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# A.M. versus F.M.: End of a Controversy

INTEREST in proposals for the setting up of a v.h.f. broadcasting system may be stimulated by the announcement, made in Parliament on February 18th, that the Postmaster-General has accepted the recommendation of the Television Advisory Committee that frequency modulation should be used. Acceptance of this recommendation was accompanied by a statement that B.B.C. proposals for making a start on an initial group of stations are now under discussion with the Corporation and "further developments will be considered in due course."

This somewhat lukewarm acceptance of the T.A.C.'s Report* is perhaps on a par with the slightly unenthusiastic nature of the Report itself, which has provoked surprisingly little comment in radio circles since it was published on January 18th. The Report starts off on a rather doleful note by saying that the introduction of v.h.f. broadcasting is an "unwelcome complication." In addition to the question of modulation already mentioned, the main recommendations are that the service should be conducted in the band 88-95 Mc/s and that a start should be made on a fairly large scale. The Committee points out the radio industry should be given encouragement to embark on the production of suitable receivers in reasonable volume. This recommendation, if accepted, is a matter for some satisfaction, and is in welcome contrast to the Government's proposals for starting competitive television on a severely restricted basis.

It should be added that the Committee's recommendations apply either to a scheme designed to give national coverage of three programmes or to a network of stations planned to give merely "a substantial reinforcement" of the services at present provided by the B.B.C. on long and medium waves.

A lengthy report from the Technical Sub-Committee is appended to the document, and in it the relative merits of frequency and amplitude modulation are discussed from the point of view both of transmission and reception. As the main point at issue has now been finally decided by the P.M.G.'s acceptance of the Committee's recommendation, there is little value in commenting on these arguments in detail. Considerable stress is laid on the greater capital and upkeep cost of a.m. transmitters, and also on the economics of receivers for the two modulation systems. The conclusions reached are, however, simple and straightforward: "The a.m. wide-band system has specific disadvantages and no advantages relative to the f.m. system. For the a.m. narrow-band system the only advantage is a possible saving in the frequency spectrum required."

Perhaps the most interesting part of the Technical Sub-Committee's report, now that the a.m./f.m. issue is settled, is that dealing with some of the details of f.m. receiver and convertor design. We are pleased to see a recommendation (which is endorsed by B.R.E.M.A.) that standards of good practice should be set up from the start in order to minimize harmful radiation from v.h.f. broadcast receivers. These problems should be studied jointly by the Post Office and Industry.

In general, the discussion on f.m. is based on the acceptance of the almost universal standards of a maximum deviation of $\pm 75$ kc/s and a modulation bandwidth of 15 kc/s.

Just as the Report opens on a rather doleful note, it ends in similar vein. There is a minority statement signed by C. O. Stanley, who considers that adequate attention has not been given by his colleagues to the broader questions of fundamental policy. Mr. Stanley says v.h.f. broadcasting has been a failure in practically every country in which it has been introduced, and casts strong doubts on its advantages in general. He also makes a point of the "incompatibility" of f.m., as recommended for the new service, with a.m. as used for all existing broadcast sound, and which, presumably, will be used for the proposed competitive television service. This last is a provocative point, and in this matter at least Mr. Stanley will probably find some supporters among those who believe that television and sound broadcasting may ultimately be merged into a more-or-less integrated service.

* Second Report of the Television Advisory Committee, H.M.S.O. 1s

# EDWIN H. ARMSTRONG

***The following appreciation of Major Armstrong, whose tragic death is recorded on page 124, has been received from Capt. H. J. Round, who has been responsible for many radio developments in parallel fields.***

The tragic death of Armstrong has given a sincere shock to all his friends, many of whom are on this side of the Atlantic.

The writer first met him in 1917 during the later stages of the war when he was a Major in the U.S. forces then going into Europe, and the friendship then established has been maintained throughout the years.

I had the good fortune to be given a very early demonstration of his superheterodyne in the Paris laboratory he had established, and, as the world knows, this basic invention was followed first by super-regeneration and in 1935 by wide-band frequency modulation.

This, as with some of his other inventions, involved him in very prolonged and expensive litigation, a good deal of which his closest acquaintances thought could have been avoided. However, the intensity with which he attacked technical problems he also applied to his legal problems and there is not much doubt in my mind that this double load clouded his very great intellect in the end.

Since those early years I have met him a few times and have been in constant correspondence with him, and I am happy to think that only a year ago I was able to spend considerable time with him in New York. A sentence of Armstrong's own in his recent paper on "The Spirit of Discovery," in which he eulogizes the work of Marconi, I think applies very well to Armstrong himself: "It is seldom that a man makes two basic discoveries. When a man makes three, his attitude towards problems and his method of work merit close analysis and study." Armstrong should go down in American history as one of her great sons, worthy to be classed with Edison, Bell and Westinghouse.

# INTERFERENCE LIMITS

THE publication by the British Standards Institution of a revision of the Standard specifying the limits of radio interference is of particular interest in view of the announcement that the two committees appointed to advise the P.M.G. on interference from small electric motors and refrigerators have now submitted their reports and, too, that he hopes shortly to lay regulations before Parliament.

The revised BS 800:1954* now covers Band 1 in addition to the long- and medium-wave bands. The limits of magnitude of noise voltages measured from each line terminal to earth are laid down as 750 $\mu$V (40-70 Mc/s) and 1,500 $\mu$V (200-1,605 kc/s) and the limits of noise fields at a distance of 10 metres are 50 $\mu$V/m and 100 $\mu$V/m for the respective frequency ranges. Measuring apparatus and methods of measuring are specified in BS 727:1954,† which has been revised and now covers the range 150 kc/s to 150 Mc/s.

* "Limits of Radio Interference," price 4s.
† "Characteristics and Performance of Apparatus for Measurement of Radio Interference," price 4s.

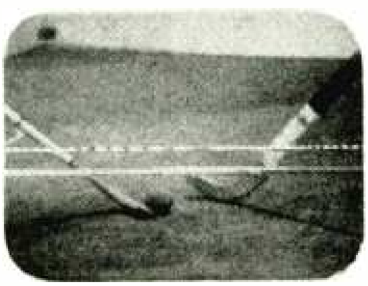
# LAMP INTERFERENCE

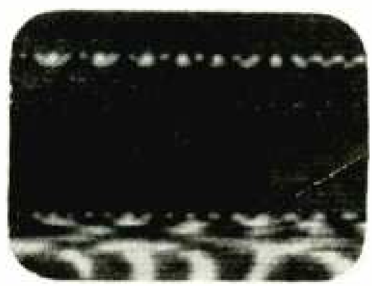
THERE was some mild controversy in our correspondence columns last year over the question of radio interference from electric lamps. The writers of most of the letters contended that radiation was restricted to vacuum lamps, but others stated that trouble was also caused by gas-filled types.

The facts seem to be that neither kind is entirely free of blame, though the vacuum lamp is by far the most serious source of trouble, as it can radiate interference throughout its life and when in apparently perfect condition. Radiation from the gas-filled lamp, on the other hand, usually occurs when the bulb is coming to the end of its life, and is produced by arcing across a minute break in the filament.

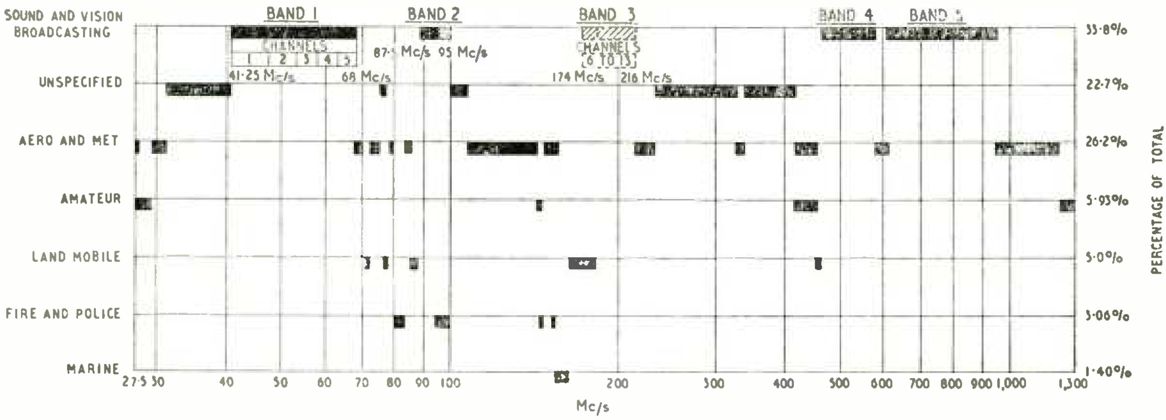
So far as television receivers are concerned, interference from vacuum lamps is generally of the nature shown in the accompanying illustrations (by John Cura). The double line of interference, as in the middle picture, is perhaps the most typical, though the single line on the left is not uncommon. The right-hand picture is an enlargement which shows (at top) the broken nature of a typical interference line.

*Characteristic interference patterns produced on a television receiver by a nearby 60-watt vacuum (traction type) lamp.*





V.H.F. FREQUENCY ALLOCATION (UNITED KINGDOM) 27·5–1,300 Mc/s (LOGARITHMIC SCALE)




# Squandered V.H.F. Channels

*Why There is a Lack of Space for Television and Mobile Radio Developments*

By J. R. BRINKLEY*

IT has been suggested in these columns and elsewhere that the administration of radio frequencies in this country is not working satisfactorily. The situation which has come to light as a result of the pressure for frequencies in Band 3 for additional television services is certainly disturbing and this article has been written in an attempt to clarify as far as possible in a short article what has become a very complicated situation.

The block allocation of the very high frequencies in the United Kingdom is shown at the head of this article and, in conjunction with the diagram, the following three points should be noted:—

1. The "single programme" service of the B.B.C. operating in the band 40-68 Mc/s has room for five 405-line TV channels. This block is probably more than adequate for nation-wide coverage with one programme.

2. The desire for competitive television in this country no doubt stems greatly from the example to be found in the U.S.A. where most large cities have a choice of two or three programmes and where New York has six and Los Angeles seven programmes, all operating on the *immediately practicable* frequencies below 216 Mc/s.

3. If the total frequency spectrum available below 216 Mc/s to sound and TV broadcasting in the U.S.A. (a total bandwith of 92 Mc/s) were currently available in Britain, there would be no difficulty in providing multi-programme TV. It would, in fact, be rather easier, since a British TV channel requires only 5 Mc/s as against the American 6 Mc/s.

Why is it that instead of a total of 92 Mc/s, as in the United States, probably something less than 10 Mc/s can be found in this country for the immediate expansion of television? The answer is, that unlike the U.S.A. and most of the rest of Europe, the U.K. did not reserve adequate frequencies for television at the last International Conference (Atlantic City, 1947) and that subsequently, some of the frequencies which were reserved for television have been given to or taken by other services. Under the Atlantic City agreement, the world is divided into three regions and the U.K. and Europe are in Region 1. The Region 1 allocations to broadcasting (below 216 Mc/s) are 41-68 Mc/s, 87.5-100 Mc/s and 174-216 Mc/s—a total of 81.5 Mc/s. If these bands were available in the U.K., they would be adequate for immediate broadcasting requirements.

Of these three bands, however, it is now apparent that only the "B.B.C." block (Band 1) is available intact. There are two reasons for this: first, Atlantic City footnotes inserted by the British delegation which allocated parts of them to other services, and second, subsequent "national" allocations made in this country to other services. As a result, frequencies have been "lost" on the 87.5-100 Mc/s band to the police and fire services (95-100 Mc/s). Further frequencies have been "lost" in the 174-216 Mc/s to mobile and "fixed" services (174-184 Mc/s) and, in the band 200-216 Mc/s, to aeronautical navigation services (Distance Measuring Equipment—DME). Since the band 87.5-95 Mc/s is intended for sound v.h.f. broadcasting, the outcome of all this is that the only frequencies at present available for TV expansion lie between 184 and 200 Mc/s. But it is important to

* Pye Telecommunications, Ltd.

note that when guard bands and other factors are considered, even this small band is probably not available intact.

We shall now examine the "intruding" services to see how they got where they are.

**Aeronautical Navigation Services—200-216 Mc/s** The authority for operating these services is drawn from footnote 89 to the Atlantic City agreement which states—"In the U.K. DME will be operated on the band 200-235 Mc/s until such time as world standardization (of DME) on 1,000 Mc/s has been accomplished." This footnote precludes the use of TV in this band since it is obviously incompatible with DME. On the other hand, continental Europe plans TV stations in this band *authorized by the agreement*, which would make 200-Mc/s DME unworkable in the U.K. It will be observed in passing that world standardization of DME on 1,000 Mc/s was an even more remote possibility in 1947 than it is at this moment.

It is unfortunate, therefore, that these frequencies were earmarked for a service which is prejudiced by Continental TV planning, and yet at the same time could only be used by British TV stations by closing down such services and ignoring the Atlantic City provisions. (Footnote 87 states categorically—"the band 200-216 Mc/s is allocated for the aeronautical radio navigation service.")

**Fixed Services—174-200 Mc/s.**—These are point-to-point G.P.O.-type telephone links (e.g., between islands in the Channel Isles). International authority for them is obtained under footnote No. 87 which states "In the U.K., the band 174-200 Mc/s is *also* allocated for the fixed service." This footnote was not very realistic since with anything but exclusive band allocations, the planning of broadcasting services will prove unnecessarily difficult.

**Mobile Services—174-184 Mc/s.**—The occupiers of these frequencies include mobile services operated by ambulances, railways, the Press, industrial users, electricity, gas and oil undertakings and the majority of radio taxi services. These services have been operating in this band since 1948-9. Such services were first allocated frequencies in the 70-Mc/s band, but in 1948 the G.P.O. made it known to manufacturers that all future allocations would be in the 156-184-Mc/s band which would be the "permanent and secure band for such services." This was a great embarrassment at the time since no suitable apparatus or valves were available for these frequencies. After 12 months development, fitting in the new band began and has been proceeding ever since. It was not realized, and the G.P.O. did not point out, that this allocation was not in accordance with Atlantic City. The recent official statement by the Postmaster-General that these frequencies will be cleared for TV has created a situation in which manufacturers and users, who have invested heavily in this band, have lost confidence in all official statements regarding the allocation of mobile frequencies. Their confidence will only be restored by adequate compensation for loss of frequencies and capital investments and written Government undertakings giving long-term security in any new arrangements made for them.

One of the outstanding shortcomings of the Atlantic City agreement and most of the subsequent planning provisions is that virtually no account is taken of guard bands. Thus, for example, in continental Europe one country may operate mobile stations up to the limits of the International allocation; for example, up to 174 Mc/s, and an adjacent country may operate TV down to 174 Mc/s. In the border areas, the two types of transmission will experience serious mutual interference, but both countries will be operating within their rights. A very substantial guard band will be required to obviate such interference, but no agreed assessment exists as to the extent of such guard bands or as to how their provision will be shared between the adjacent services.

This problem is equally important within the borders of any one country. In the U.K. it has a most significant bearing on the present Band 3 problems. The interference suffered will be two-way. It will be caused to the mobile service because as can be seen from Fig. 1, TV transmitters radiate appreciable power several megacycles beyond their allocated channels. Likewise, interference will be caused to the TV service because of the very poor selectivity employed in most TV receivers. An example of sound

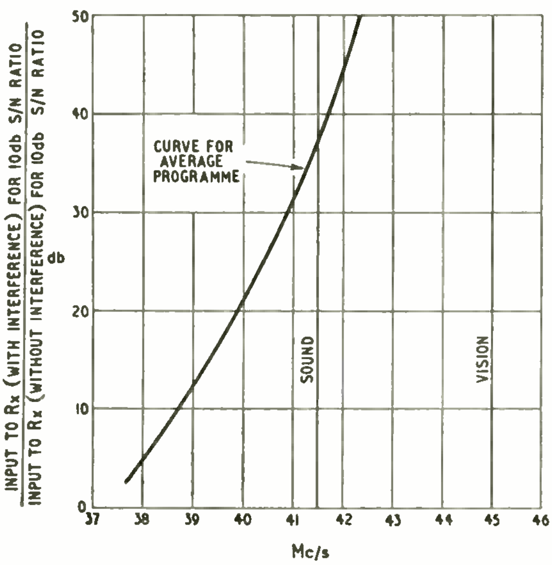



*Fig. 1. This diagram shows the increase of wanted signal level required to restore the signal-to-noise ratio after the Alexandra Palace TV transmitter has been switched on. The out-of-band radiation was measured at 1½ miles from the television station.*

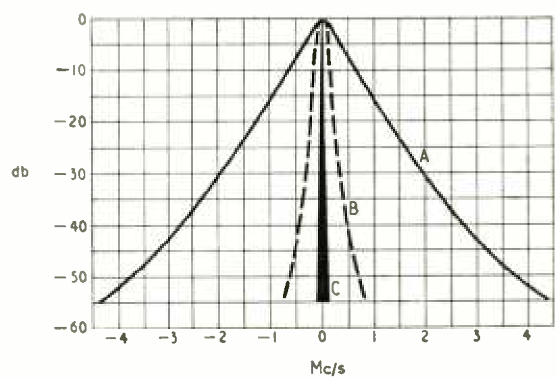



*Fig. 2. Comparisons of the selectivity of different receivers. A, sound channel of typical television receiver; B, German domestic v.h.f. receiver; C, typical mobile v.h.f. receiver.*

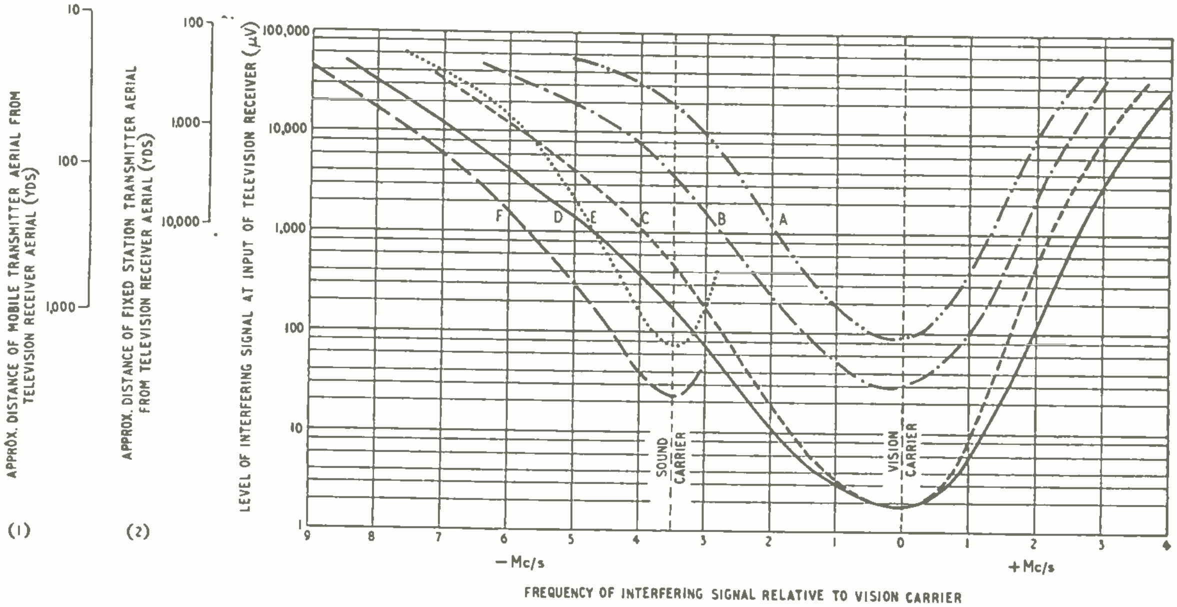



*Fig. 3. Estimated interference from mobile services to TV receivers. The curves show the input of interference needed at the television receiver and frequency separation from the vision carrier for various conditions of interference. Curves A (300$\mu$V) and B (30$\mu$V) are for interference just sufficient to cause picture tearing, while C (300$\mu$V) and D (30$\mu$V) are for just discernible interference. Curves E (170$\mu$V) and F (25$\mu$V) are for just audible interference on the sound channel. The curves are for the TV signal levels shown in brackets. Scales are added to relate the interference input to distance in yards between the TV aerial and the aerial of a mobile transmitter (1) and a fixed transmitter (2), in both cases for a power of 15W.*

channel selectivity characteristics is shown on Fig. 2. Television receivers have so far been designed without any serious attention being paid to providing adjacent-channel selectivity, and the effect of this is shown in Fig. 3, in which interference to a TV receiver from a mobile transmitter is estimated for various ranges.

This article is not necessarily a plea for adopting American methods of frequency allocation which have their own shortcomings and are being currently criticised. It is to be noted, however, that the present U.S. methods have made multi-programme TV widely available in that country, while "frequency shortage" is making it more than difficult in this country. Direct comparisons are not easy, but the U.S. achievement does not appear to have been at the expense of mobile radio development. There are estimated to be more than 300,000 radio equipped mobiles operating in the U.S. as against fewer than 10,000 in the U.K.

In America, the Federal Communications Commission has been able to publish a great deal of documentation on the subject of frequencies, much of which is well conceived. It is specific in matters of policy and detail in a way in which it is of the greatest possible value to manufacturers and operators alike. No such documentation is available in this country.

It is suggested that three preliminary steps are necessary to put frequency allocation on a sound basis. First, there must be a clear legal basis for frequency allocation. The only existing legislation relating to frequencies is the Wireless Telegraphy Act. This gives the P.M.G. the widest possible powers relating to the establishment of transmitting stations. But it has been stated that the P.M.G. does not regard himself as responsible for "overall" frequency allocation which is carried out by an "Inter-departmental Committee." This vital function is, therefore, apparently carried out by an anonymous committee for which the writer can discover no legislative authority. Such an arrangement is not likely, in the writer's opinion, to produce the best results.

