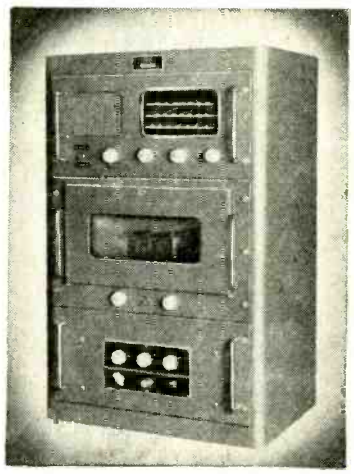
Coaxial Relay

ALTHOUGH the coaxial relay recently introduced by Londex appears to be quite a simple device, it performs the difficult task of switching a coaxial line without interfering appreciably with the transmission characteristics. It is a changeover device and is suitable for such purposes as switching a common aerial between a transmitter and a receiver. The energizing coil, which consumes 1 watt and can be supplied for 6 V, 12 V or 24 V, switches the "inner"



Londex coaxial relay

of the top connector (see picture) to the "inner" of either of the bottom two, the three "outers" being common. Care has been taken with the internal mechanical configuration to maintain the coaxial characteristics throughout and the result can be judged from the fact that when the relay is inserted in a line, the standing wave ratio measured at 200 Mc/s is only 1.08. Models are available for either 45-ohm or 70-ohm cable and are supplied by the makers from their works at 207, Anerley Road, London, S.E.20.



RANDOM RADIATIONS

By "DIALLIST"

Radio Eavesdropping

How PUZZLING those intermittent cases of interaction between the G.P.O. telephone and one's wireless receiver can be! This one, for instance. Some weeks ago, while we were listening to the 9 o'clock news, my wife was called to the telephone (which is in another room and a good thirty feet from the wireless set). To my surprise, the loudspeaker delivered both sides of the conversation as a clearly audible *obbligato* to what the announcer was saying; but try as I will, I cannot arrange a repeat performance. I had a shot, for instance, just before sitting down to write this, and not a sound of the 'phone conversation was to be heard. When I say that I have done my best to obtain a repeat performance, I mean, of course, with the same telephone connections: either we called the neighbour in question, or we arranged for her to call us. In the course of the fourteen years in which we have been in our present house there have been three other instances of this radio eavesdropping. The calls in progress were all to different numbers; one, in fact, was a trunk call.

Over to You

If this sort of cross-talk occurred regularly, there would be nothing particularly strange about it. One would suspect induction or re-radiation effects between telephone and aerial wires, the cause of which should not be hard to track down. But four cases in fourteen years! During that time there has been no alteration in the positions of the wireless set used for broadcast reception, its aerial, the telephone and the telephone wires. Inward and outward calls have taken place almost daily while the set was working on the Home Programme wavelength. The aerial used with the broadcast receiver is an indoor one, consisting of 25 feet of flex stapled to the picture rail. It is true that the telephone wires do run parallel with it for some distance, where they are brought along the outside wall of the house; but they are some 20 feet from it *and* they run through earthed lead sheathing. I have no doubt that readers have equally mystifying experiences of occasional receiver-telephone interaction. Perhaps some of the brainy ones can suggest an explanation. I can't.

Not So Hot

MAY I BE ALLOWED, just for once, to turn to the programme side of broadcasting? I don't see why I shouldn't, since the livelihood of so many of us depends, directly or indirectly, on the programmes being good enough to maintain the interest of those who are already listeners and to attract new ones into the fold. Here's an example of how *not* to do either. On the last Saturday in January running commentaries were broadcast on the rugger matches, France *v* Ireland in Paris and South Africa *v* the Barbarians at Cardiff, commentators at each match being switched in turn by turn. The score was 11 points to 5 against the French towards the end of the second half; but they were pressing hard and there was a chance that they might snatch a last moment win. With two minutes of play to go and a Frenchman's foot poised to take a penalty kick right in front of the posts, Paris was faded out! We were taken back to Cardiff, where eight minutes of play remained. Four minutes before the end the commentator announced that he was returning General Overseas listeners to the studio. That sort of thing should not happen. You can never tell to a minute when a match will end; the necessary flexibility in programme timing could surely be achieved by billing a short gramophone record period to follow any important commentary.

Sing: or Pl:?

THOSE WHO WRITE scientific books and articles seem to have different opinions about the status of the word "data." Some use it as a singular noun, writing "the data is insufficient." Others (of whom I am emphatically one) maintain that this is just as much a linguistic crime as "Cows is queer beasts." Everyone admits that the word is a Latin neuter plural, meaning "given things"; but those who write "data is" claim that it has been absorbed into English as a singular collective word. In support of their contention they often quote "agenda" as a parallel case. Actually, there is no similarity at all, for agenda is just a shortened form of "agenda paper." Data, on the other hand, is the plural of datum; and we do regularly use terms such as "datum line" and "datum level." I await epistolary half-bricks with no misgivings!

Germanium

UNTIL FAIRLY RECENTLY germanium was to most of us nothing more than an element appearing in the Periodic Table under atomic number 32 and with an atomic weight of 72.60. It's a pretty important metal now, for it may have far reaching effects on the future of radio. I wonder if you know the story of its discovery? In 1869 the great Russian chemist, Mendeléev, announced his periodic law and produced the first table of the elements. Though founded on atomic weights (for the significance of atomic numbers was not to be discovered by H. G. J. Moseley until nearly half a century later), it came much nearer to the truth than anything that had preceded it. It contained many gaps, representing elements then unknown. Mendeléev was so sure that three of these elements would soon be found that he named them provisionally eka-boron, eka-aluminium and eka-silicon. The last-named, he foretold, would turn out to be a dull-grey metal, not readily attacked by acids, with a density of 5.5 and an atomic weight of 72. All three were found within the next six years and were given names commemorating the mother countries of their discoverers.