Secondly, there must be a clear declared policy in matters relating to frequency allocation. As an initial step in establishing a policy, the Government must make up its mind whether or not it intends to stand by the international frequency agreements to which it is signatory.

Thirdly, there must be adequate independent machinery to administer the policy laid down in an equitable manner. The writer suggests that the American F.C.C. is by far the most advanced example of such machinery to be found anywhere in the world to-day.

## "Introduction to Valves"

MOST radio textbooks either take it for granted that the reader knows all about valves or deal with the subject rather sketchily. On the other hand, books written about valves specifically are often too highbrow and specialized, not to mention expensive. Where, then, is the radio man with only a nodding acquaintance of the subject to get the sort of information he wants? The answer is to be found in "Introduction to Valves" by R. W. Hallows, M.A.Cantab., M.I.E.E., and H. K. Milward, B.Sc.Lond., A.M.I.E.E. This is a comparatively small book, but a careful selection of material has ensured that its 152 pages and 107 illustrations provide just the right kind of information for everyday radio work.

An important feature of the book is that it explains the operation of the valves in typical circuits—they are not just left in mid-air, so to speak. Beginning with an exposition of fundamental principles, there are chapters on diodes as rectifiers and detectors; triodes; tetrodes and pentodes; multiple-grid valves for frequency changing; power-output valves; and valves for v.h.f. and e.h.f.

The book can be obtained from any bookseller, price 8s 6d, or direct from our publishers at 9s by post.

# Cathode Follower Oscillator

*Using RC Networks with a Voltage Step-up*

By THOMAS RODDAM

IN an article in last month's issue I described an oscillator circuit in which the valve was connected as a cathode follower. The valve in this circuit really uses a cathode follower, too, with a sufficiently high cathode load for the negative feedback to dominate the system completely. The circuit was analysed as a particular circuit, but it was mentioned that it could be regarded as a member of a class of oscillators, those using over-balanced rejector circuits. In fact I had overlooked one variant, which is not a rejector circuit at all, so that the classification becomes just that of a cathode-follower oscillator. Most of these use only resistances and capacitances (or inductances), although last month's variant included all three types of element, and it is of some interest to survey the properties of the group as a whole.

The feature of the cathode-follower oscillators which makes them especially interesting is that most of them use a resistance-capacitance network to give a voltage step-up. When we think of an RC network we always see ourselves carrying out a lot of voltage divider calculations, and getting out less than we put in: it isn't necessarily so, however, and the way in which these circuits provide the step-up is so simple that it seems incredible that no one should have spotted it before 1947.* We need a step-up, of course, if we want to use a cathode follower, because we can never get quite as much at the cathode as we put in at the grid. The step-up need not be very large.

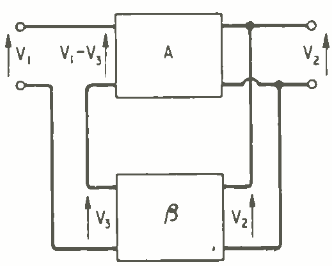



*Fig. 1. The basic feedback amplifier or oscillator consists of the amplifier A and the feedback β.*

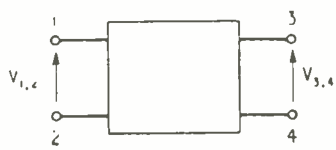



*Fig. 2. A passive quadripole with two input terminals, 1,2 and two output terminals, 3,4.*

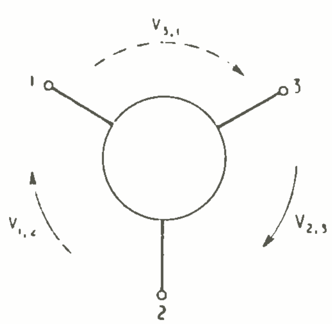



*Fig. 3. If terminals 2 and 4 have an internal connection in Fig. 2, the system can be drawn like this. The input terminals are still 1,2, but the output can be taken from 3,2 or 3,1.*

First of all, let us look at the basic feedback oscillator. This is one way of looking at the general idea of an oscillator, a way which happens to be very convenient for purposes of analysis. The circuit is shown in Fig. 1 and it looks, indeed is, just our old friend the feedback amplifier. As you will remember, the basic equations for this take the form:

$$V_2 = A(V_1 - V_3)$$
$$V_3 = \beta V_2$$
$$\text{so } V_2(1 + A\beta) = AV_1$$
$$\frac{V_2}{V_1} = \frac{A}{1 + A\beta}$$

These are the equations in the form most convenient for amplifier working, with no minus signs to think about: some people prefer to put in a minus sign in the appropriate place, and with the gain as $m = \mu(1 - \mu\beta)$. It boils down to the same thing in the end.

As you can see, if $A\beta = -1$, the gain will be infinite, so that if we close the input terminals through a finite but very small resistance, the noise in this resistance will still be amplified up to the overload point of the circuit. In fact, it will oscillate, and that bit about noise was just to show how the oscillation starts. A practical oscillator will always have $A\beta = -k$, where $k > 1$, with very low level conditions, and the amplitude of oscillation will grow until something in the circuit alters A or $\beta$ to reduce $A\beta$ to unity. It is perfectly possible for such a circuit, with $-A\beta > 1$, to be stable, and amplifiers which are "conditionally stable" have in fact been used. One of the advantages of the feedback amplifier approach to oscillator theory is that it helps to clarify the behaviour in these special cases, which are often associated with "mode jumping" and other awkwardnesses.

The other way of treating oscillators is to lump some components with the valve into a package which gives a negative resistance across two terminals. Transistors, with their built-in positive feedback, are easily considered in this way. Again we have two boxes, but the way the elements are split between them is different. The final answer must, of course, be exactly the same.

It will be clear that the problem which confronts us in designing a cathode-follower oscillator is that of obtaining a suitable network for the $\beta$ box, remember-

* "An RC Circuit Giving Over-Unity Gain", C.L. Longmire. *Tele-Tech*, April 1947

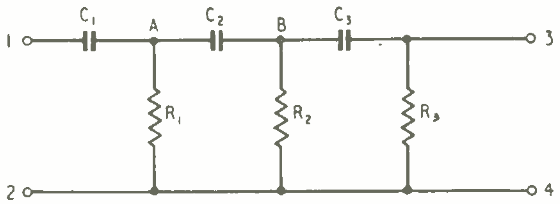



*Fig. 4. Resistance-capacitance circuit used in the phase-shift oscillator.*

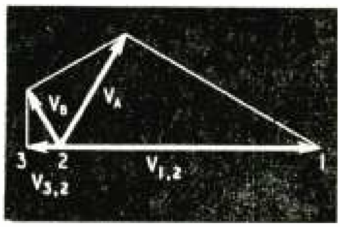



*Fig. 5. Vector diagram for the voltages in Fig. 4.*

ing that in the box marked A we have a gain of about 0.9 − 0.95 and no phase shift.

Let us consider the "passive quadripole" shown in Fig. 2. Just a box, with four terminals, of which two are called inputs (1, 2) and two called output (3, 4), looking unpleasantly like the introduction to some heavy mathematics. We can simplify matters by joining 2 and 4 together, because all the systems we want to discuss actually have got an internal connection here, which we usually think of as earth. This is the trap into which we must not fall. Let us re-draw the circuit in a more non-committal form (Fig. 3). The voltage arrows now run clockwise between each pair of terminals, and a new one, $V_{3\cdot1}$, has been dotted in. When we apply a voltage $V_{1\cdot2}$ across the input terminals 1, 2, we can now say that we get an output of $V_{3\cdot4}$ across 3, 4 in Fig. 2, or outputs of $V_{2\cdot3}$ ($= -V_{3\cdot4}$ of Fig. 2) across 2, 3 in Fig. 3 or an output of $V_{3\cdot1}$ across 3, 1 in Fig. 3. Quite clearly we must have $V_{3\cdot1} = -(V_{1\cdot2} + V_{2\cdot3})$, and looking at Fig. 2 again this means $V_{1\cdot3} = V_{1\cdot2} - V_{3\cdot4}$.

Suppose that the network inside the box in Fig. 2 produces a loss of $n$ times, with a phase shift of 180 degrees. Then we shall have $V_{3\cdot4} = -n\ V_{1\cdot2}$, when $n$, of course, is a proper fraction. Obviously $V_{1\cdot3} = (1 + n)\ V_{1\cdot2}$. We can consider terminals 1, 2 as input, and 1, 3 as output, and we have got a step-up of $1 : (1 + n)$ in this network, which we thought was just attenuating and shifting phase.

So far we have been discussing the rather depressing "passive quadripole" but it may make things rather clearer if we consider a specific circuit. The circuit shown in Fig. 4 is the one we associate with the phase-shift oscillator. The limiting case of this network is when $C_1R_1 = C_2R_2 = C_3R_3$ and $R_1 \ll R_2 \ll R_3$, and this limiting form is particularly easy to analyse. At one frequency each RC section produces 60 degrees phase shift, so that the vector diagram shown in Fig. 5 is obtained, with $V_A$, the voltage across $R_1$, equal to one-half $V_{1\cdot2}$ and rotated 60 degrees. The following RC circuits each divide the voltage by 2, giving $V_{3\cdot4} = -\frac{1}{8}V_{1\cdot2}$.

As we have already shown, $V_{1\cdot3} = (1 + n)\ V_{1\cdot2}$, where $n$ is here equal to $\frac{1}{8}$. Redrawing the circuit in the way shown in Fig. 6(a) we have a rather odd-looking network which provides a step-up ratio of 9 : 8 although it uses only resistance and capacitance elements. The network shown in Fig. 6(b) is the step-up version of the other phase-shift oscillator circuit, the one with the C's and R's interchanged, but this time it has been arranged rather differently to bring out two features of the circuit, the common connection at one side of the capacitances and the d.c. path on the output side.

These two circuits are often constructed with equal values of C's and R's, and the output voltage from the basic network is then only 1/29 times the input. This means that when twisted round we get only 30/29 times the input, which is very tight indeed for use with a cathode follower. There are various compromise solutions, all of which are inconvenient in one way or another.

## Choice of Circuit

If we want to make the collection of diagrams more impressive, we can consider the 4-stage RC networks and also the corresponding 3- and 4-stage RL networks. There is a great deal of tedious algebra already published about these networks. Some of it can be replaced by common sense: for example, it needs no mathematics to see that the arrangement of Fig. 6(b) lets harmonics through easily, while if it were an RL network the harmonics would be attenuated. It needs no algebra to show that the input impedance of the Fig. 6(b) network is more than $R_1$, and in the

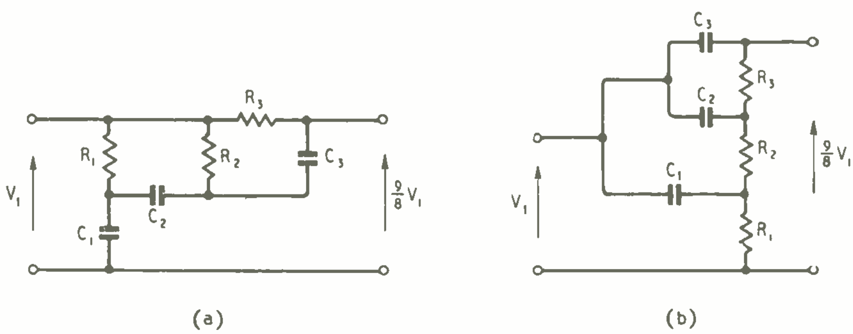
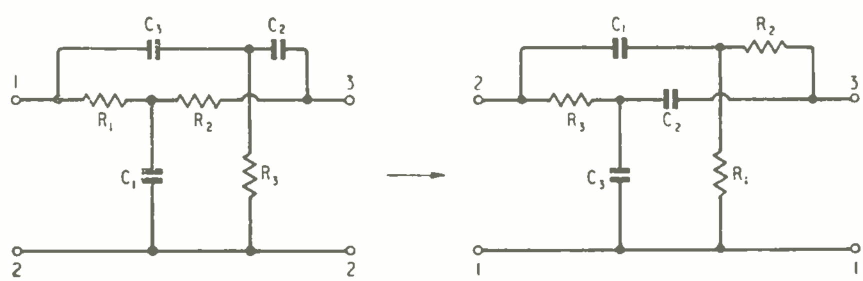



*Fig. 6. The circuit of Fig. 4 can be redrawn either as in (a) or, if we take the output across 3,1, as in (b).*

*Fig. 7. The parallel-T on the left transforms to that on the right in its step-up form.*



limiting graded case is $2R_1\ (R_1 + j\sqrt{3}R_1)$. In a practical design this input impedance will be part of the cathode load of the cathode follower, and the value of $R_1$ must, therefore, be high enough to provide the proper gain conditions.

The networks we have been considering so far have been phase-shift networks with some attenuation, but the attenuation has been of the smoothly falling kind: monotonic, the mathematicians call it. The only condition is that the network must be complicated enough to give more than 180 degrees phase shift.

We must now turn to the other sort of RC network, of which the parallel-T is the most familiar example. This network, in its basic form and its twisted round form, is shown in Fig. 7. We could write down the network equations and find out what happens: the answer, in the particular case, when $R_2/R_1 = C_3/C_2 = m \to \infty$, and $R_3/R_1 = C_3/C_1 = n = 0.41$, gives a step-up of 1.207 under zero phase conditions. A simpler way of seeing what happens is to draw the network in the form shown in Fig. 8 and build up a vector diagram on the assumption that the $R_2C_2$ arm does not load the rest of the network at all. This is, of course, exactly what the algebraists have done in taking $m \to \infty$. The resulting vector-diagram is shown in Fig. 9. and gives a clear indication of how the voltage step-up occurs.

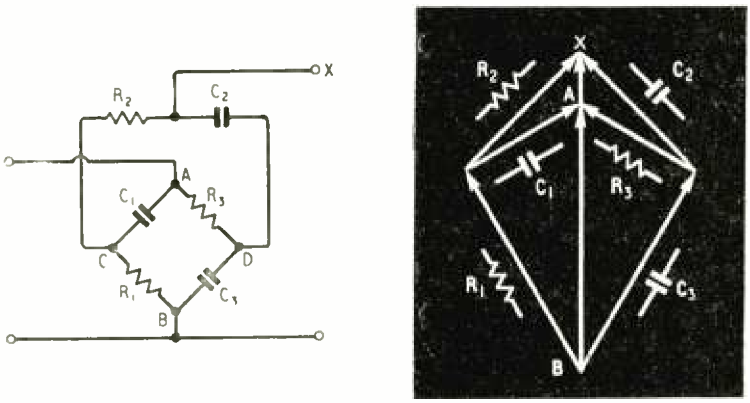



*Fig. 8. Another way of drawing the transformed parallel-T circuit, and (right), a vector diagram of the network voltages.*

You can have a busy time extending Fig. 8 too, and Fig. 9 (*Wireless Engineer* Jan. 1953, Fig. 6, p.21) shows how Bacon and Salmon have done this. Their network, with the values shown, was calculated to give a step-up of 1.98 times, and actually gave 1.68 times at 640 c s.

Just as the parallel-T network gives, in its twisted-round form, a desirable step-up, so does the series-$\pi$, its dual. As you would expect, the series-$\pi$ gives a current step-up, but by working it back to front the wanted voltage step-up is obtained. A large collection of these arrangements is given by S. C. Dunn in *Wireless Engineer* Jan. 1953 (Figs. 2 3), from which Fig. 10 has been taken (2e, 3e *loc. cit.*).

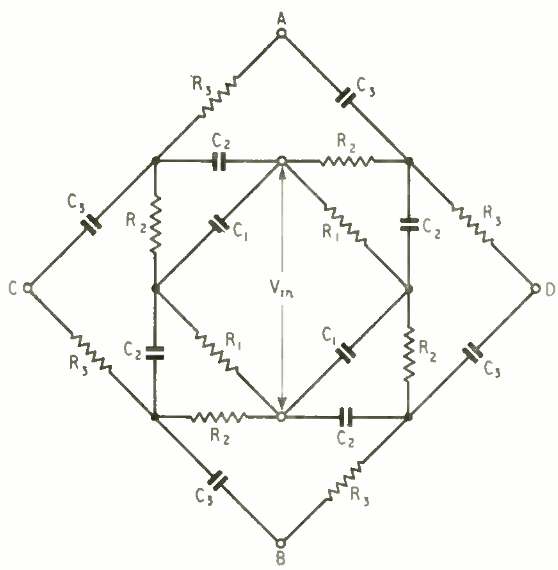



*Fig. 9. Four-phase step-up network giving a measured gain of 1.67 at 640 c s. $R_1 = 100\Omega$, $R_2 = 1k\Omega$, $R_3 = 50k\Omega$, $C_1 = 2.5\mu F$, $C_2 = 0.25\mu F$, $C_3 = 0.005\mu F$.*

It is, I think, unnecessary to add the two variants of the bridged-T LCR circuit to this figure: the relationship between bridged-T and parallel-T is well known, and the advantage of the bridged-T, the very much higher Q, is another of those things which can be regarded as self-evident.

The circuit of Fig. 10 is obviously a very useful one for oscillators. The basic oscillator circuit is shown in Fig. 11, from which you can see that there is a convenient capacitance $C/n^2$, across the grid-earth circuit to absorb some of the valve capacitances, and a d.c. path back for the grid to enable the bias conditions to be fixed. The resistance $R_4$ is rather inconvenient, because if it is large enough to make the cathode follower work properly it will upset the bias conditions. One way out of this difficulty is to replace $R_1$ by a transformer, the solution adopted in the oscillator described last month. The other easy way out is to split the bottom resistance R into two parts, $R_a$ and $R_b$, which in parallel equal R, but are connected as in Fig. 11(b) to lift the grid positive. Provided that the supply voltage is sufficiently high, this arrangement should be very stable indeed because of the very large amount of d.c. feedback applied to the valve in such a way as to keep the cathode current constant.

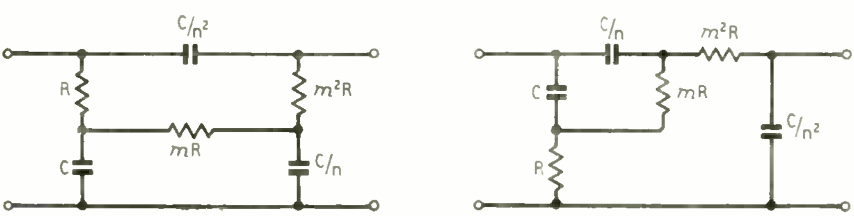



*Fig. 10. The series-$\pi$ network on the left can be twisted round to give the step-up network on the right. This form is especially convenient for use with valve circuits.*

These oscillators which use the balanced type of network must not be confused with the parallel-T oscillators which are already well known. The common form of the parallel-T network applies negative feedback through the parallel-T, and some positive feedback through a separate resistive network. The negative feedback keeps the amplifier from oscillating except at the frequency at which the network is balanced. Here the only feedback is through the network, which does not operate at the normal balance point, but at what may be termed a special over-balanced point.

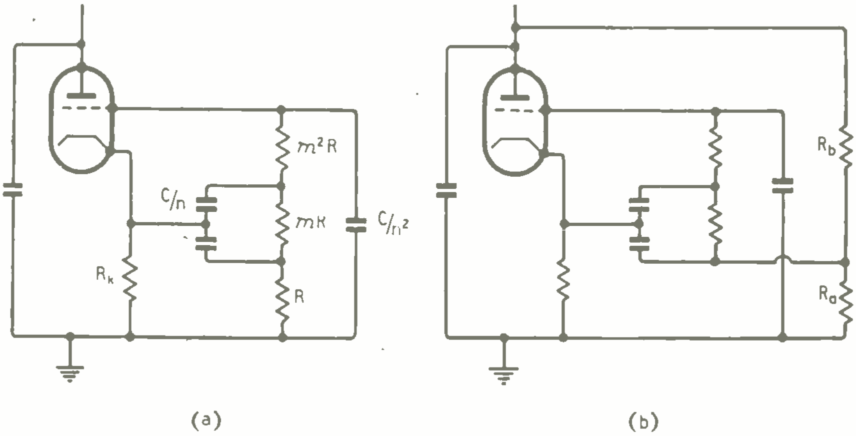



*Fig. 11. (a) Basic oscillator derived from the circuit of Fig. 10, together with, (b) a modification, $R_b$ and $R_a$ replacing R, to get suitable bias conditions.*

There is not much more to be said about these oscillator circuits, unless we settle down to calculate particular values. A great deal of the analysis has already been published by Dunn, and anyone who wishes to study the matter in more detail is recommended to refer to his paper and to the references given at the end of it. This paper also discusses the use of the system under non-oscillatory conditions, as a selective amplifier. Feedback amplifiers incorporating RC networks are extremely useful for very low frequencies, where high values of Q cannot be obtained easily with LC networks, but this is outside the scope of this article.

## CLUB NEWS

**Birmingham.**—The March 5th meeting of the Slade Radio Society will be held at the Imperial Hotel, Temple Street, Birmingham, at 7.30, when a film-illustrated talk on valve manufacture will be given by a representative of Mullard's. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

**Brighton.**—Meetings of the Brighton and District Radio Club continue to be held at the Eagle Inn, Gloucester Road, Brighton, every Tuesday at 7.30. The club transmitter (G3EVE) is on the air on the second Tuesday of each month on 80 metres using both 'phone and c.w. Sec.: T. J. Huggett, 15, Waverley Crescent, Brighton.

**Cleckheaton.**—"Crystal Microphones and Pickups" is the subject of the talk by N. G Newman, of Rothermel, Ltd., to be given at the meeting of the Spen Valley and District Radio and Television Society on March 24th. Meetings are held on alternate Wednesdays at 7.30 at the club headquarters in the Temperance Hall, Cleckheaton. Sec.: N. Pride, 100, Raikes Lane, Birstall, Nr. Leeds.

**Romford.**—"Television Interference and Transmitter Design" is the subject of the talk to be given by Louis Varney, A.M.I.E.E. (G5RV), to members of the Romford and District Amateur Radio Society on March 30th. Meetings are held each Tuesday at 8.15 at R.A.F.A. House, 18, Carlton Road, Romford. Sec.: N. Miller, 10, Rom Crescent, Romford.

**S.E. London.**—Meetings of the Clifton Amateur Radio Society (G3GHN) are held every Friday evening at the society's headquarters, 225, New Cross Road, S.E.14. Sec.: C. H. Bullivant (G3DIC), 25, St. Fillans Road, Catford, S.E.6.

**Southend.**—At the meeting of the Southend and District Radio Society on March 19th, G. T. Peck, of Ernest Turners, High Wycombe, will speak on the radio control of models. The society meets at the Municipal College Laboratories, Queens Road, Southend-on-Sea, on alternate Fridays. Morse and theory classes are again being held at 27, Park Road, on Tuesdays and Thursdays at 8.0. Sec.: J. H. Barrance, 49, Swanage Road, Southend-on-Sea.

**Wellingborough.**—A talk on television aerials will be given by J. W. Hobley at the March 18th meeting of the Wellingborough and District Radio and Television Society. The club meets each Thursday at 7.30 at the C.W.S., Silver Street, Wellingborough. Sec.: R. J. Henty, 6B, Silver Street, Wellingborough.

**Wolverhampton** Amateur Radio Society recently moved to new headquarters at Stockwell End, Tettenhall, where the club transmitter (G8TA) is being installed. The club meets fortnightly on Mondays with morse classes on the alternate Mondays. Sec.: H. Porter (G2YM), Applegarth, 221, Park Lane, Wolverhampton.

**QRP.**—Readers interested in the low-power operation of transmitters, whether it be for communication or the control of models, are invited by the QRP Research Society to send for details of membership and a specimen copy of the Society's journal. Contests for both transmitters and short-wave listeners are held throughout the year and a QRP net is organized each Sunday at 2.30 on 1.9 Mc/s. Sec.: J. Whitehead, The Retreat, 92, Rydens Avenue, Walton-on-Thames, Surrey.

**Radio Control.**—At the meeting of the Birmingham group of the International Radio Controlled Models Society on March 6th at 2.30 at the International Centre, Suffolk Street, Birmingham, J. Merrick will speak on "A Reliable Receiver." A demonstration of a radio-controlled model land vehicle will be given by R. F. Stock at the meeting of the London group on March 14th at 2.0 at the Horseshoe Hotel, Tottenham Court Road, London, W.1. Sec.: C. H. Lindsey, 55, Tenison Road, Cambridge.

## Standard Valve Symbols

ADDITIONAL symbols for electronic tubes and valves, including gas switches, are given in Supplement No. 3 (1953) to B. S. 530:1948 (Graphical Symbols for Telecommunications). The basic electrode symbols are given, together with examples of their assembly to represent complete valves. The emphasis is on cold-cathode discharge valves and many of the symbols are unfamiliar ones. Travelling-wave valves, cavity magnetrons, velocity-modulation valves and photo-voltaic cells are included, as well as TR cells or gas switches. The Supplement is issued by the British Standards Institution, 2, Park St., London, W.1, price 2s 6d.

# Measurement of Harmonic Distortion

*Self-contained Direct-reading Instrument for Works Testing and Servicing*

By T. D. CONWAY,* B.Sc.(Eng.). A.C.G.I., A.M.I.E.E.

NUMEROUS articles have been written on the general aspects of audio distortion, its detection, and cure, but these notes are intended to cover the specifically practical problem of measuring distortion on a mass production flow-line, and objectively assessing distortion in a service department handling audio equipments. Many methods of distortion measurements are already available, but on examination they were all found to require skill and time to give accurate results, whereas what was wanted was a direct-reading instrument capable of giving accurate repeatable measurements with unskilled labour.

This type of measurement is becoming of great importance in the manufacture of tape recorders, where it is usual to set the maximum recording level to correspond to a definite amount of distortion, which is a compromise between dynamic range and quality. The increasing emphasis on fidelity in amplifiers makes it necessary to check quickly performance figures of output against distortion to verify that the equipment meets the published specification.

In this article it is proposed to deal only with harmonic distortion, that is to say harmonics produced in the output of a system when a single frequency is applied to it: normally the amount of harmonics produced will depend upon the input signal and hence it may often be necessary to plot a curve relating input to distortion in the output. The distortion factor of a periodic voltage is the ratio of the total r.m.s. voltage of the harmonics (i.e., the square root of the sum of their squares) to the total r.m.s. voltage. When this figure is multiplied by 100 it gives what is known as the percentage of total harmonic distortion, or more simply percentage of total distortion.

In some cases where we know that a certain harmonic is more pronounced than others we may consider only its ratio to the total r.m.s. voltage, and this we will call the percentage of second or third, etc., harmonic distortion. In tape recorders the third harmonic is dominant and of chief interest, as it is in push-pull amplifiers. In Class A triodes the second harmonic is dominant, and in pentodes all harmonics up to the fifth are usually significant.

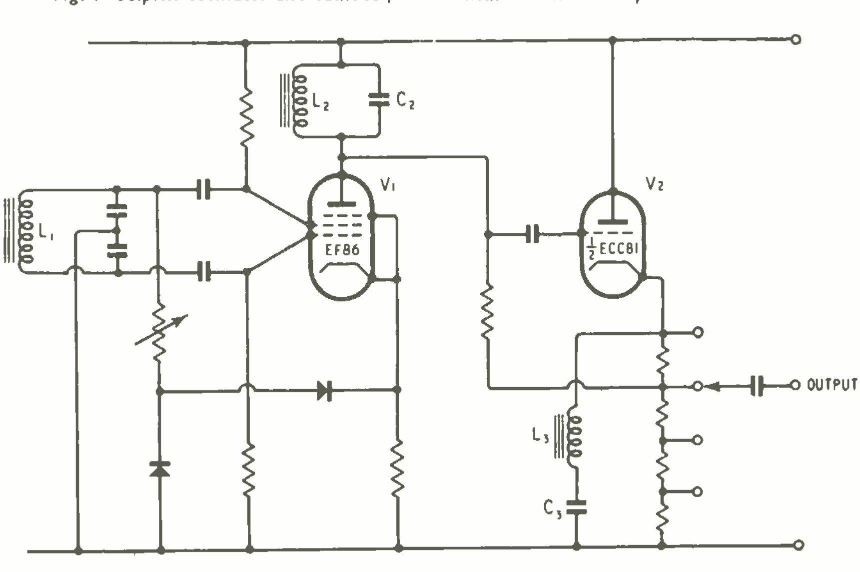
When the percentage of total distortion is small (i.e., less than 10 per cent), it may be more simply expressed as the square root of the sum of the squares of the individual harmonic percentages. The calculated error of such a simplification is less than one part in two hundred,

i.e., $D_{total} = \sqrt{(k_2)^2 + (k_3)^2 + \ . \ . \ .}$ where $k_2$ = percentage 2nd harmonic, $k_3$ = percentage 3rd harmonic, etc.

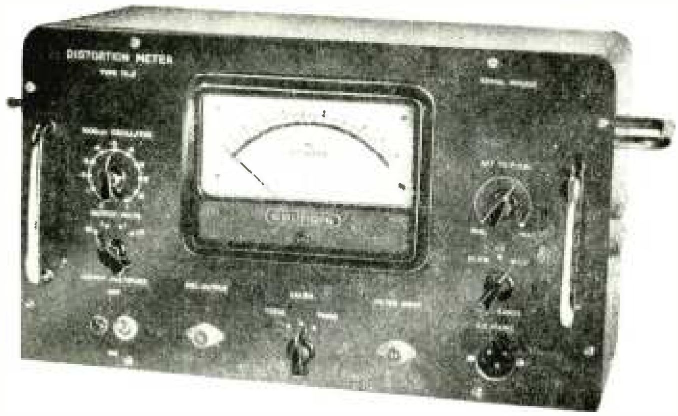
In order to make a comprehensive assessment of distortion on a piece of equipment, measurements should be carried out over the whole of the working frequency range, due regard being paid to neglect those harmonics which lie outside the audible range. The test procedure is lengthy and considerable skill is needed to give the correct results. A simple system should be usable by unskilled labour, involve no calculation or charts, and preferably be direct reading.

Since we are more concerned here with the testing of distortion, the first simplification to suggest itself is the use of a single frequency, and to provide that frequency with the distortion-measuring circuit in a

*Fig. 1 Colpitts oscillator and cathode follower with less than 0.25 per cent distortion.*




*Grundig (Gt. Britain) Ltd.




*In the Grundig Type TGS distortion meter, controls associated with the 1,000-c s oscillator are on the left and those for range selection and calibration on the right.*

single self-contained unit. The next problem is to decide which individual harmonics are of interest, or alternatively whether the total harmonic distortion is to be measured. For our particular problems a frequency of 1,000 c/s was chosen, and it was decided to provide facilities for measuring either the percentage of total distortion of that of third harmonic distortion.

As explained previously a true measurement of total distortion involves the r.m.s. summation of all harmonics, and this can only be carried out by using either a thermal instrument, square-law valve voltmeter or a suitable dynamometer. For practical purposes these all have to be ruled out, and it was decided to carry out some tests on a "1-milliamp" full-wave bridge instrument rectifier, in conjunction with a 100-microamp meter. First, it was found that the superimposition of 10 per cent of second or third harmonic on the fundamental only affected the reading by less than $\pm 1$ per cent as its phase was changed, hence as an indicator of the r.m.s. value of a distorted wave it is sufficiently accurate. Secondly, 5 volts of 2,000 c/s and 5 volts of 3,000 c/s fed together gave a deflection of 6.8 volts, which is within reasonable limits of the calculated value of 7.07; again phase variation between the two can cause a difference, but since all harmonics will be generated from the original signal the phase relationship on any equipment should be constant.

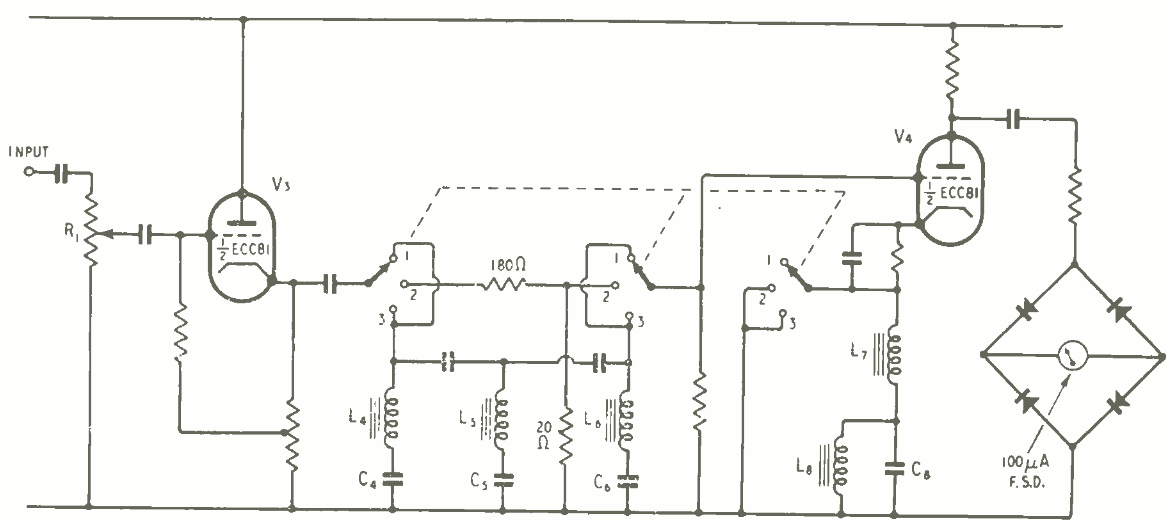
An equipment was developed on the above lines, provision being made to measure up to 10 per cent of third or total harmonic distortion by direct reading, for a 1,000-c/s oscillator of low harmonic content having an output continuously variable up to 10 volts, and for the accommodation of inputs between 10 millivolts and 100 volts.

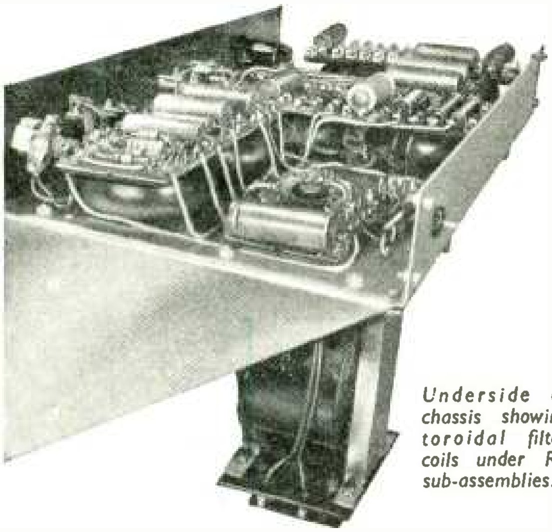
**Oscillator Unit.** The oscillator needs to be stable in operation and to have as low a harmonic content as possible. A Colpitts circuit was chosen and arranged as an electron-coupled oscillator to buffer the tuned circuit, with a tuned anode to reduce the output of harmonics. In order to maintain the minimum of harmonic content the amplitude of such an oscillator must be closely controlled, and as a first approach the h.t. supply was regulated by a neon type stabilizer. Next some attempts were made to limit the amplitude by negative feedback, but although this produced excellent results, satisfactory starting could not be guaranteed.

Finally a germanium diode was used between the anode of the oscillator and the cathode via a variable feed resistor which gave perfect control of amplitude. When oscillation starts the diode acts as a high impedance across the tuned circuit, biased by the cathode-to-earth voltage, and does not conduct. As the amplitude of oscillation increases the diode begins to conduct and increases the cathode potential of the oscillator, thus automatically controlling its amplitude. A high-impedance d.c. return for this current is provided by a second diode.

The final arrangement as shown in Fig. 1 was extremely stable and had a harmonic content of less than ¼ per cent. A cathode follower was used for the output stage to give complete isolation and to provide a simple form of output attenuator. Since

*Fig. 2. A three-section filter, with toroidally wound inductances, is used to suppress the fundamental.*





*Underside of chassis showing toroidal filter coils under RC sub-assemblies.*

a trace of second harmonic was introduced by the cathode follower, a simple acceptor circuit was added across the cathode load, bringing the total distortion content of the output down to less than ½ per cent.

**Distortion Measuring Unit.** The design of filter units is greatly simplified by the use of low-impedance values, and this in turn limits the dangers of stray pick-up and removes the necessity for shielding. For the inductances toroidal windings were used, since high Q's can be readily obtained and the stray field is virtually negligible.

To remove the fundamental 1,000 c/s a three-section *m*-derived high-pass filter was employed, fed from a cathode follower input of approximately 200 ohms output impedance. Attenuating ranges were fitted both in the grid and cathode circuits so that a range of inputs between 100 millivolts and 100 volts could be accommodated.

The general circuit layout is shown in Fig. 2. In the central position (2) the signal passes straight from cathode follower input via a 10/1 attenuator to the output stage which has a full-wave bridge rectifier meter in its anode circuit. In the final arrangement an additional RC-coupled stage was added before the output valve in order to give sufficient gain to work at inputs down to 100 millivolts. A conventional "1-milliamp" full-wave bridge rectifier is employed with a 100-microamp movement meter. The incoming wave is adjusted by the input control $R_1$ to give full-scale deflection of the meter, and the instrument is now "calibrated" to measure the distortion of the incoming signal.

To measure the third harmonic percentage the switch is placed in position 1 when the signal passes first through the high-pass filter which attenuates the fundamental by 40 db. At the same time, since the 10/1 attenuator is now out of circuit, the gain has been increased by that amount and the full-scale deflection of the meter corresponds to only 10 per cent of the original signal. The cathode of the output valve, V4, now introduces two inductances $L_7$ and $L_8$, and a condenser $C_8$. $L_8$ and $C_8$ are tuned to 2,000 c/s and introduce very considerable negative feedback at this frequency, thereby eliminating the second harmonic from the output. At 3,000 c/s the $L_8$-$C_8$ combination is capacitive, and $L_7$ is therefore added in series to resonate with it and give virtually zero impedance : thus the third harmonic is amplified with low loss. In practice the amplifier gain is fractionally increased in the switching to make up the loss, which is about 2 db. All higher harmonics i.e., fourth, fifth, etc., suffer considerable attenuation due to negative feedback, and the output is the percentage of third harmonic distortion, the full-scale reading being 10 per cent.

For the measurement of percentage total harmonic distortion the switch is placed in position 3, when the 1,000-c/s fundamental is removed as before, but all harmonics are amplified equally and summated into the rectifier meter.

**Mechanical Construction and Layout.** The simplicity of the switching arrangements permits an easy and symmetrical layout of the front panel, as may be seen in Fig. 3. On the left is the oscillator unit with its output control and multiplier, and on the right the attenuator and input control to the distortion measuring unit. In the centre is a spring loaded switch, normally resting in the second position, for selection of the distortion measurement.

A normal folded chassis is employed, and, to avoid the necessity for special screening, the toroidal coils are placed underneath the chassis and clamped by the various tag panels ; this form of coil is used throughout the equipment. The oscillator second harmonic rejector alone was screened.

Two double triodes ECC81 (12AT7) are used to provide the two cathode followers and the two RC stages ; an EF86 is employed as oscillator with a 150B2 to stabilize its h.t. supply. No further h.t. stabilization was found necessary, but since the h.t. supply is derived from a full-wave bridge metal rectifier, a relay was added with its coil in series with the two cathode follower anodes. This normally shorts out the sensitive meter and prevents the series of bumps which occur as the valves warm up : it is also a useful transit protection.

**Performance.** Two of these instruments have been in continuous use for six months for setting the programme level meters of tape recorders. An endless tape is employed and recording is made at a standard input level and adjusted to correspond to maximum indicated recording level. It is immediately played back through the distortion meter. The programme level meter is successively adjusted till the required value of distortion is obtained, and it is found that with semi-skilled operators the whole of the adjustment and measurement may be completed in some two to three minutes.

For measuring distortion on audio amplifiers readings may be obtained immediately and quickly over a wide range of inputs ; it is only necessary to adjust the input attenuators to full-scale deflection and then turn the switch for a direct reading. In conjunction with an output power meter a curve of distortion against output watts may be readily obtained.

The overall accuracy obtained on third harmonic measurement is $\pm 0.3$ per cent distortion and on total harmonic distortion measurement $\pm 0.5$ per cent distortion. These figures relate to the full scale of 10 per cent and are better on the lower half of the scale. Allowance can be made for the oscillator distortion if required, but since this is normally less than ¼ per cent for all measurements over half scale it may be neglected.

The author wishes to thank Mr. O. E. Dzierzynski for his assistance in carrying out the experimental work involved in developing this equipment.

# Electronic Analogue Computing

*Survey of Modern Techniques*

By

RAYMOND B. QUARMBY*

M.Sc., M.I.E.E.

So much has been written recently about the truly wonderful achievements in the field of digital computing that there has been a tendency to forget about analogue computers and to overlook the progress they have been making. Indeed there are those who would say that the analogue computer is outdated and dispute the need to improve it further. It is hoped in this article to show that the need still exists, and further that the digital computer as it stands, in spite of its undoubted superiority in many cases, still has a long way to go before it can surpass the analogue device in all applications.

A useful distinction between the two classes of computer may be drawn by referring to analogue *instruments* on the one hand and digital *machines* on the other. The instrument handles continuously varying quantities, but to an accuracy limited by the attainable perfection of its manufacture: this is not easily made better than about one part in 10,000. The machine handles numbers expressed in finite digital form and is thus incapable of handling continuously variable quantities, but within this restriction is theoretically capable of any required finite degree of accuracy; in practice, accuracies of one part in a million are being achieved with machines of the size now available.

From what has been said, it will be clear generally that if problems of an essentially arithmetic nature are posed, and exact answers required, the digital machine is called for, but that if continuously variable quantities are to be dealt with the analogue device is more suitable. The precise nature of the difference between the two classes of computer will be evident if we consider the way in which the digital machine handles its input data. First of all, it samples its data at particular instants of time. Secondly, at each sample, it recognizes only a finite number of magnitude levels, i.e., it quantizes each sample of the data. In digital computer programming, it is good practice to try to equalize the errors due to sampling and quantizing. In the analogue instrument, the counterparts of quantizing and sampling errors are respectively the imperfections in the computing components, or the static errors, and the finite response times of the computing servos, or the dynamic errors. Again, the best design requires these errors to be of equal magnitude.

Optimum balancing of the computing errors is not the only factor to be taken into account, however, in the choice of a computing system. It is sometimes essential for a natural time scale to be used in the computation, for example in certain classes of simulator.

In a simulator the system to be studied is represented by the circuits of the instrument, and the behaviour of these circuits is studied under representative working conditions. A natural time scale is essential when actual components are to be inserted, as is done sometimes to allow a check on their performance during design. These component tests may be carried out not only under representative circuit performance conditions but also under representative operating conditions of temperature, humidity, vibration and the like. It is also possible to reproduce the conditions under which a human operator is included in the servo loop.