The first two "eka" elements found were scandium and gallium. The last was germanium, found by the German chemist, Winkler, and having properties very close to those predicted for eka-silicon.

Solder-proof Tags

I EXPECT you have come across at some time or other the tag on to which even 60/40 cored solder cannot be made to flow unless you use an iron far too hot for a proper job, and keep it applied much longer than is good for the health of many components. The solder behaves just like a drop of water on a greasy surface, remaining as a little bead and refusing to spread evenly and thinly. That's what happens with the tag that is obviously allergic to solder; but there are other kinds, perhaps even more undesirable owing to the deceptive behaviour of solder when applied to them. At first it refuses to flow on, but your perseverance is eventually rewarded (?) by what looks like a proper "wetting" of the tag. You fix on a wire and the joint looks good enough. But is it? Give the wire a good pull and see. It comes away, bringing most of the solder with it—a dry joint. In their own interests all component makers should be careful to see that all tags used can be easily and quickly soldered, even by the not very skilled. Quickness is essential, for the longer a joint is in the making, the hotter does the component to which the tag is attached become.

UNBIASED

By FREE GRID

Thirty Years of It

IT is by no means too early to start thinking about what improvements we should like to see at the Earls Court Show in the autumn. Now I hate to strike a jarring note in the Hallelujah chorus which was heard on all sides after last year's show, but one thing I missed was the intimate and homely atmosphere of Olympia. This is not, however, a plea for returning there but for removing the air of sepulchral gloom from Earls Court by filling up certain vast spaces which were left almost bare last year.

In particular, I would instance that section of the hall that, in the Motor Show, is filled with yachts and launches. At the Radio Show this large space contained but a few scattered stands and reminded me of one translator's version of Dante's graphic description of "the awful place of doom, where dead men lie as in a tomb."

Surely this space can be filled, this year at any rate, by a replica of the first All-British Wireless Exhibition held just thirty years ago at the Horticultural Hall, London. I feel certain that the big radio and electrical manufacturers who exhibited at the 1922 show would be willing to co-operate by reproducing, as far as possible, the stands—and above all the exhibits—just as they were three decades ago. But we don't want just a dead museum.

It is, of course, the B.B.C.'s thirtieth birthday too and so let the Corporation play its part by feeding a programme complete with 1922 distortion to the stands, and the vintage sets and loudspeakers on show will add their own quota of cacophony. Also, could we not have a reproduction of the Marconi House studio complete with, as far as possible, the original announcers and artistes of that year, not forgetting Captain Eckersley—"Please don't do it."

Another suggestion is for a special Psychic Section where Radiæsthesia and suchlike things would be exhibited and demonstrated. I would undertake to run a stand there myself and demonstrate not only Radiæsthesia itself — or Rhabdomancy, as it used to be called—but also Psycheuresis.

Shades of 1922

Give Us Jacks

APART from their function of providing an extra horror to the so-called delights of picnics, the small mains-battery attaché-case receivers are very useful as second sets for plugging in at home; or at least they would be if they had the small addition of a jack so connected that the loudspeaker is cut out when phones are plugged in. I also find my portable useful in my car to while away the interminable hours spent in the back streets near Oxford Circus while Mrs. Free Grid is choosing a new hat. One does not, of course, need an additional licence when using a portable in a car, so long as the set is not *installed*.

Reverting to the question of phones, it may be objected that nobody uses them nowadays, but I would retort that if they don't do so then a second set in the average household is simply a wanton extravagance. In these days of housing shortage there is no chance of retiring to a separate room if we want to listen to a different programme; the only solution to the problem is a jack on every portable and a *comfortable* pair of headphones — and this means the hearing-aid type. So far as I am aware, no manufacturer turns out a set fitted with a headphone jack; if I am misinformed, please correct me.

I think, too, that in certain households a jack would be a useful feature on the domestic set, but in this case the connections should be such that the loudspeaker is *not* cut out when the phones are plugged in. I refer, of course, to households like my own where some of us who are on the churchyard side of forty are beginning to suffer, not only from presbyopia, which makes us need glasses for reading, but also from what I will call presbyotia, which makes us need something a little more intimate than the loudspeaker; in other words, we are a little hard of hearing, more especially where certain frequencies are concerned, and would welcome a pair of headphones with a variable tone-correcting unit to flatten out the hills and dales of our particular auditory response curve.


Interminable hours

Oriental Statistics

"SAUL hath slain his thousands and David his tens of thousands." Most readers of *W.W.* will, I feel sure, be familiar with this quotation and won't think it comes from Shakespeare. I should, however, have hardly thought that Government officials, who only appear to read their own Blue Books, would have been acquainted with the ancient Eastern custom whereby the higher a person stands in the hierarchy or in popular estimation the greater the number of things he is allowed to dabble in, be it wives, scalps or merely statistics.

That this is so, however, is clear from recent newspaper reports. In the morning papers a person described as "an official of the Post Office" said that the number of television licence dodgers was to be reckoned in thousands. In the evening papers a "*high* official of the Post Office" had played David to the lowlier Saul by raising the estimate to "tens of thousands." But now a very much higher official has quite properly donned the mantle of a much greater than David — presumably Solomon—and we are told that the defaulters are to be numbered in hundreds of thousands—200,000 to be exact.