In problems of any degree of complexity, where operation in natural time scale is desired, digital computers are sometimes too slow. Since limitation in speed of response is a characteristic of digital computers that is not always appreciated, it may be of interest to illustrate it by means of an example. In some work on the behaviour of a controlled missile, a problem was posed which involved the time dependence of the missile's position and attitude in space, as well as the behaviour of certain important parts of the control system. A simplified mathematical description of the problem involved over twenty first-order simultaneous differential equations, and these were solved on the Manchester University digital computer using a step-by-step method of integration in which the step interval was adjusted according to the shortest time constant of interest in each part of the solution.

It was found that, in a range of interest where a time interval of an eighth of a second was adequate, investigation of each ten seconds of the solution took just over an hour of computing time, i.e., the ratio of machine time to natural time was about 400. In another range, where step intervals of 1/32 second were used, the ratio worked out to 1,800. Time ratios of this order of magnitude appear to be typical for problems of this degree of complexity. In many cases, as in the example given, such a change of time scale is unimportant because the time is available, but in other cases, as we have seen in connection with the simulator, operation in the natural time scale is often essential. In some applications, where the analogue simulator or computer is used purely for design purposes and high accuracy is not the primary requirement, it is convenient to arrange for the computer time scale to be much less than natural and to display the response of the system to a repetitive square wave on the screen of a cathode ray tube. The results of any changes in system parameters may then be observed directly with consequent saving of a great deal of the designer's time.

* Ferranti, Ltd

In other problems where the data provided are continuous and high accuracy answers are required continuously, either in the natural time scale or faster than this, neither the digital nor the analogue computer may be capable of dealing with the situation adequately. It is evident that there is a need for faster digital machines, of the order of 100 to 1,000 times faster than the present Manchester machine, and also a need for electronic analogue devices of 100 to 1,000 times the accuracy at present attainable. It may be that the solution will lie in the development of a machine using a combination of both computing techniques.

## D.C. Amplifier Networks

Most of the accurate analogue computing being carried out in this country at the present time is done on electro-mechanical analogue computing instruments which use techniques developed during the war for anti-aircraft predictors and component production facilities set up at that time. While computers of this type have been considerably improved in recent years, a new and interesting field is now being opened up by the use of all-electronic devices, which require no moving parts.

In these electronic techniques the basic computing procedures of scale changing, adding, subtracting, integrating and differentiating may be carried out by d.c. amplifier networks, as shown in Fig. 1. Though balanced amplifiers have some advantages, mainly in reduced h.t. smoothing demands, a form of d.c. amplifier often used is the unbalanced one shown in Fig. 2. It is a three-stage amplifier with resistive interstage coupling ; the odd number of stages ensures an overall sign reversal and permits feedback, while the direct coupling between stages permits operation at frequencies down to zero. As the overall gain of such a three-stage amplifier may be several tens of thousands, a small grid-to-cathode input potential suffices to produce the full output. In this case, the amplifier gain is about 50,000 and the output varies over a range of $\pm 150$ volts, so that the required grid-to-cathode voltage variation is only $\pm 3$ millivolts. Thus, in the normal operating state the input grid may be considered as being at earth potential.

A circuit incorporating a d.c. amplifier of this type which can be used either for scale changing or for sign reversing is shown in Fig. 1(a). The input voltage, $E_1$, is applied to the input grid through a resistor, $R_1$. Neglecting the feedback resistor, $R_0$, for the time being, it will be seen that since the input grid is virtually at earth potential the input current, $I_1$, is given by Ohm's law as :

$$I_1 = \text{input current} = \frac{\text{input voltage}}{\text{input resistance}} = \frac{E_1}{R_1}.$$

This flow of current drives the input grid (Fig. 2) positive in potential and the amplifier responds by driving the output anode voltage down. Considering now the action of the feedback resistor, $R_0$, it is evident that it draws from the input a current of magnitude $I_0 = E_0/R_0$ and that this current increases until it equals the current $I_1$, when the amplifier settles down to steady state operation. Equating the expressions for the currents $I_1$ and $I_0$ gives :

$$(E_1/R_1)+(E_0/R_0) = 0$$

or $E_0 = -E_1(R_0/R_1)$, while if the input and feedback resistors are equal in value $E_0 = -E_1$, i.e., the output is equal in magnitude to the input but has opposite polarity.

Since a large current may be taken from the output without causing a drop in the output voltage, these amplifiers are often used as buffer stages between high output-impedance circuits and their loads.

If two input resistors are provided, as shown in Fig. 1(b), then the current drawn off from the grid through the feedback resistor equals the sum of the input currents, i.e., the output voltage is equal to minus the sum of the input voltages. The accuracy of the summation depends, of course, on the accuracy with which the resistors can be matched;

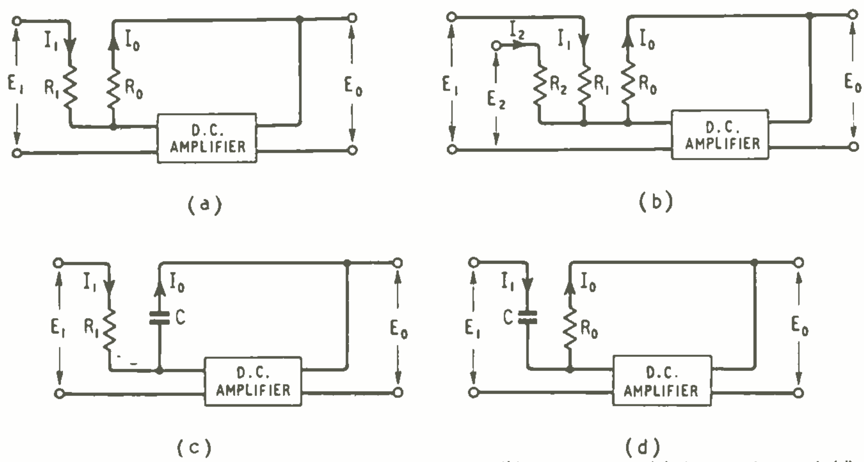



*Fig. 1. D.C. amplifiers used for (a) sign reversing, (b) summation, (c) integration and (d) differentiation.*

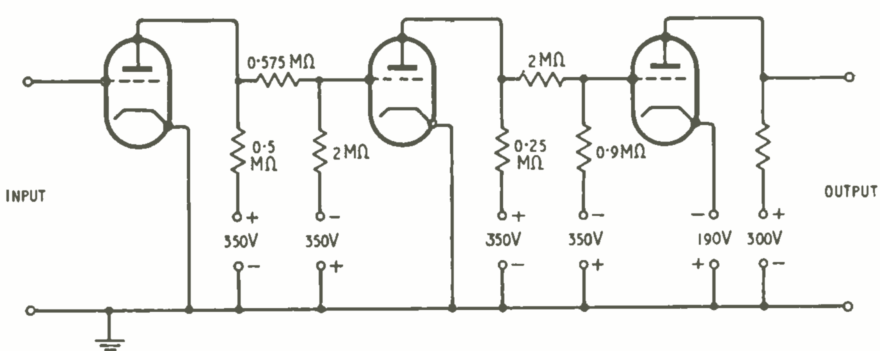
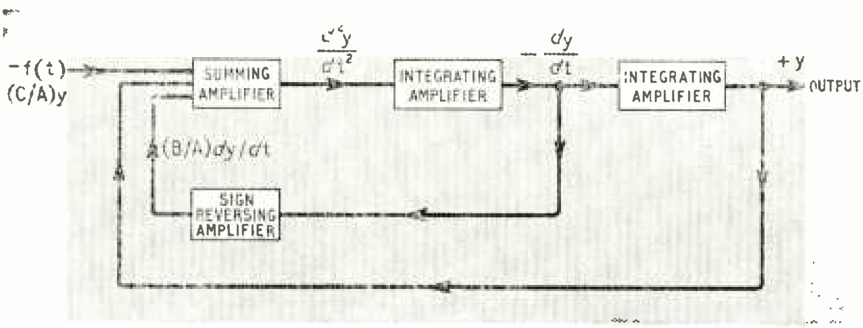
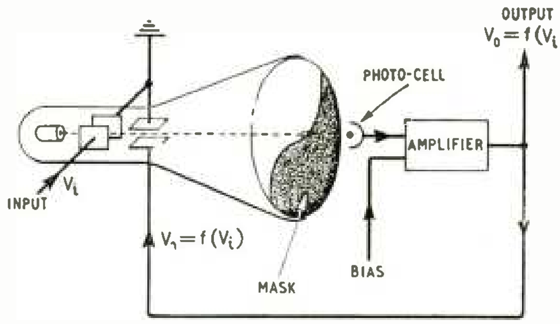



*Fig. 2. Unbalanced d.c. amplifier suitable for circuits such as those in Fig. 1.*




*Left: Fig. 3. Four d.c. amplifiers arranged as a differential analyser.*

*Below: Fig. 4. Electronic function generator in which the required function of the input voltage is represented by the profile of a mask.*




high stability wire-wound resistors are normally used. Subtraction is achieved by the addition of a voltage of opposite polarity.

Incorporating a capacitor in the feedback loop in place of the resistor, as shown in Fig. 1(c), converts the arrangement into an integrator. Since the current passed by the capacitor is proportional to the rate of change of the voltage across it, we have

$$E_1/R_1 + C\,dE_0/dt = 0 \text{ or } E_0 = -(1/CR_1)\int E_1 dt$$

Polythene capacitors are usually employed because of their high leakage resistance.

With the capacitor in the input, as shown in Fig. 1(d), the arrangement becomes a differentiating circuit, and $E_0 = -CR_0\,dE_1/dt$. One drawback to differentiating amplifiers is their tendency to accentuate any irregularities in the input voltage. When a computer is being set up for the solution of a differential equation, however, it is always possible to rearrange this in the form of an integral equation. The solution then allows the use of integrators in place of differentiators.

## Differential Analyser

An arrangement of four d.c. amplifiers for solving a second-order differential equation is shown in Fig. 3. The equation solved is:

$$Ad^2y/dt^2 + Bdy/dt + Cy = f(t)$$

and its solution is a time function, y(t), representing the response of a system with two energy storage components, A and C, and an energy dissipating component, B, to a forcing function of time, f(t). When the system is linear, A, B and C are constant and this is assumed in this case.

The first amplifier is connected for summing and the quantity $d^2y/dt^2$ is assumed to exist at its output. This is then fed to the second amplifier, connected as an integrator, in which $-dy/dt$ is evaluated. The third amplifier is also an integrator and gives y. In the first amplifier, $d^2y/dt^2$ is evaluated by summing the three terms $(B/A)dy/dt$, $(C/A)y$ and $-f(t)$, the various proportions in which they are summed being obtained by a suitable choice of the input resistors. The fourth amplifier is needed to give a sign reversal to the quantity $-dy/dt$. Initital conditions, representing the levels in the two energy stores, are set into the two integrators before the forcing function is applied. This forcing function is sometimes just a step function; at other times, however, a repetitive solution is required and then a continuous square wave is applied. This enables the solution for y to be presented as a steady trace on a cathode ray tube provided the frequency of the square wave is high enough to avoid flicker.

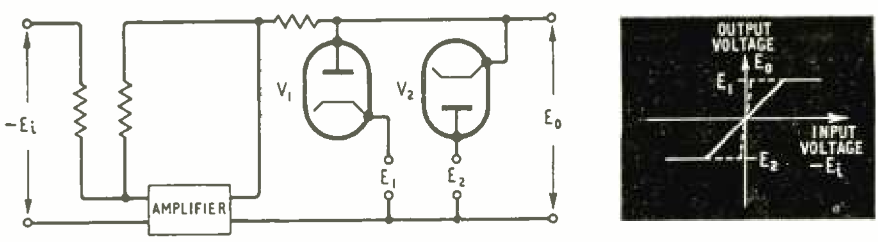
Usually it is convenient for the repetition frequency to be that of the mains. The time scale will then be chosen to allow the whole output transient to occur in less than 1/50th second, and also to allow enough time for the flyback and reset of initial conditions.

If a plot of the response is required, inaccuracies are introduced in trying to obtain this from the cathode ray tube screen directly. It is better to use a pen recorder, in which the accuracy is comparable with that of the computing network and in which the paper drive mechanism can have a greater speed constancy than the cathode ray tube time base. One way of doing this is by sampling the output waveform with a pulse of repetition frequency slightly different from the 50 c/s, so obtaining from each successive transient a portion slightly displaced from the last. The pen recorder, being unresponsive to frequencies as high as 50 c/s, will draw a smoothed version of the required response, though taking the whole of a beat period to do so.

## Function Generators

With the aid of a multiplying device, or a non-linear function generator, it is possible to solve more complicated equations in which the coefficients A, B and C are no longer constants but functions of time. The circuits used do not differ radically from that of Fig. 3, and the method of getting the answer is very similar. The same cannot be said of the analytical solutions, as the modified equations are much more difficult to solve than the linear.

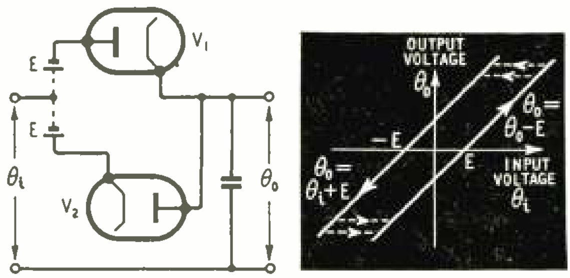
An all-electronic non-linear function generator developed recently is shown in Fig. 4. It consists of an opaque mask, having a profile representing the required function, placed on the screen of a cathode ray tube. A photocell receives light from the fluorescent spot on the screen when this is not obscured by the mask, and the output of this photocell controls the voltage applied to the vertical deflecting plates, through an amplifier. The input voltage is applied to the horizontal deflecting plates and causes the spot to move horizontally. A bias voltage is applied through the amplifier to the vertical deflecting plates in such a sense as to cause the spot to rise until it reaches the edge of the mask. As the spot becomes unmasked, the photocell input to the amplifier opposes the bias increasingly until the amplifier output attains a value at which the spot is prevented from rising further. The spot is thus forced to follow the mask profile, and the required function of the input voltage is generated at the output terminals of the amplifier. This device has been used in an aerial simulator to represent the functional relationship between aerial gain and offset angle, and can be used to simulate any empirical relationship of this kind.




(a) (b)

*Fig. 5. Arrangement of biased diodes to simulate a mechanical system with limits on displacement, rate or torque.*

Arrangements of biased diodes allow the representation of various non-linear saturation characteristics, such as occur in the the simulation of mechanical systems. Fig 5 (a) shows two diodes arranged to limit the output of an amplifier and the full lines in Fig. 5(b) show the resulting output characteristic. Diode $V_1$ conducts when the output voltage, $E_0$, exceeds the bias voltage, $E_1$, so $E_1$ corresponds to the maximum value of $E_0$ which can be passed. Conversely, $V_2$ conducts when $E_0$ is less than $E_2$, so this voltage corresponds to the minimum value of $E_0$. The circuit thus gives a characteristic typical of a system with position, rate or torque limits.

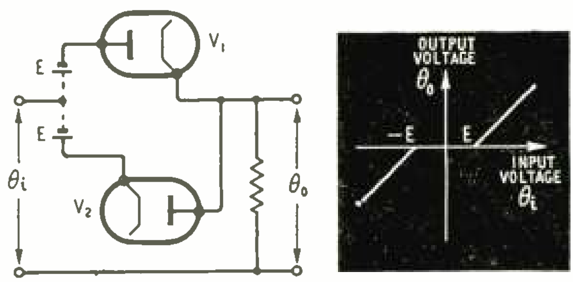



(a) (b)

*Fig. 6. Biased diodes simulating a dead zone in a mechanical system, as shown by $-E$ to E in (b).*

When a characteristic representing friction torque as a function of speed is to be generated, a circuit similar to that in Fig. 5(a) is used, but without the feedback connection to the amplifier input. The amplifier then drives its output to the limiting value for any slight departure of its input voltage from zero, in either the positive or negative direction. The resulting characteristic, which is of the desired form, is shown dotted in Fig. 5(b).

A dead zone often exists in mechanical instruments and this may be represented, in a computer, by the arrangement of Fig. 6(a). If the input signal $\theta_i$ is positive, it must exceed $+$ E for the diode $V_1$ to conduct or, if negative, be less than $-$ E for the diode $V_2$ to conduct. A positive or negative threshold of value E is thus introduced into the output $\theta_0$ as shown in Fig. 6(b).




(a) (b)

*Fig. 7. Including a capacitor in the Fig. 6 circuit modifies the characteristic to represent backlash in a system of gears.*

The inclusion of a capacitor at the output, as shown in Fig. 7(a), somewhat modifies the behaviour of the circuit. The diode $V_1$ now conducts when $\theta_i - \theta_0 > E$, and $V_2$ when $\theta_i - \theta_0 < -E$. This results in the characteristic of Fig. 7(b), which represents the backlash in a system of gears. If a limiter is combined with this arrangement a hysteresis characteristic results.

## Approximating Characteristics

The method may be extended to the approximation of any non-linear function to within specified limits of accuracy by a number of straight-line sections, provided the slope of the characteristic remains of the same sign throughout. If the slope of the required function varies in sign then the characteristic is obtained as the sum of a number of simpler characteristics. A high-speed electronic differential analyser at the University of Bologna has function generators of this type which permit any function to be set up as a combination of ten connected line sections whose slope and length can be adjusted independently.

An application of the method is shown in Fig. 8. At low input voltages, when the diodes are all biased off, the circuit acts as a simple potential divider, but as the input voltage increases the diodes become conducting one after the other and make the effective potential divider ratio progressively less. With the circuit values and bias voltages shown, the arrangement gives a logarithmic law over a wide range, and this particular circuit has been used as an attenuator for compressing voltages from one to 1,000 volts, so allowing the voltage values in both low- and high-level regions of the signal to be read on a meter to the same percentage accuracy.

A good deal of attention has been given recently to the development of fast multipliers. Some work has been done on improving the speeds of response of electromechanical devices, but purely electronic devices are more common.

One form of electronic multiplier uses a cathode ray tube and photocells, as shown in Fig. 9. There are the usual vertical and horizontal deflection plates in the neck of the tube and a coil is fitted round the tube in the vicinity of the horizontal deflection plates. One of the input voltages, $V_1$, is applied to this coil and produces a magnetic field along the axis of the tube of magnitude proportional to $V_1$. So long as the electron beam is undeflected, the electron beam current acts in the same direction as this magnetic field and does not interact with it. When, however, the second voltage, $V_2$, is applied to the vertical deflection plates it imparts a vertical velocity to the electron beam so that the beam current now has a component in the vertical direction of magnitude proportional to $V_2$. This component of the beam current interacts with the axial magnetic field and produces a force on the electron beam, in the horizontal sense, of magnitude proportional to the product $V_1V_2$.

The tube face is divided by a vertically placed knife edge having a photocell on either side. This enables any horizontal deflection of the beam to be detected as a difference signal, which is amplified and applied to the horizontal deflection plates in a restoring sense. The resultant behaviour of the system is to produce a voltage across the horizontal deflection plates proportional to the product of the two input voltages.

In another electronic multiplier, the mark space ratio of a repetitive square wave is made to depend on one voltage, and its peak-to-peak amplitude on another. The detected and smoothed output then varies as the product of the inputs. A multiplier may also be made from function generators arranged to give square law responses. If two such generators are arranged to evaluate $(A+B)^2$ and $(A-B)^2$, their difference, when scaled down by a factor of four, is equal to the product AB.

Large computing assemblies, being expensive, are rarely justified when suited only to the solution of a special problem. The exceptions to this rule are when the problem has to be solved quickly, as in an anti-aircraft predictor, or frequently, in which case substantial savings in computing effort may rapidly outweigh the initial cost. An example in this latter class is the aerial radiation pattern computer constructed recently at the Telephone Manufacturing Company

Aerial array design involves computing a great variety of radiation patterns until one of suitable form is found, which has the right compromise between the conflicting requirements of narrow main lobe width and adequate suppression of side lobes. Since high accuracy is not demanded, an electronic computer may be used, and the computed radiation patterns presented on the screen of a cathode ray tube. This allows the designer to see at once the effect of changing any design parameter and speeds up what is essentially a trial and error process.

### Synthetic Radiation Pattern

The voltage which produces the synthetic radiation pattern on the c.r.t. screen is an analogue of what would be measured by a field-strength measuring set moving in a circle round the real aerial array. In the real array the waves emitted from the elements would combine to produce various maxima and minima which would be detected by the revolving measuring set. The same effect is obtained in the computer by combining a number of 450-kc/s r.f. carriers, corresponding to the emissions from the elements, after modulating their respective amplitudes and phases in different ways corresponding both to the amplitudes and phases of the currents fed to them, and to the transmission lags between them and the rotating measuring set. Thus at various points on the modulating cycle the resultant carrier output goes through maxima and minima analogous to the maxima and minima detected by the measuring set at corresponding points on its circle of rotation. Fig. 10(a) shows the apparatus for simulating the contribution of a single element, while (b) shows the combining and display system.

In order to obtain a continuous presentation of the maxima and minima on the c.r.t. screen the modulating

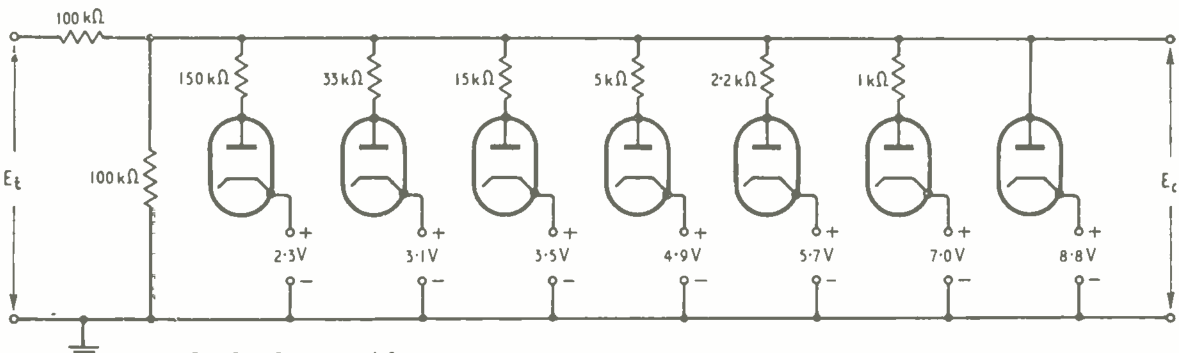



*Fig. 8. Circuit used for compressing an input voltage range to a logarithmic scale.*

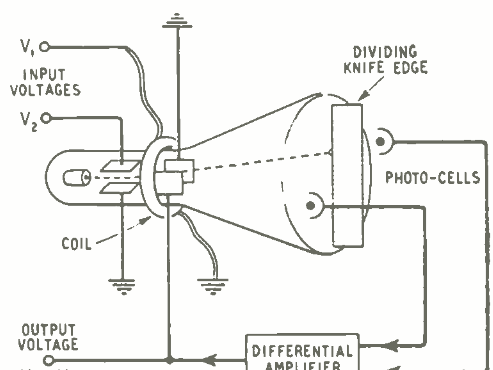



*Fig. 9. Electronic multiplier using a cathode ray tube and two photo-cells.*

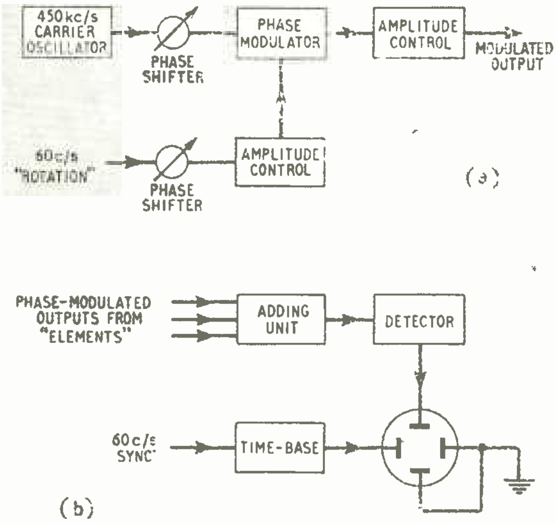



*Fig. 10. Aerial radiation pattern computer with (a) apparatus for simulating contribution of a single element, and (b) combining and display system.*

cycle is chosen to be 60 c/s and the time base is synchronized with this frequency. (This being equivalent to a rotation of the hypothetical measuring set round the array sixty times in every second.) Thus, with the azimuth angle represented along the time base and the combined carriers applied to the Y plates, the radiation pattern is presented in rectangular co-ordinates. Manual adjustment of the amplitudes and phases of the 450-kc/s carriers gives the effect of similar adjustments to the currents in the elements of the real array, while alteration of the amplitudes and phases of the 60-c/s modulating signals gives the effect of changing the positions of these elements.

Very often the problem to be solved does not justify the building of such a large special-purpose computer. In this event it is sometimes possible to arrange for the problem to be solved on a general-purpose computer, which can be used in the solution of a large variety of problems and so be more economical. General-purpose electronic analogue computers have been built at the National Physical Laboratory, Teddington, and also at the Royal Aircraft Establishment, Farnborough.

The N.P.L. computer is intended mainly for use in the design of servo systems and comprises exponential time delays, pure time delay or distance velocity lag, balanced d.c. amplifiers, mixers, integrators, square-wave and pulse generator working at 1,600 c/s, phase advancers, resonant circuits, and an on-off controller. Combinations of these elements allow most types of servo to be studied.

By contrast, the R.A.E. computer is arranged as a differential analyser, similar to those discussed previously but more complex. It comprises 16 integrators, 15 summing amplifiers, 12 curve followers or function generators, 15 multipliers, and 30 units for scaling and inserting initial conditions. The multipliers are of the variable mark/space ratio type previously described; all the other units are based on unbalanced d.c. amplifiers.

One very large use of differential analysers of this type is in the solution of flutter and vibration problems in airframe design. Since the data on which designers work are very rarely accurate to better than a few per cent, highly accurate computers are out of place, and the purely electronic type with repetitive solutions presented on the screen of a cathode tube is ideal.

## BOOKS RECEIVED

**Radio Receiver Design,** by K. R. Sturley, Ph.D., B.Sc., M.I.E.E. Revised second edition of Part 1 dealing with radio-frequency amplification and detection. Pp. 667+xx; Figs. 260. Price 56s. Chapman and Hall, 37, Essex Street, London, W.C.2.

**Low-frequency Amplification,** by Dr. N. A. J. Voorhoeve. Philips Technical Library treatise on the principles of a.f. amplifier design, with chapters on auxiliary apparatus and acoustics as applied in sound reinforcing systems. Pp. 495+xv; Figs. 479. Price 50s. Cleaver Hume Press, Wright's Lane, Kensington, London, W.8.

**Ultra High-frequency Radio Engineering,** by S. A. Knight. Elements of the theory of transmission lines, wave guides, magnetron and klystron valves, etc., with chapters on propagation and aerial systems. Pp. 256+viii; Figs. 202. Price 21s. Sir Isaac Pitman and Sons, Parker Street, London, W.C.2.

**Microwave Spectroscopy,** by M. W. P. Strandberg. Theory of molecular rotational states and their measurement by interaction with microwave fields. Pp. 140; Figs. 15. Price 9s 6d. Methuen and Company, 36, Essex Street, London, W.C.2.

**World Radio Handbook for Listeners (1954).** Compendium of information on broadcasting and television stations, their wavelengths, interval signals, times of transmission, etc. Pp. 136 with numerous illustrations. Price 8s 6d. Edited and published by O. Lund Johansen, English edition distributed by W. Dawson and Sons, Cannon House, Macklin Street, London, W.C.2.

**Electrical Engineering Progress Series,** Editor M. G. Say, Ph.D., M.Sc., M.I.E.E. Collections of articles on recent developments by specialist contributors.

**Cathode Ray Tubes.** Radar, television, instrument and camera tubes. Pp. 216+vii; Figs. 113. Price 25s.

**Rotating Amplifiers.** Amplidyne, Metadyne Magnicon and Magnavolt machines and their applications. Pp. 125+vii; Figs. 74. Price 17s 6d.

**Electrical Earthing and Accident Prevention.** Current practice in domestic, industrial, mining and ship installations. Pp. 248+viii; Figs. 116. Price 25s.

The above three books are published by George Newnes, Tower House, Southampton Street, London, W.C.2.

**Mechanism of Economic Systems,** by Arnold Tustin, M.Sc., M.I.E.E. Application of control system engineering methods, feedback and stabilization, to the problems of economic fluctuations. Pp. 161; Figs. 57. Price 25s. W. Heinemann, 99, Great Russell Street, London, W.C.1.

**Technique de la Télévision,** by A. V. J. Martin, A.M.Brit.I.R.E. Outline of television receiving technique with special reference to Continental standards. Pp. 295; Figs. 358. Société des Editions Radio, 9 Rue Jacob, Paris 6.

**Gears for Small Mechanisms,** by W. O. Davis. Theory and practice of designing small gears for instruments, clocks and automatic control mechanisms. Pp. 157+ix; Figs. 76. Price 25s. N.A.G. Press, 226, Latymer Court, Hammersmith, London, W.6.

# Surface-Barrier Transistors

## *New Technique for Making High-frequency Junction Types*

ARTICLES in this journal have already described the point transistor and the junction transistor: variants, like the analogue transistor which is now reported to be approaching the practical stage, have not passed unnoticed. It is a feature of both these basic types of transistor that they are all of the *a-b-a* type, the junction transistors either *n-p-n* or *p-n-p*, and the point transistors actually having small areas of *p*-germanium under the points, so that internally they are *p-n-p* systems.

The technological problems of constructing the germanium sandwich are, like the problem of getting the jam into the doughnut, extremely difficult. The central layer must, like the jam, be extremely thin and methods used so far have not been very successful in achieving the required uniformity except for relatively thick base layers, with the corresponding limitation to low frequency operation.

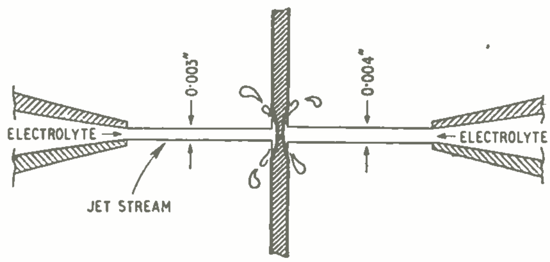
A new type of junction transistor has now been announced by Philco in America, in which many of the difficulties are overcome. In some ways this new transistor reminds us of the coaxial point transistor described by Kock and Wallace[1]. The coaxial transistor consisted of a disc of germanium one-eighth of an inch in diameter and 0.02in thick, in the faces of which two concave depressions were ground. The point contacts were applied coaxially, one fitting in each hollow. It seemed quite a good idea, but no more has been heard of it. The surface-barrier transistor is also made from a small plate of germanium, cut from a single crystal of *n*-germanium and initially 0.05 × 0.10in in area and 0.006in thick. Since the cutting operation damages the crystal structure, the small blanks are etched to a thickness of 0.003in, and a nickel contact tab is then soldered to one end.

This slab of germanium is still far too thick, and the working section must be reduced in thickness. Here we meet Part I of the new invention. Jet electrolytic etching is used to dissolve away some of the germanium. Fig. 1 shows how two jets are played on opposite sides of the germanium blank from glass nozzles about 0.005in in diameter. The jets are a solution of an indium salt, and a current of about 1.5 mA is passed along the jets and through the germanium, the circuit being closed through the nickel tab. Light must fall on the jet-germanium junction during the etching process, because the current is flowing through the back resistance of the jet-germanium diode, and it turns out that the effect of these combined conditions is to make the window flatten out as it gets thinner. This helps to give good high-frequency performance.

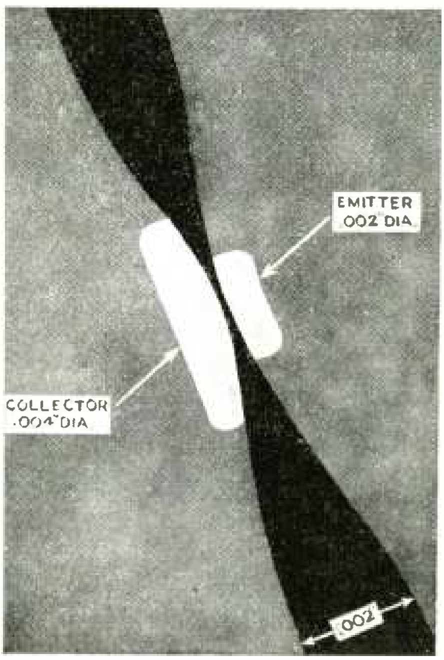
A hole is first drilled right through, to find out how long it takes on the particular blank being processed. Then the blank is moved, and the etching process carried out, stopping when calculations show it must have left a window about 0.0002in thick. This takes rather under two minutes.

The current through the jet-germanium diode is now reversed, so that the system becomes an electroplating unit. Indium is deposited on the surface of the germanium, and the layer is built up to give an electrode thickness of 0.0005in. Wires are fastened to these two electrodes and the unit is mounted and sealed. The etched wafer is shown in Fig. 2, and the method of mounting in Fig. 3.

There is no forming action, no heating to produce

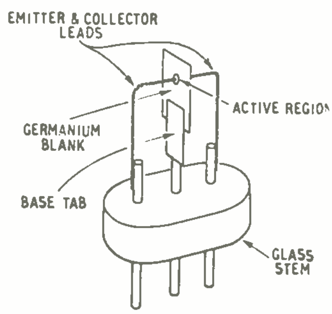



*Above: Fig. 1. Etching of germanium wafer by jets of electrolyte.*




*Left: Fig. 2. Photomicrograph of section of etched wafer. The white areas show the relative sizes of the indium electrodes.*

*Below: Fig. 3. Experimental mounting for surface transistor.*




[1] Elect. Engng., N.Y. March 1949.

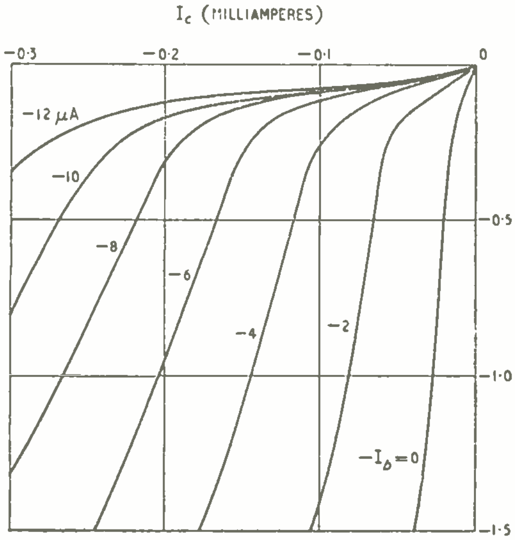



*Fig. 4. Earthed-emitter characteristic of the surface-barrier transistor.*

*Fig. 5. Circuit of video amplifier using surface-barrier transistors.*

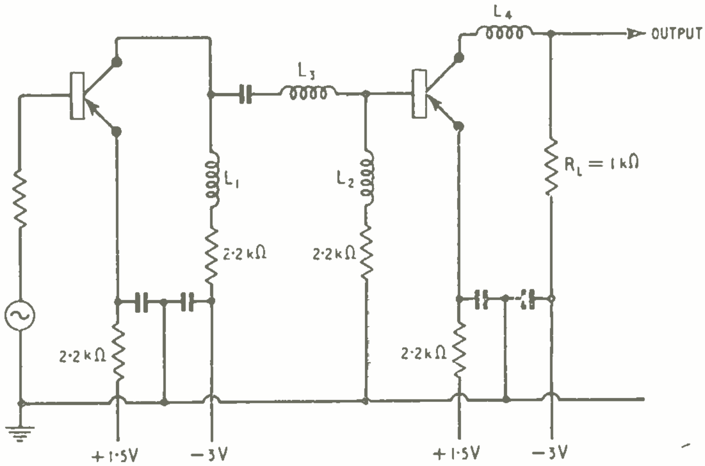
diffusion. Here we see the fundamental difference between the transistor which results from this method of manufacture and the transistors we have encountered before. The junction with which we are concerned is that between the germanium and the indium, at the actual surface of the germanium. This is, of course, much more clearly defined than the *n-p* junction in either a grown type or a diffused type of junction unit.

A typical set of characteristics is shown in Fig. 4. These are measured using the base current as parameter. It can easily be seen that for very small signal working the point $I_C = -0.06$mA, $V_C = -0.5$V and $I_b = -2\mu$A is quite satisfactory. Amplifiers giving a power gain of 18db at 30 Mc/s and using only a 3-volt supply have been made. The values of $\alpha$ cut-off published for 10 units range from 36 to 49 Mc/s, and the values of $\alpha$ from 0.905 to 0.962.

The circuit shown in Fig. 5 shows a video amplifier having a gain of 28 db and a bandwidth of 9 Mc/s. It will be noticed that the collector supply is only -3 volts. The alternative junction tetrodes, which also have good high-frequency characteristics, require much high supply voltages, usually over 15 volts.

The surface-barrier transistor appears to be a stage nearer the solution of the problem of reproducible high-frequency transistors.

*Acknowledgments.* Figs. 1, 2 and 3 are based on Figs. 1, 3 and 4 of "Electrochemical Techniques for Fabrication of Surface-Barrier Transistors," by J. W. Tiley and R. A. Williams, *Proc. I.R.E.*, Dec., 1953, p. 1706; Fig. 4 on Fig. 4 of "Principles of the Surface-Barrier Transistor," by W. E. Bradley, *Proc. I.R.E.*, Dec., 1953, p. 1702; and Fig. 5 on Fig. 2 of "Circuit Applications of Surface-Barrier Transistors," by J. B. Angell and A. P. Keiper, *Proc. I.R.E.*, Dec., 1953, p. 1709.




## COMMERCIAL LITERATURE

**Tubular Ceramic Capacitors** for handling high pulse voltages (up to 5kV peak) in radar and television. Technical bulletin No. 43, Series 2, from The Telegraph Condenser Company (Radio Division), North Acton, London, W.3.

**Radio Books** to be published in the first half of 1954 included in a spring list from Sir Isaac Pitman & Sons, Parker Street, London, W.C.2.

**Eddystone** short-wave components and accessories for transmitting and receiving described in a 28-page catalogue, with illustrations and technical data, from Stratton and Co., Alvechurch Road, West Heath, Birmingham, 31.

**Connectors** for coaxial and balanced twin cables for general-purpose use, including television. Also, details of special microwave, v.h.f. and miniature types. Leaflets from Transradio, 138A, Cromwell Road, London, S.W.7.

**Portable Electric Gramophones** with Collaro pickups and motors (or record-changers). Range of four types described in a leaflet from Electric Audio Reproducers, 17, Little St. Leonards, Mortlake, London, S.W.14.

**Resistance Boxes,** calibrating potentiometers, Wheatstone and plug bridges, resistance standards and other measuring instruments listed on a leaflet from the Croydon Precision Instrument Company, 116, Windmill Road, Croydon, Surrey.

**Tape Recorder** with Truvox tape deck, crystal microphone and 10-in elliptical loudspeaker. Specification on a leaflet from Unitelex (London), Deptford Bridge, London, S.E.8.

**Instrument Cases** of welded steel construction and chassis to fit (also in aluminium). Range of sizes given on leaflets from Phillips & Bonson, Pond Works, 8, Millfields Road, Hackney, London, E.5.

**Television Aerial Outlet Boxes.**—Instructions for wiring extensions to other rooms given on a leaflet from Aerialite, Castle Works, Stalybridge, Cheshire.

**U.H.F. Turret Attenuator** (0-3,000 Mc/s) with six tubular pads which, in turn, are brought in line with the coaxial input and output sockets. Characteristic impedance is 50Ω and attenuation steps can be from 0.1 db to 60 db. Full description on a leaflet from Stoddart Aircraft Radio Company, 6644, Santa Monica Boulevard, Hollywood, 38, California, U.S.A.

**"Transistor Research Bulletin,"** a new publication covering progress in the field of transistors, crystal diodes and other semi-conductor devices. The December, 1953, issue contains information about developments in Germany and a semi-conductor bibliography. From National Scientific Laboratories, 2010, Massachusetts Avenue, N.W. Washington, 6, D.C., U.S.A.

# Transistorized Megohmmeter

*Compact Two-range Instrument Using a Transistor E.H.T. Generator*

By P. B. HELSDON, A.M.Brit.I.R.E.

THE small size and low power consumption of a transistor e.h.t. generator makes the electrostatic type of megohmmeter an attractive proposition. The complete unit to be described measures 6in × 4in × 3in and operates from a small hearing-aid type battery. There are two ranges, 3 to 1,500 megohms and 35 to 22,000 megohms.

In principle, the electrostatic megohmmeter is the dual of the well known milliohmmeter or bonding meter. The basic circuit of the bonding meter is shown in Fig. 1. Its dual in Fig. 2 is the basis of the electrostatic megohmmeter. The constant voltage source equals the full-scale deflection (f.s.d.) of the meter. The voltmeter is connected across the standard resistor and is calibrated in terms of the unknown resistance. To measure very high resistances the meter must be electrostatic.

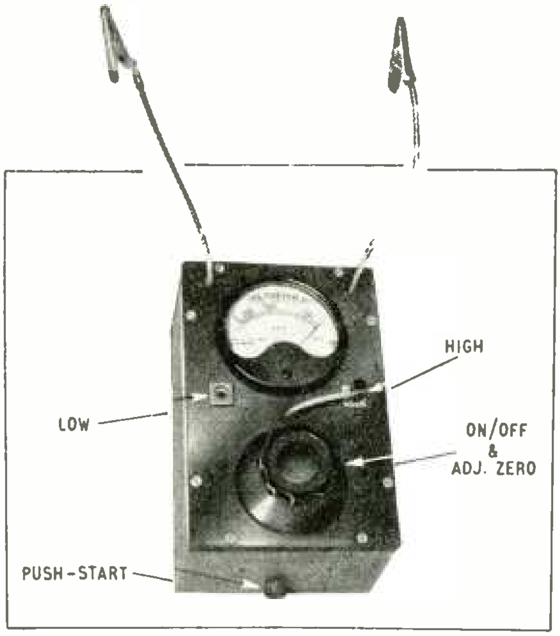
Electrostatic meters have a modified square law of deflection, so that greater sensitivity is obtained near full-scale reading. With the arrangement of Fig. 2, large values of the unknown give low voltage reading. But when the standard and unknown are interchanged as in Fig. 3, large values of the unknown give readings near full scale, so that the meter is used to best advantage. In practice the meter is switched according to the range in use. One is used for unknowns less than the standard and the other for those greater. The meter reads half-scale voltage on each range when the unknown equals the standard.

In theory, the value of the standard can be as high as desired, but in practice it is limited by considerations of leakage. Meters can be obtained with leakage resistance greater than one million megohms, so that with care and a suitable standard, resistances of this order can be measured. The 750-volt electrostatic meter used by the writer is of war surplus stock and unfortunately has a leakage of 1,750 megohms. This value has been measured on several different occasions and is assumed to be fairly stable. For the standard resistor ($R_{STD}$) a value of 250 megohms is used.

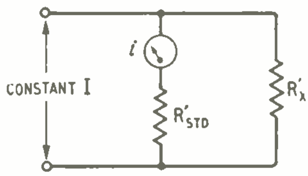
## Source Impedance

Power requirements are modest. Allowing for the leakage, the low range requires up to 3.4 μA at 750 V and the high range up to 3.25 μA at 815 V. Regulation must be such that the effective source impedance obtained is small compared with the standard. No serious attempt has been made to analyse the regulating properties of the e.h.t. generator. Measurement shows the effective source impedance to be 14 MΩ.

After adding elements for leakage and source impedance the circuit of Fig. 2 becomes as shown in

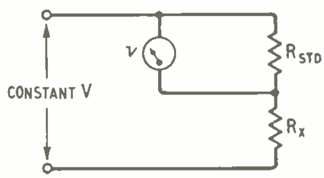



*Polythene-insulated leads and wander-plug switching are employed. The meter is of the electrostatic type.*



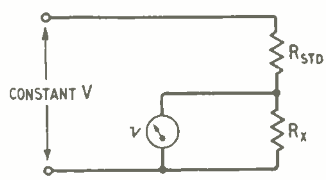

$$R'_x = \frac{R'_{STD}}{\frac{I}{i} - 1}$$

*Fig. 1. Basic circuit of milliohmmeter.*




$$R_x = R_{STD}\left(\frac{V}{v} - 1\right)$$

*Fig. 2. Basic circuit of electrostatic megohmmeter* ($R_X < R_{STD}$)




$$R_x = \frac{R_{STD}}{\frac{V}{v} - 1}$$

*Fig. 3. Circuit of Fig. 2 altered to give readings near full-scale deflection when* $R_X > R_{STD}$

Fig. 4, with an effective standard resistance (1,750 and 250 in parallel) of 220 MΩ.

So when $v = 100$, $R_x = 1{,}526$ MΩ; and when $v = 740$, $R_x = 3$ MΩ.

The same procedure changes Fig. 3 into Fig. 5. Applying Thévenin's theorem, the complex resistance network seen from the $R_x$ terminals can be reduced to a single (standard) resistance of approximately 228 ohms, in series with an open-circuit generator voltage of 750.

From the formula in Fig. 5, when $v = 100$, $R_x = 35$ MΩ; and when $v = 740$, $R_x = 22{,}800$ MΩ.

## Oscillator Circuit

A battery driven transistor oscillator with a step-up transformer to a selenium rectifier system is used to supply the high voltage. In this oscillator circuit the transistor acts more like an astable switch, rather than as an amplifier with positive feedback. This triggering mode of oscillation is desirable since the collector dissipation is low, both during the conducting and non-conducting parts of the cycle. During the transition, however, the dissipation is high, so the switch should be as fast as possible. The Class "C" mode of operation would seem desirable for high efficiency, but every attempt at this failed because of "squegging." The peak instantaneous collector dissipation under "squegging" conditions is very high and soon damages the transistor. Satisfactory results are obtained when Class "B" operation is adopted.

The switching capabilities of a transistor can be demonstrated by the circuit of Fig. 6. The ohmmeter should have an internal 9-V battery and a half-scale reading of about 5,000 ohms. If the bias resistor has the right value the collector-emitter resistance indicated with base floating can be either high or low.

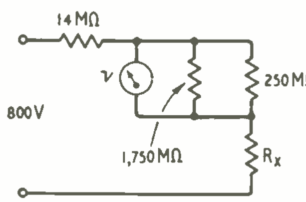
If the base is momentarily connected to the emitter, the transistor triggers to high resistance (off), but if the base is momentarily connected to the collector the transistor triggers to low resistance (on.) This constitutes a bistable switch. A pair of headphones added as in Fig. 7 makes a simple astable switch.

A better oscillator circuit is shown in Fig. 8. The base bias resistance $R_2$ should be increased until oscillations just start and then the emitter series resistance $R_1$ adjusted for maximum output. The tap on the inductor should be about $\frac{1}{8}$ of the total down from the base.

The transistor can be regarded as a switch which connects the tuned circuit to the battery throughout each negative half cycle. The peak-to-peak voltage developed across the tuned circuit is then twice the battery voltage. The collector has to withstand this double battery voltage at the peak of the non-conducting half cycle. As 33V seems a safe peak collector voltage, the battery must be limited to $16\frac{1}{2}$V.

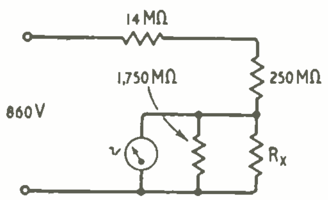
In practice the $16\frac{1}{2}$ V to the transistor is obtained from a 30-V battery (Type B105) through a decoupled series resistance. This resistance is provided by a fixed safety resistor and a variable resistor ganged to the on-off switch. The variable resistor compensates for battery ageing and gives a precise control of the e.h.t. voltage. In addition it reduces the current to a low value before switching off, so that dangerous inductive surges are avoided. The complete circuit is shown in Fig. 9.

The oscillator is sometimes reluctant to start in cold weather. A transistor, unlike a valve, has no gain at zero bias. The emitter is biased only by the small collector leakage current passing through the base bias resistor $R_2$. When the crystal is cold this current is small, due to the negative coefficient of resistance with temperature of high-purity germanium. After switching on, the collector current slowly rises as the crystal warms up. Seconds or even minutes may pass before the circuit bursts into oscillation. Quick starting can be obtained by connecting a fixed resistor of about 39 kΩ from collector to base. This is wasteful of current and also loads the tuned circuit. The method adopted is to connect this resistance by way of a push-button starting switch. Lightly loaded oscillators can be made to start by suitably phasing the switching-on surge, but the rectifier load in the present case initially constitutes a virtual short circuit on the tuned circuit and prevents "kick" starting.



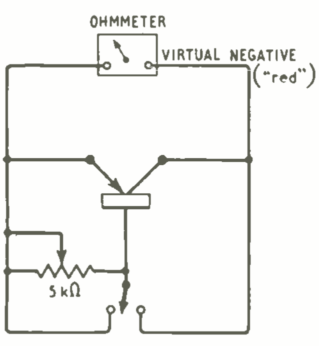

$$R_x = 220\left(\frac{800}{v} - 1\right) - 14\,\text{M}\Omega$$

*Fig. 4. Practical equivalent circuit of Fig. 2 for low resistance range.*




$$R_x = \frac{228}{\frac{750}{v} - 1}\,\text{M}\Omega$$

*Above: Fig. 5. Practical equivalent circuit of Fig. 3 for high resistance range.*




*Left: Fig. 6. Circuit for demonstrating the function of a transistor as a bistable switch.*

## Auto Transformer Design

To obtain 830 volts d.c. from the peak-to-peak rectifier system, the inductance must be made into an auto transformer with a step-up ratio of 830/33 = 25/1 approx. The battery voltage adds in series giving the required total output of 860 volts on no load.

The auto transformer is wound on a four-section polystyrene former with a small pair of "Ferroxcube" E cores (FX 1105/A4) un-gapped. A total of 1250 turns of 42 s.w.g. vinyl acetal enamelled grade M (medium thickness) wire is tapped at 5 turns for the emitter and 50 turns for the battery positive. Total inductance is 4.25 H with a Q of 50 at the self-resonant frequency of 32 kc/s. The extra stray capacitance of

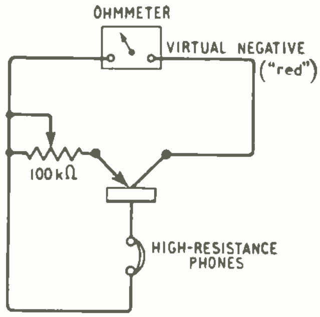
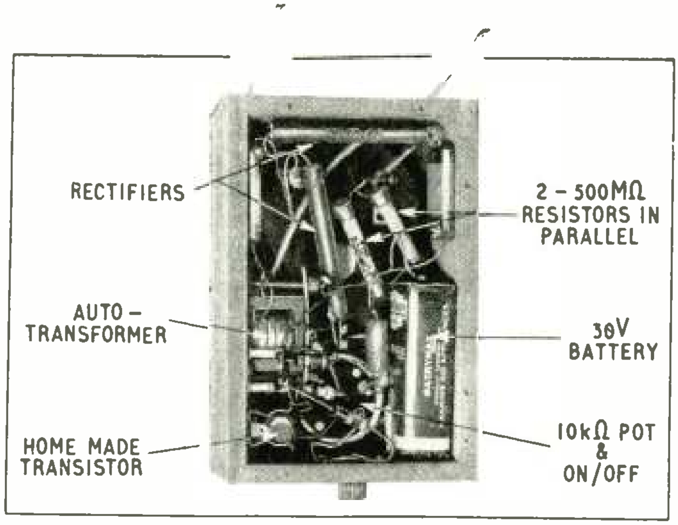



*Fig. 7. High resistance headphones in the base circuit demonstrate the astable switching function of the transistor.*




*Underside showing single hearing-aid battery and general arrangement of components.*

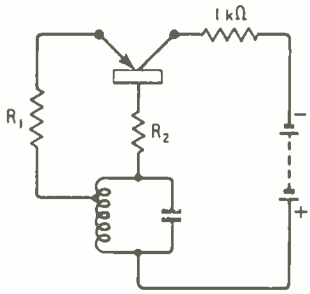



*Fig. 8. Sine-wave oscillator using the astable switching circuit.*

the rectifier system reduces the frequency of oscillation to about 20 kc/s. The waveform is a distorted sine wave on which is superimposed damped oscillations at a higher frequency. These high-frequency ripples are produced during the switching transitions and are caused by the several leakage inductances resonating with stray capacitance. It is important to keep leakage inductance to a minimum, so that the switching transients do not over-dissipate the collector.

## Reduced Current Consumption

A large percentage of the power loss is due to collector-to-base leakage within the transistor. The low current consumption of 2.2 mA was obtained by forming a transistor to an $I_{co}$ (collector current for zero emitter current) of 0.6 mA at 30 volts. The average commercial point-contact transistor has an $I_{co}$ of 1 to 2 mA at $E_c = 30$ volts.

The complete unit is contained in a wooden box with high-grade insulation where necessary. The polythene test leads are brought out to crocodile clips to avoid the use of terminals. Meter switching is by plug and socket, since few switches have sufficiently good insulation.

On the low range the zero is set by shorting the test leads together and adjusting the variable resistor to give f.s.d. on the meter. Infinity on the high range is set by separating the test leads and adjusting the variable resistor to f.s.d. as before.

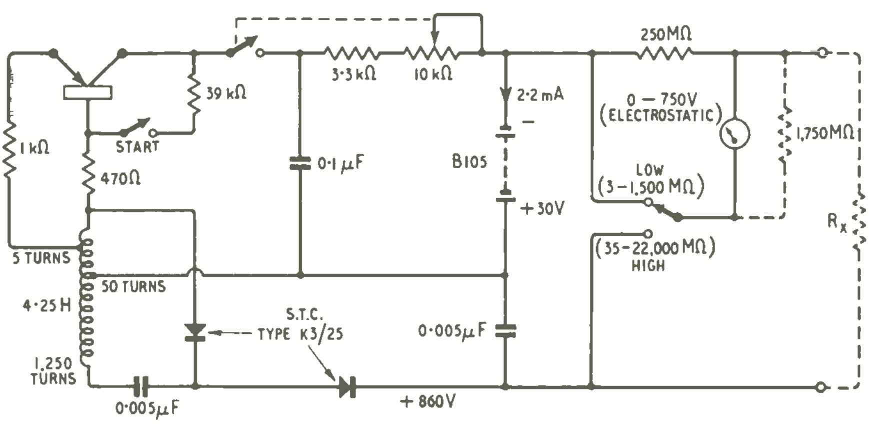
The meter has a hign internal impedance and no shock can be felt when handling the test leads.

One inconvenience is the time taken to measure large low-leakage capacitors. For example, a 1-$\mu$F capacitor takes over 15 minutes to test. This time could be reduced to about 1 minute by temporarily short-circuiting the standard resistance. Once a large capacitor is charged, however, it is highly dangerous and should be carefully discharged after testing.

The transistor megohmmeter appears to be quite reliable. One has been in use for three months, at the time of writing, without any loss of efficiency or output, even after transport by bicycle on several occasions.

The e.h.t. generator itself has several applications apart from the megohmmeter; it could supply e.h.t. for Geiger-Muller radiation counters, image-convertor tubes, flash-tubes or small cathode-ray tubes, to name a few.

*Fig. 9. Complete circuit diagram of two-range megohmmeter with transistor e.h.t. generator.*



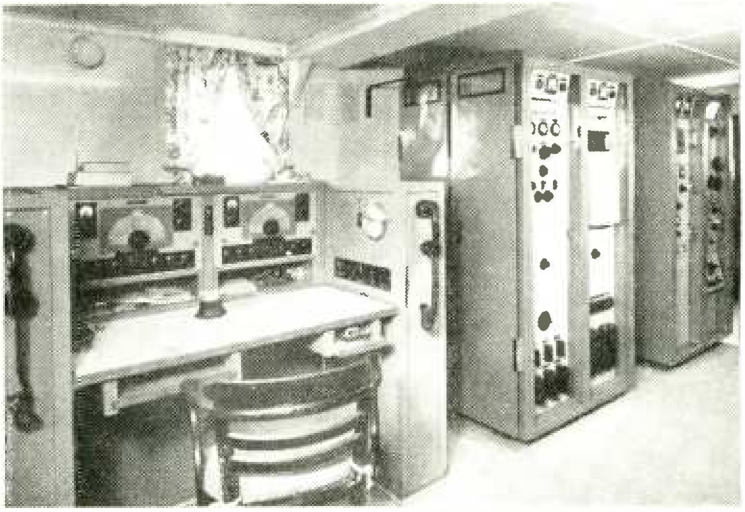
# WORLD OF WIRELESS

**Death of Major Armstrong**

**Radio Fuse Awards**

**More Band 1 Stations**

**F.M. Broadcasting in U.S.**



*RADIO INSTALLATION on the floating whaling factory "Abraham Larsen" which is the headquarters vessel for a whaling fleet operating in the Antarctic. The equipment was supplied by Redifon.*

## *F.M. Pioneer's Death*

WITH REGRET we record the death in tragic circumstances in New York on February 1st of Major Edwin H. Armstrong, the f.m. pioneer. Born in December, 1890, Edwin Armstrong graduated in electrical engineering from Columbia University at the age of 23 and had worked there ever since, becoming Professor of Electrical Engineering in 1934.

Professor Armstrong will be remembered not only for his work on f.m. but for his earlier work on the regenerative and super-regenerative receiving circuits and also the principle of the super-heterodyne. He contributed a letter on the significance of regeneration to our January issue. His latest work was concerned with a multiplex system of f.m. transmission, a brief description of which will be found elsewhere in this issue.

## *More Radio Fuse Awards*

IN ADDITION to the £20,000 awarded by the Ministry of Supply to Pye, Ltd., for the development during the war of the proximity fuse and the No. 19 tank set (see our January issue), recommendations of awards to seven claimants have been made by the Royal Commission on Awards to Inventors. Four of the claimants—H. Cobden-Turner, G. M. Tomlin and L. Rollin, all of Salford Electrical Instruments, Ltd., and W. H. B. Lord, late of that company—have been awarded jointly £11,500. Individual awards have also been made to A. Stratton (£2,000), N. Coles (£750) and G. A. Whitfield (£750), who are at R.A.E., Farnborough.

## *New TV Stations*

AMENDED PLANS for the completion of the B.B.C.'s single-programme chain of television stations were recently announced by the Assistant P.M.G. in the House. Whereas it was originally planned for eight of the twenty stations to go into Band 3, six of them will now be accommodated in Band 1, although this is contrary to the plan drawn up at Stockholm.

The two channels in Band 3 (186-191 and 191-196 Mc/s) to be made available for television will now be used for the proposed competitive stations. Channel 9 (191-196 Mc/s) will be assigned to London.

The six B.B.C. stations referred to above will be at, or near, Norwich, Dover, Inverness, Londonderry, Towyn and Carlisle They will each use horizontal polarization. The site for the Norwich station, where it is hoped to have a temporary 0.5-kW transmitter working within twelve months, is at Tacolneston, some 10 miles south west of the city.

A temporary station is also to be brought into service this year at Redmoss to serve Aberdeen until the permanent transmitter is installed at Core Hill.

The much-debated North Hessary Tor site for the Devon-Cornwall television transmitter has now been approved by the Minister of Housing. This 5-kW station will operate in Channel 2.

## *Mobile Radio*

A WRIT has been served on the Post Office by the Colchester engineering firm, Davey, Paxman & Company, alleging that the fees collected for licences for the operation of their mobile radio transmitters are not lawfully chargeable. They also claim that some of the conditions regarding frequencies and power, etc., laid down in the licence, are contrary to the provisions of the Wireless Telegraphy Act.

The outcome of the action will be of interest to all civil users of mobile radio.

## *Whither F.M. Broadcasting?*

IN AMERICA, the home of f.m. broadcasting, there are indications that all is not well in the f.m. camp. A member of the Federal Communications Commission recently stated that "if the broadcast industry does not take some steps to increase the utilization of the f.m. frequencies" he had no hesitancy in saying that in the public interest he would have difficulty in retaining the whole of the 88-108-Mc/s band for f.m. broadcasting should the Commission be asked to make use of part of it to relieve congestion in other services.

According to the latest returns available from the F.C.C., the number of f.m. broadcasting stations has decreased from some 750 to 560 during the past four years.

## *Radio Exports Up*

A RECORD YEAR for radio exports was reported in the Board of Trade returns for 1953. The total value of exports of radio equipment of all kinds was £25,761,818, compared with the 1952 figure of £24,495,950.

The contributions by the four sections of the industry are given below in £M, together with (in parentheses) the 1952 figure:—

| | | |
|---|---|---|
| Transmitters and radio navigational aids | 11.001 | (7.963) |
| Components and sound reproducing equipment | 9.042 | (8.481) |
| Domestic receivers | 3.517 | (4.435) |
| Valves and cathode-ray tubes | 2.200 | (3.615) |

## PERSONALITIES

**H. O. Sampson,** who has been appointed head of technical operations, B.B.C. Television Studios, joined the Alexandra Palace staff in 1936 and remained there until the television service was suspended at the outbreak of the war. During the war he served at several of the Corporation's high-power transmitting stations and with the London Recording Unit. He returned to the television service in 1946.

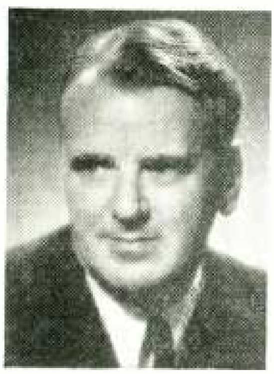
**Eric E. Jones,** who was for some years in charge of the Telecommunications Division of the Philips group of companies in this country and has, since 1949, been commercial manager of Savage and Parsons, Ltd., recording equipment manufacturers of Watford, has taken over the direction of the commercial activities of the Solartron Electronic group of companies.

In our note in the last issue recording the appointment of **Rear-Admiral (L) C. P. Clarke,** C.B., D.S.O., R.N. (ret.), as a Knight Commander of the British Empire (K.B.E.) in the New Year Honours, we omitted to mention his position at the Admiralty and his radio associations. At present director of the Naval Electrical Department, Rear-Admiral Clarke has been a vice-president of the Brit.I.R.E. since October, 1952.

**Hugo Gernsback,** editor of our New York contemporary *Radio-Electronics*, has been appointed Officer of the Oaken Crown by H.R.H. The Grand Duchess Charlotte of Luxembourg. The award was made to Mr. Gernsback, who was born in Luxembourg, "for his meritorious service to science."

## OUR AUTHORS

**J. R. Brinkley,** who has been technical director of Pye Telecommunications, Ltd., since 1949, writes on the problems of frequency planning on page 103 of this issue. He received his early technical training in the Telephone Department of the Post Office, and after a year as inspector in the Engineer-in-Chief's Office went to the Radio Branch at Dollis Hill in 1939. He was later seconded to the Home Office, where he was responsible for the development of police v.h.f. radio systems and in particular for the introduction of the multi-carrier mobile radio system.



*J. R. BRINKLEY*

*T. D. CONWAY*

**T. David Conway,** author of the article on the measurement of harmonic distortion, has been chief engineer of Grundig (Gt. Britain), Ltd., since its formation in 1952. He joined Grundig from the Ministry of Supply, where he had been an instrument engineer for two years. Throughout the war he was with Ultra Electric as a radar engineer and from 1945 to 1947 he was concerned with the development and testing of ceramic and mica condensers at the United Insulator Company's works. Mr. Conway was with Standard Telephones and Cables as a factory valve engineer from 1947-1950.

**R. B. Quarmby,** contributor of the analogue computing article in this issue, became a probationary college apprentice at Metropolitan Vickers in 1936. A year later he went to Manchester University, where he graduated in 1940, and then spent some time on extra-mural research on the properties of polythene dielectrics, etc., for the Ministry of Supply. Wartime work at the Royal Military College of Science was followed by a year's lectureship in electrical engineering and electronics at the University of Capetown and in 1950 he joined the staff of Ferranti, Ltd., where he has been working on the design and construction of analogue computers and simulators for use in the design of guided weapons.

**D. H. C. Scholes,** who contributes an article on frequency-shift radio telegraphy in this issue, has been with the Plessey Company since 1946, where he is now chief engineer and sales manager of the Telecommunications Division. For a short while at the beginning of the war he worked at the Royal Aircraft Establishment, Farnborough; then, in 1941, joined the Royal Navy as an air engineering officer and was engaged in various theatres of war on engineering duties concerned with airborne radio and radar equipment. Lt. Cdr. Scholes was at the Admiralty for a year after the war. For seven years before his war service he was with the Marconi Company.

## IN BRIEF

**Broadcast Receiving Licences** current in the United Kingdom at the end of December totalled 13,268,270, including 2,956,846 for television and 206,348 for car radio sets. The month's increase in television licences was 110,619.

**French Components Show.**—The annual Paris exhibition of radio components, valves, accessories and measuring equipment will be held in the Parc des Expositions, Port de Versailles, from March 12th to 16th.

A course on **Point-to-Point Radio Services,** which is open to overseas senior planning and operating engineers and telecommunications administrators, is being conducted in London from June 27th to July 10th by the British Council in conjunction with the Engineering Department of the Post Office. Information on the course, for which there is a limited number of vacancies, can be obtained from overseas offices of the British Council, or from 65, Davies Street, London, W.1. The fee is £38.

**Quick Work.**—At the time of the Comet airliner crash near Elba, Pye engineers were developing a new underwater television camera for operation at a depth of 500 fathoms. Although the equipment had hardly gone beyond the drawing-board stage, the camera, in a case for operation at the estimated depth of the Comet (some 40 fathoms), was ready within six days. It was then learned that the wreck was probably 100 fathoms below the surface. A new case was designed and completed within seven days and flown to Italy for use by the Admiralty in the search for the wreck.

**Bronze Medallist.**—The City and Guilds' Bronze Medal for the best student in Great Britain in the 1953 Intermediate Radio Servicing Examination has been awarded to John McCubbin, a Glaswegian, who is employed by James Anderson & Son (Glasgow), Ltd. He is a fourth-year student at Allan Glen's Further Education Centre, Glasgow, studying for the R.T.E.B. final certificate.

**F.M. for Marine V.H.F.**—On the question of the proposed change to f.m. for international maritime mobile radio services, the Radio Communication and Electronic Engineering Association states in its annual report that it has advised the Post Office that the majority of its members favour the change provided there are suitable safeguards to minimize dislocation of services, especially during the changeover.

**R.C.E.E.A. Council.**—The following member-firms of the Radio Communication and Electronic Engineering Association were elected to the Council of the organization for 1954 (the names of the companies' representatives are given in parentheses): B.T.-H. (V. M. Roberts), Decca Radar (C. H. T. Johnson), E.M.I. (S. J. Preston), G.E.C. (M. M. Macqueen), Kelvin & Hughes (C. G. White), Marconi's (F. S. Mockford), Metrovick (L. H. J. Phillips), Mullard (T. E. Goldup), Murphy (K. S. Davies), Plessey (P. D. Canning), Redifon (B. St. J. Sadler) and S.T.C. (L. T. Hinton). C. G. White, general sales manager and director of Kelvin Hughes (Marine), Ltd., who has been vice-chairman of the Association for the past two years, has been elected chairman in succession to T. E. Goldup.

## INDUSTRIAL NEWS

**Moroccan Television.**—The first television station in North Africa, established by a private company at Casablanca, has been equipped with Pye, a camera chain, telecine camera and vision and sound transmitters. The station operates on the French 819-line standards.

**Hi-Fi Agencies.**—Enquiries from Hollywood and Hong Kong to act as representatives of U.K. manufacturers of high-fidelity sound recording and reproducing equipment have been received through the Export Services Branch of the Board of Trade. Interested firms should write direct to Gordon Agencies, 1506, North-Western Avenue, Hollywood 27, U.S.A., and Scientific Service Company, 447, Alexandra House, Hong Kong. The Board of Trade, Lacon House, Theobalds Road, London, W.C.1, should also be notified, quoting references ESB/1614/54 (Hollywood) and ESB/1897/54 (Hong Kong). An enquiry has also been received from Long Island, New York, for the agency for a tape recorder. The firm concerned is Rek-O-Kut Company, Inc., 38-01, Queens Boulevard, Long Island City 1, New York. The B.o.T. reference is ESB/1103/54.

A contract for the supply of a quantity of airfield control radar equipment has been awarded to **Decca Radar** by the Ministry of Supply. The equipment, which is the air-transportable version of the Decca 424 described in our November issue, will be used by the R.A.F.

"The Ship of the Year," as the new P. & O. liner *Arcadia* was described at her launching last May, is being fitted with radio communication and navigational equipment by the **Marconi Marine Company.** In addition, a comprehensive sound-reproducing system, including 156 loudspeakers fed by seven power amplifiers, each having an output of 60 watts, has been installed. Four sources of programmes—microphones, broadcast receiver, wire recorder and record player—are available and switching permits selected groups of loudspeakers to be fed simultaneously from the four separate sources.

Sound amplifying equipment provided by **Hadley Sound Equipments, Ltd.**, of Smethwick, Birmingham, has been installed in the Roman Catholic cathedral in Calabar, Southern Nigeria.

W. F. Randall, B.Sc.(Eng.), M.I.E.E., director of the **Telegraph Construction and Maintenance Company,** is on a two months' visit to the company's branches and representatives in the Far East and Australasia.

New premises have been opened by the **G.E.C.** at Magnet House, Mincing Lane, Blackburn. The depot is equipped for the supply and servicing of the company's radio and television equipment.

**British Insulated Callender's Construction Company,** manufacturers of radio masts and the like, recently moved to 30, Leicester Square, London, W.C.2 (Tel.: Trafalgar 7777). The central administrative offices of the parent company, British Insulated Callender's Cables, remain at 21, Bloomsbury Street, London, W.C.1 (Tel.: Museum 1600).

**Goldring Manufacturing Company (Gt. Britain), Ltd.,** is the name of the company recently formed to conduct the business of Erwin Scharf, manufacturer of the Goldring pickup, and associated concerns The company will operate from the present address: 49-51a, de Beauvoir Road, Kingsland Road, London, N.1 (Tel.: Clissold 3434).

**Excel Sound Services, Ltd.,** tape-recorder and amplifier manufacturers, of Shipley, Yorks, have moved to Celsonic Works, Garfield Avenue, Bradford, 8, Yorks (Tel.: Bradford 45027).

## MEETINGS

### Institution of Electrical Engineers

*Radio Section.*—"A Study of some of the Properties of Matter affecting Valve Reliability" by E. A. O'Donnell Roberts, M.Sc., Ph.D., on March 10th.

"Colour Television" by C. J. Hirsch on March 22nd.

Both the Radio Section meetings will be held at 5.30 at Savoy Place, London, W.C.2.

*Cambridge Radio Group.*—"Computing Machines" by T. Kilburn, M.A., Ph.D., at 8.15 on March 9th at the Cavendish Laboratory, Cambridge.

*Mersey and North Wales Centre.*—Faraday Lecture "Electro-Heat and Prosperity" by O. W. Humphreys, B.Sc., at 6.45 on March 25th at the Philharmonic Hall, Liverpool.

*North-Eastern Radio and Measurements Group.*—"A Study of some of the Properties of Matter affecting Valve Reliability" by E. A. O'Donnell Roberts, M.Sc., Ph.D., at 6.15 on March 15th at King's College, Newcastle-upon-Tyne.

*North-Western Centre.*—Faraday Lecture "Electro-Heat and Prosperity" by O. W. Humphreys, B.Sc., at 7.30 on March 23rd at the Free Trade Hall, Manchester.

*North-Western Radio Group.*—"Distributed Amplifiers" by W. S. Percival, B.Sc., at 6.30 on March 17th at the Engineers' Club, Albert Square, Manchester.

*North Lancashire Sub-Centre.*—"Some Aspects of the Design of V.H.F. Mobile Radio Systems" by E. P. Fairbairn, B.Sc., at 7.15 on March 10th at the N.W. Electricity Board, North Road, Lancaster.

*South-East Scotland Sub-Centre.*—"Some Aspects of the Design of V.H.F. Mobile Radio Systems" by E. P. Fairbairn, B.Sc., at 7.0 on March 16th at the Heriot-Watt College, Edinburgh.

*South Midland Radio Group.*—"Some Aspects of the Design of V.H.F. Mobile Radio Systems" by E. P. Fairbairn, B.Sc., at 6.0 on March 22nd at the James Watt Memorial Institute, Great Charles Street, Birmingham.

*Southern Centre.*—"Technical Arrangements for the Sound and Television Broadcasts of the Coronation Ceremonies" at 6.30 on March 3rd at the S.E.E.B. Headquarters, Hove, by W. S. Proctor, M. J. L. Pulling, M.A., and F. Williams, B.Sc.

"Demonstrations of Synthetic Speech" by W. Lawrence, M.A., and R. A. Eades, B.Sc., at 6.30 on March 5th at the South Dorset Technical College, Weymouth.

*Western Centre.*—"Telemetering for System Operation" by R. H. Dunn, B.Sc., and C. H. Chambers at 6.0 on March 8th at the Electricity Offices, Colston Avenue, Bristol.

*South-Western Sub-Centre.*—"Colour Television: Some Subjective and Objective Aspects of Colour Rendering" by G. T. Winch at 3.0 on March 10th at the Rougemont Hotel, Exeter.

*Oxford District.*—"Modern Trends in Television" by G. G. Gouriet, B.Sc., at 7.0 on March 17th at the Southern Electricity Board, 37, George Street, Oxford.

*London Students' Section.*—Visit to G.P.O. Research Station, Dollis Hill, N.W.2, at 2.15 on March 3rd.

"Metallic Resistance at High Frequency" by A. D. Stevens at 7.0 on March 3rd at the Public Library, Chelmsford.

"Servo Mechanisms" by Capt. R. A. Middleton, R.E.M.E., at 7.0 on March 30th at the Drill Hall, 185, London Road, Chelmsford.

### British Institution of Radio Engineers

*London Section.*—"Radio Astronomy" by R. Hanbury Brown (Jodrell Bank Experimental Station) at 6.30 on March 31st at the London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.

*Scottish Section.*—"The Acoustic Design and Measurement of Buildings" by H. C. Watson (Newall's Insulation Co.) at 7.0 on March 11th at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2, and at 7.0 on March 12th in the Department of Natural Philosophy, The University, Edinburgh.

*North-Western Section.*—"Colour Television" by G. B. Townsend (G.E.C. Research Laboratories) at 7.0 on March 11th at the College of Technology, Manchester.

*West Midlands Section.*—"Industrial Applications of Electronic Instruments" by A. G. Wray, M.A., (Marconi Instruments) at 7.15 on March 23rd at the Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.

### British Sound Recording Association

*London.*—"High Quality Microphones: The Assessment of Performance" by D. E. L. Shorter, B.Sc., at 7.0 on March 19th at the Royal Society of Arts, John Adam Street, London, W.C.2.

*Manchester Centre.*—"Disc Recording with special reference to Long Playing" by A. R. Sugden at 7.30 on March 15th at the Engineers' Club, Albert Square, Manchester.

### Television Society

*London.*—"Trick Effects in Television Production" by D. R. Campbell (B.B.C.) on March 12th

"An Industrial Television Channel" by R. J. Boddy and C. D. Gardner (E.M.I.) on March 25th.

Both the London meetings of the Television Society will be held at 7.0 at the Cinematograph Exhibitors' Association, 164, Shaftesbury Avenue, London, W.C.2.

*Leicester Centre.*—"Transistors and Other Crystal Valves" by D. D. Jones (G.E.C. Research Labs.) at 7.0 on March 29th in Room 45, The College of Art and Technology, The Newarkes, Leicester.

### Institution of Electronics

*North-Western Branch.*—"Semi-conductors" by R. Cooper, Ph.D., M.Sc., (Liverpool University), at 7.0 on March 26th in the Reynolds Hall, College of Technology, Manchester.

### Radio Society of Great Britain

"'Trustworthy' Valves and Their Manufacture" by G. P. Thwaites, B.Sc.(Eng.), at 6.30 on March 26th at the I.E.E., Savoy Place, London, W.C.2.

### Engineers' Guild

*Metropolitan Branch.*—"Television Broadcasting and the Engineer" by M. J. L. Pulling, M.A., (B.B.C.) at 6.0 on March 4th at Caxton Hall, Westminster, S.W.1.

### Institution of Production Engineers

*Liverpool.*—"Induction Hardening" by R. H. Barfield, D.Sc., at 7.30 on March 24th at the Adelphi Hotel, Lime Street, Liverpool.

# LETTERS TO THE EDITOR

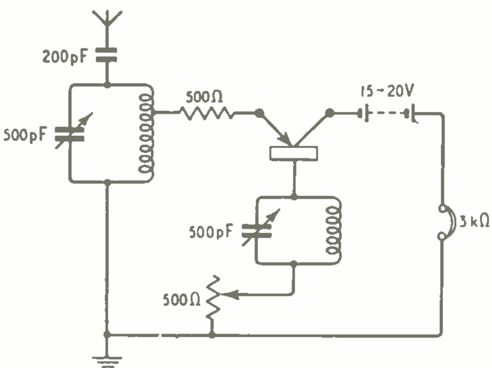
*The Editor does not necessarily endorse the opinions expressed by his correspondents*

## *Regenerative Single-Transistor Receiver*

WE read with great interest the article on transistor receiving circuits by B. R. Bettridge in your January issue, having been experimenting in the same field with the GETI for some time. We cannot add to his useful information on 2-stage circuits for local station loudspeaker reception, but some of your readers who may be able to afford only one of these treasures to begin with, and are interested in getting the greatest sensitivity with a single stage, may find Mr. Bettridge's warning against positive feedback in the base circuit unduly discouraging. With the circuit shown in the accompanying diagram, controllable bias and r.f. feedback are combined, and the danger of destructive oscillation is avoided by the limiting resistor in the emitter circuit.

In operation with a very poor "tree aerial" the circuit brings in continental stations at good signal strength, once you get used to co-ordinating the three variable controls. Moreover, with patient resolution of carriers, in which the variable base resistance is critical, many American stations can be received at stable listening volume. New York and New Orleans are particularly easy; both are in what seems to be the most favourable frequency band, around 870kc/s, though others between 600 and 1,200kc/s come in well; talks and plays can be comfortably followed between 2 and 3 a.m. The total consumption is only 18 mW.

Youngsters who have the patience to experiment with transistors in this way may thus get a taste of the thrills




which two of your earliest readers recall, sitting up at night with one of the wonder sets of the period to get the first whisper from across the Atlantic.

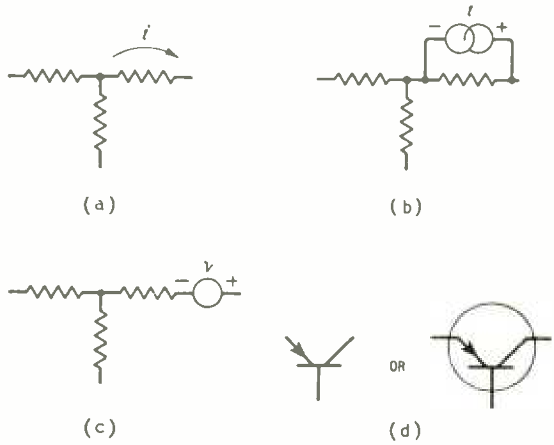
W. GREY WALTER, KARL WALTER.

Bristol, 9.

## *Symbols*

THE symbol for the current source in the technical literature is usually chosen to be an arrow as shown at (a) in the accompanying diagram. I would suggest that the symbol (b) should be adopted, this being more logical as well as exactly analogous to the symbol for a voltage source commonly used and shown at (c).

The ideal constant-current generator is assumed to have no shunt admittance, just as the ideal constant-voltage generator has no series impedance. In practical circuits internal shunt admittance and internal series impedance appear connected in their appropriate places. For example, the equivalent circuit for a transistor shown at (b) can easily be correlated with that at (c). There is the additional




advantage that the current source appears *connected* to the rest of the circuit which is not the case with the arrow symbol of (a).

In this connection, it is felt that the introduction of new symbols for the triode transistor is rather superfluous, bearing in mind that the symbol originally introduced by W. Shockley and shown at (d) is quite adequate.

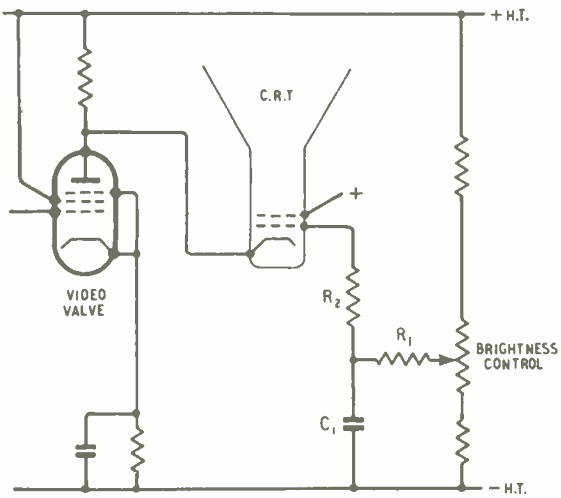
F. OAKES.

Ferguson Radio Corporation,
Enfield, Middx.

## *"C.R. Tube Safety"*

THE article in your January issue considers the importance of correctly choosing the time constants associated with the cathode and grid of a television tube in order to prevent the bias going positive immediately after the receiver is switched on or off. I cannot however, altogether agree with W. Tusting's approach to this matter. In modern television receivers in which the e.h.t. potential for the tube is derived from an overwind on the line transformer and no e.h.t. bleeder resistor is used, the time constants in question are normally chosen so that the tube passes beam current immediately after switch-off. This ensures that the e.h.t. smoothing capacitor is discharged via the tube whilst the time bases are collapsing. If in a receiver which has a permanent magnet focussing unit the grid potential of the tube decays more quickly than that of the cathode, the tube will be biased off immediately the set is switched off. Then as both potentials approach zero the cathode may still be emitting and a bright focused spot will appear at the centre of the screen. To obviate this possibility many receiver designers prefer to arrange the grid and cathode circuit time constants so that the tube bias decreases immediately after the set is switched off.

However, if in meeting this requirement or because of some other circuit condition there is a danger of the tube grid becoming positive with respect to the cathode, the positive bias may be limited by means of a series grid resistor. The value of this resistor will depend upon the grid-cathode characteristic of the tube in the positive grid region and the extent to which the source of bias voltage travels positively. In general a resistor of 22 kΩ will serve to limit the positive grid excursion to +1 volt, a value which is generally accepted by tube manufacturers as being allowable for a short period immediately after switch-off. The general circuit arrangement is shown in




the accompanying diagram, the time constant C1R1 serving to hold the grid voltage up to ensure that the e.h.t. capacitor is discharged through the tube. The grid limiting resistor is R2. D. A. WARD.

Mullard, Ltd., London, W.C.2.

### "*Weathering of Polythene*"

I HAVE read with interest the short note in your December issue (page 570) which is a *précis* of a Ministry of Supply document "Reports on Plastics in the Tropics: 2—Polythene."

Neither your note nor the report itself brings out the point that the addition of 0.1 per cent of carbon black is intended only to provide identification of the cores and is not intended to provide protection against ultra-violet light. The approved practice, for this use, established over a number of years, is to include 2 per cent of carbon black of suitable grade and well dispersed in the polythene. This material would be found to possess resistance against the effect of ultra-violet light adequate for commercial use and immeasurably superior to most natural or synthetic cable materials. The addition of this quantity of carbon black does, of course, impair the initial power factor of the material at all frequencies, but it will be found that the power factor is quite stable on exposure to tropical sunshine. Observation of power factor during the course of testing is valuable as a sensitive method of revealing physical or chemical changes in the material.

Our tests indicate that the power factor of polythene with 2 per cent carbon black is not higher than $30 \times 10^{-4}$ at frequencies up to 3000 Mc/s. except in the band 3-15 Mc/s. where it rises to a maximum of about $65 \times 10^{-4}$ at 5 Mc/s. The commonest application where polythene is exposed to sunlight is when used as a cable sheath and here the power-factor is rarely of direct interest.

It would perhaps be unwise to deduce firm estimates of the life of this material from accelerated ageing tests, but it may be mentioned that exposure tests in India for periods which have so far attained four years have failed to reveal any change whatsoever in its electrical or physical properties.

One further characteristic of polythene is its resistance to oxidation and this matter is not considered in great detail in the Ministry of Supply report. The anti-oxidant most generally used with polythene is not well suited to continued operation at high temperatures on account of its volatility. However, other suitable anti-oxidants are available for use where the polythene is to be used as a black cable sheath exposed to tropical sun.

In view of your conclusion in the penultimate paragraph that polythene cables are unsuitable for desert conditions, I should be grateful if you would give this contrary opinion adequate publicity.

Although the work reported in the M.o.S. document is extremely valuable and no doubt correct in its facts, it was realized in many quarters that it was open to misunderstanding, and representations have already been made to the Department concerned. R. C. MILDNER.

The Telegraph Construction and Maintenance Co., London, S.E.10.

### "*Measuring Non-linearity*"

IN my article in the February *Wireless World* I find that Appendix 1 is full of mistakes which I overlooked because the final equation (5) gives a correct numerical answer. For my gross carelessness in this matter I hope readers will accept my apology. The equations in Appendix 1 should read as follows:—

$$(v_a - v_o)/R_3 = (v_1 - v_a)/R_1 + (v_2 - v_a)/R_2 \quad .. \quad (1)$$

$$v_o = Av_a \quad .. \quad .. \quad .. \quad .. \quad .. \quad (2)$$

$$v_a = -(v_1 + v_2)R_3/R + v_o(1 + 2R_3/R) \quad .. \quad (3)$$

$$v_o = (v_1 + v_2)/(2/A + R/R_3 - R/AR_3) \quad .. \quad (4)$$

$$v_o = -(v_1 + v_2)/(1 + 3/A) \quad .. \quad .. \quad .. \quad (5)$$

$$R_3 = R(A + 1)/(A - 2) \quad .. \quad .. \quad .. \quad .. \quad (6)$$

The above equation (6) also appears in the main text as equation (5). Fortunately, these mistakes do not effect the body of the argument. There is also one misprint in Appendix 2—a redundant capital "I" has been inserted at the end of the last term in equation (7).

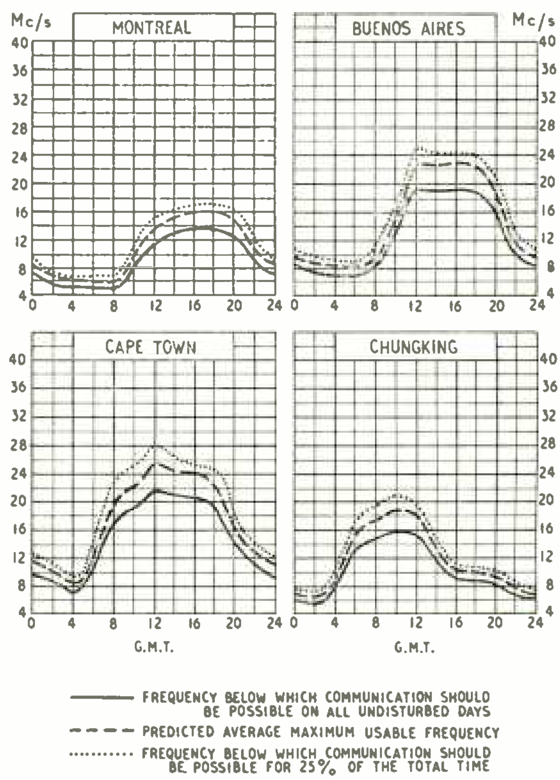
Camberley, Surrey. D. C. PRESSEY

# 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.



# Frequency Shift Radio Telegraphy

*Modifying Radio Equipment for Teleprinter Operation*

By D. H. C. SCHOLES*

READERS have already been given a very adequate introduction to this subject in an article by Thomas Roddam,† and it will consequently be possible to devote our present attention to considering in rather more detail some of the problems and latest developments, particularly in connection with the receiving end of the circuit.

The various techniques for f.s.k. (frequency shift keying) reception seem to be surrounded by as much controversy as the f.m.-a.m. question, and many systems which seem theoretically sound are discredited by at least a proportion of the practical results. The whole question is complicated by the many factors which enter into long-distance radio working, and it is not possible with present experience to draw any firm conclusions as to the best system. However, some of the main advantages and shortcomings of the two principal reception systems are fairly firmly established and these will be discussed in the appropriate place.

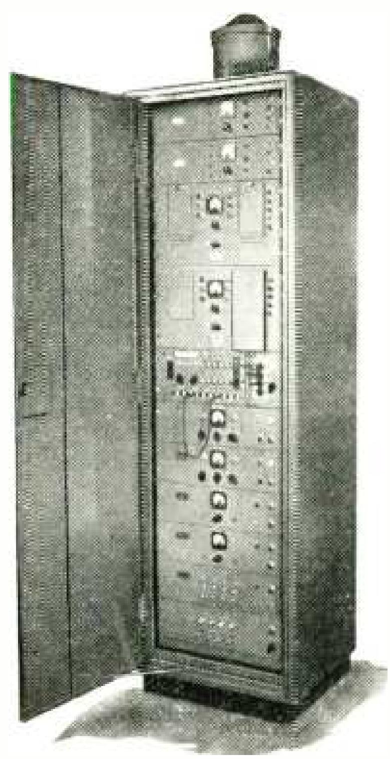
Whatever system of resolving the teleprinter signal is employed, it is now firmly established that while for on-off c.w. operation, of either auto-morse or teleprinter, triple space-diversity reception is desirable, in the case of f.s.k. triple diversity shows no improvement over dual. It now appears that the most effective receiver is a dual diversity system where the channel giving the poorer signal is completely suppressed. The switching system should have a very rapid response and should be operated by very small level differences even during deep fades on both channels.

## Teleprinter Characteristics

In discussing radio teleprinter systems, in radio publications generally little consideration is given to the characteristics of the machine itself. The writer feels that this is unfortunate, in that the whole design of such systems is directed to the one end of producing a signal which will enable the teleprinter to operate without error. For this reason the electronics is inextricably bound up with the peculiarities of the machine itself, which must be understood before the problems connected with the radio side can be appreciated. As the teleprinter is a specialized machine it seems probable that many readers, while knowledgeable in the electronic field, may not be so well informed regarding the teleprinter, and the writer asks the indulgence of those skilled in the art during a brief digression on the operation of the machine.

Operation of any key on the sending machine causes it to produce a signal of varying polarity consisting of marks and spaces lasting for 150 milliseconds. This comprises a "start" signal followed by a 100-msec. period during which the polarity may be any combination of marks and spaces, the change-over from mark to space (if any) taking place at 20-msec. intervals. These five 20-msec. periods are the five units of the "five unit" code, and each letter or symbol on the keyboard has a corresponding combination of marks and spaces. The complete signal is terminated by a 30-msec. "stop" signal of opposite polarity to the "start" signal. The purpose of the start and stop signals is to control the mechanism of the receiving teleprinter. The timing of the transmitted signals is controlled by a closely speed-controlled motor. There are no pauses between the signal elements and the transitions between mark and space are as nearly instantaneous as the transit-time of the mechanisms and relays will allow. The signal may, therefore, be regarded for all practical purposes as a square wave.

Reception of a start signal causes the selecting mechanism of the receiving teleprinter to be connected to a motor whose speed is regulated to within 0.5% of that of the sending motor. The purpose of the selecting mechanism is to investigate the position of the receiving relay at intervals corresponding to the



*F.S.K. transmitter drive unit, Model PVT, made by Plessey.*

* The Plessey Company.
† "Frequency Shift Keying"; *Wireless World*, November, 1948.

middle of the five 20-msec. code elements to determine whether the incoming signals are mark or space. As each element is interrogated in turn the mechanism in the machine is progressively set until finally the type head is positioned and the letter is printed.

For reasons connected with the operation of the machine which we need not go into here, the receiving teleprinter needs 6 msec. of each code element to carry out its interrogation, thus, in the case of characters involving changes between mark and space, the change-over point cannot be advanced or retarded more than 7 msec. without danger of wrong selection and misprinting. Temporal displacement of the change-over points is called telegraph distortion and is expressed as the percentage of the 20-msec. element length by which the change-over is early or late. The maximum distortion the teleprinter will tolerate without danger of misprinting is 35%.

## Waveform Distortion

Bias distortion is another phenomenon which may prove troublesome, and this arises when the receiving relay is not driven symmetrically in both directions by the incoming signal. Although bias distortion is not particularly serious when the incoming signals are perfect steep-sided square waves, if the pulses are rounded, sloped or otherwise distorted in transmission (as they may well be in a long radio link) the effect of bias distortion may be to alter the apparent time of change-over with consequent telegraph distortion. In "single-current" working such as on-off c.w. or single tone m.c.w., where a d.c. bias of half the signal level has to be introduced to polarize the receiving relay, not only is half the signal wasted but, in the case of varying signal strength, bias distortion arises if the signal departs from twice the bias value (as it may do with fading). Automatic bias control can mitigate this effect but has practical difficulties. F.S.K., being a true "double-current" system in which signals are sent equally for mark as for space, has considerable advantages in this respect. It will further be seen that as distortion of the shape of the signal is detrimental any system should have as its aim preservation of the signal shape. F.S.K., being a c.w. double-current system, furthers this end by making more efficient use of the transmitted signal than either c.w. on-off or single or two-tone m.c.w. It is further thought that certain effects of the f.m. nature of the signal have advantages in the presence of certain types of fading.

Having reviewed the method of reception of the radio signal and some of the problems connected with the teleprinter, we can now pass on to consider the resolution of the teleprinter signal from the radio signal. Only the two main methods will be considered here, these being the linear and non-linear discriminator systems, usually referred to as the "discriminator" and "two-filter" methods.

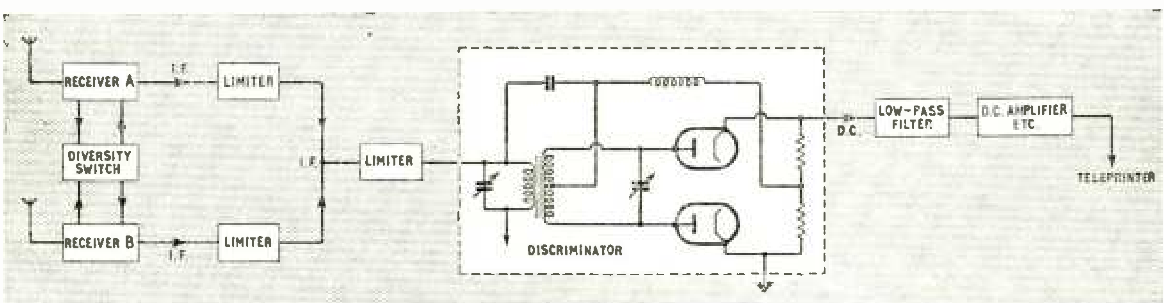
In considering this phase of the operation we must bear in mind that we are conveying intelligence by varying a signal, whose frequency may be as high as 30 Mc/s, by 850 c/s or less. Consequently, frequency stability is of more than secondary importance whatever system of reception is used.

In the discriminator system, Fig. 1, the r.f. signal is converted to a fairly low i.f. and passed through a limiter to a linear discriminator of the conventional f.m. type. The frequency-shifted signal will thus produce at the discriminator output a d.c. signal of positive or negative sign (polarized) which can be passed through a low-pass filter and further amplifiers, shaping circuits, etc., to the teleprinter. At first sight, it would appear that provided the discriminator be made with a sufficiently long linear characteristic, this system should be very tolerant of frequency drift, but in practice any drift causes a standing d.c. component to appear at the discriminator output resulting in bias distortion. Various methods of eliminating this bias have been evolved but they all involve other difficulties. The discriminator system is, however, much more tolerant of varying values of shift than the two-filter system and this is an advantage in some types of service as shift values are not yet by any means standardized.

The two-filter system, Fig. 2, involves the use of a heterodyne oscillator at i.f. to produce an audio note of 2,000 to 3,000 c/s whose frequency depends obviously on whether the transmitter is sending mark or space.

This audio signal is passed through a bandpass filter and limiters to two further filters tuned to the mark and space frequencies respectively. The outputs of these filters are rectified, filtered and dealt with as before to produce the polarized d.c. signal for the teleprinter. With the two-filter system in the case of small drifts the bias distortion per cycle of drift is very much lower than with the discriminator system. As long as the mark and space frequencies stay within the pass-bands of their respective filters there will be virtually no bias distortion. However, as these filters should for other considerations be made as narrow as possible it could be that the discriminator method would produce some signal from a carrier which had drifted too far to work with the two-filter system, but for many commercial applications, where accuracy is all-important, this might be a doubtful advantage.

*Fig. 1. Simplified diagram of a f.s.k. dual-diversity discriminator receiving system.*



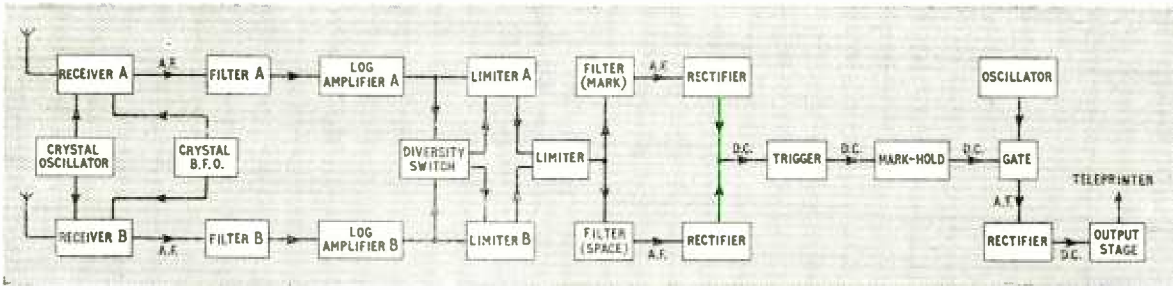



*Fig. 2. Schematic diagram of a two-filter dual-diversity f.s.k. system.*

It appears, therefore, that while the discriminator system may produce polarized signals under worse conditions than the other, the bias distortion in such circumstances would probably be excessive and at lower values of drift there is reason to believe that the two-filter system would produce lower distortion.

Work has been done in connection with both systems on the application of a.f.c. (automatic frequency control) and automatic bias adjustment at various points in the system but in the present congested condition of the short-wave bands, there is always a grave danger of the a.f.c. locking on to a strong interfering signal and causing a complete breakdown of communication.

It will be appreciated that in f.s.k. systems, the effects of level changes at the receiving aerial are less important than with some other systems since the continuous carrier simplifies a.g.c. problems and the ability to use a.f. or i.f. limiters further helps to reduce the effects of fading.

## Holding Signal

A further feature which has to be introduced into the telegraph converter arises from the arrangement whereby the sending teleprinter, when not sending traffic, transmits a continuous mark signal. This prevents the receiving machine from being operated by noise and also after a continuous mark has been received for a given time the motor of the receiving machine is stopped until a further start signal is received. Because an interruption of the carrier would result in the mark signal not being received, with a consequent chance of the receiving machine being started by noise, it is usual to incorporate in a radio teleprinter system a "mark-hold" device which automatically produces a mark signal locally at a fixed time after the last space pulse, in the absence of any further signal.

It is not proposed to deal in detail with transmitting systems as these were covered at some length in the article by Roddam already referred to. Two points are worth noting, however; first, that compared with the c.w. on-off system f.s.k. is much less likely to distort the signal elements in the transmitter. In the case of c.w. on-off (which is for all practical purposes a 100% square wave amplitude modulation) the keying, being usually carried out in an early stage, may be subject to considerable distortion by the succeeding non-linear amplifiers. As there is a constant level of carrier in f.s.k., this trouble is avoided. The second point to be noted is that it is most important that the transition between mark and space be as smooth as possible; an abrupt and discontinuous change between mark and space will give rise to spurious radiations and other undesirable effects.

Now to consider the question of frequency stability in relation to practical conditions. First, the comparatively small clear space allocated to each radio telegraph circuit makes it essential, no matter what system of telegraph conversion is used, to have the highest selectivity in the receiver compatible with conveying the intelligence. (In the case of an 850-c/s shift the bandwidth cannot safely be much less than 1,500 c/s). The skirts of the i.f. response curve should be as steep as possible. With such selectivities the stability of both transmitter and receiver must be high and crystal control of the transmitter and of the receiver change-frequency oscillator is really essential if the system is not to fail by simple inability to convey any signal at all.

Stability of shift must next be considered. If the mark and space frequencies drift in opposite direction by the same amount no bias distortion will be introduced but if both drift in the same direction, or if only one drifts (both of which effects are more likely in practice) bias distortion will be introduced, particularly in the discriminator system and in the two-filter case excessive drift of any type may overstep the pass-band of the filters.

It will be seen that a fairly high degree of frequency stability at all points in the system is essential, but if the station is to be continuously attended by a skilled operator who can devote most of his attention to a single radio channel it is possible (having made sure that neither shift, carrier nor receiver c.f.o. frequency are subject to violent and random changes) to provide monitoring devices and fine controls so that the operator may at all times keep the circuit at peak efficiency. A drawback of this system is that before a new circuit can be brought into service, some time must be wasted in lining up before traffic can be accepted as such a system cannot be adjusted in the absence of a signal from the corresponding transmitter.

## Unattended Operation

For certain types of service (such as aeronautical) the teleprinters may be located remotely from the radio station and many circuits may be in use at once under the control of operators whose accomplishments do not in any case lie in the direction of skilled adjustment of radio equipment. Similarly, it may be necessary to make many changes of frequency during a 24-hour period under circumstances which allow no time to be wasted in preliminary lining up. This problem has been the subject of some years' investigation by the writer's company in collaboration with International Aeradio and it is now believed that field test data has been collected on a scale sufficient to show that given stabilities of mean transmitted carrier, shift and receiver change-frequency oscillator and b.f.o. of the order of 1 part in $10^6$ (which is quite practicable) a system can be built which is capable of virtually unattended operation and in which new channels may be brought into use without preliminary lining up. A typical receiving equipment might have four dual-diversity channels and any one of four radio circuits can be selected remotely, but it is only necessary in this account to describe one channel.

A pair of receivers operating from spaced aerials has its c.f.o. signal provided by a separate unit using a temperature-controlled crystal oscillator in an oven stabilized by a temperature-sensitive resistance bridge.

B.F.O. signals to each receiver are supplied from another temperature-controlled unit which has alternative crystal-controlled and variable oscillators. The stability of all the above crystal oscillators is of the order of 1 part in $10^6$. Alarm circuits on all the ovens give warning should the temperature control fail.

A.F. signals from both receivers are passed to a converter unit via an input band-pass filter whence they pass through logarithmic amplifiers and limiters to the mark and space filters. The outputs from these filters are rectified and combined to produce a low-level polarized d.c. signal.

The converter unit also accomplishes the diversity switching. The signals from the receivers are made to operate an electronic switching device which selects the stronger of the two signals and suppresses the other. The characteristics of the switch are such that with the signals on both aerials subjected to a 20-db fade the stronger signal is still selected as long as there is a difference of 3 db. The output level of the converter is arranged to vary not more than 1 db for a 60-db change in input.

The converter output is fed to a keyer amplifier unit where the signal is re-shaped and amplified to a level sufficient to work three teleprinters. The ability of the keyer amplifier to re-shape the signals to some extent is an important factor in operation under adverse conditions.

Various built-in test and measuring devices enable the apparatus to be set up in the absence of a signal. The variable b.f.o. facilities enable some degree of compensation to be carried out under local-control conditions when working against an unstable transmitter, but full realization of the benefits of the precise frequency control system necessitates the use of a very stable transmitting system and the drive equipment illustrated was designed to provide such a facility although there are many transmitters already in service of adequate performance.

The drive equipment uses h.f. oscillators and keyer amplifiers identical with those already described, together with shifter units giving crystal control of mean carrier and shift frequencies. These shifter units enable a number of preset channel frequencies to be selected by remote control and on each channel the shift is automatically adjusted to allow for the multiplication in use in the transmitter. A drive guard unit ensures that power cannot be applied to a transmitter unless drive is available. Warning devices operate should any of the ovens fail.

Using the two equipments described it is possible to set up a communications system on a number of frequencies between two points and to switch from one channel to another as propagation conditions dictate without any lining up or other attention and without interruption of the service.

# MOBILE RADIO

## *Compact Sets Intended for Unskilled Operation*

A RANGE of compact radio-telephone sets for use in motor cars, taxi cabs and various kinds of commercial vehicles and at the communicating fixed stations is now made by Hudson Electronic Devices, Ltd., Appach Road, London, S.W.2.

The sets are intended for unskilled operation and ease of servicing, and work on fixed frequencies controlled by close-tolerance quartz crystals in the band 60 to 185 Mc/s. While the same basic-circuit is used throughout, slight differences are found in the sets for the high and the low part of the band; for design purposes it is divided into two parts, low covering 60 to 100 Mc/s and high 101 to 185 Mc/s. In general the high-band sets have one or two valves more than the low.

Transmitters follow well-tried practice, using a crystal-controlled oscillator and frequency multipliers to give the working frequency and an r.f. power amplifier which is normally anode modulated. The r.f. output is about 5 watts for mobile and 6 watts for fixed sets.

*Hudson v.h.f. mobile radio-telephone installation. The unit on the left is the power supply.*

Receivers are a little different to the usual in that they employ a double superheterodyne circuit with one oscillator only. This is crystal stabilized and different harmonics are selected for the two frequency changers.

Installation costs of such equipment must inevitably vary according to circumstances, but a typical mobile equipment complete works out at about £85 and a fixed station at £120, plus cost of aerial.

Alternative models are available for f.m. or a.m. and for rotary generator or vibrator operation.

# Focusing Cathode Rays

*How Electron Lenses are Arranged in C.R. Tubes*

By "CATHODE RAY"

THIS is really a continuation of last month's issue ("Electron Optics") on the principles of electric deflection and focusing. So first will come a summary of the findings; then examples of how they are applied in cathode-ray tubes; and lastly something about magnetic focusing.

Here, then, is the summary. Cathode rays are streams of electrons in a vacuum. Each electron conforms very closely to Newton's laws of motion; that is to say, so long as it is not acted upon by any force it stays where it is or moves at constant speed in a straight line, and when a force acts on it in any direction it accelerates in that direction at a rate proportional to the force. An electron is so light that the force of gravity on it is negligible, but it responds smartly to electric and magnetic fields. An electric field is usually measured in volts per metre (or cm), and an electron placed in such a field accelerates positive-wards along the imaginary lines of electric force. These lines are at right angles to the equipotential lines, i.e., lines joining all points at the same potential. If the electric field is curved, or the electron already has some velocity in a different direction, its track does not coincide with any line of force, but bends in towards it as the acceleration in that direction increases; just as a ball thrown out of a top-floor window does not immediately follow the lines of gravitational force downwards but curves gradually towards that direction. Consequently an electron's track can be bent more sharply by a given electric field when the electron is travelling slowly than when it is fast. Its speed depends on the field strength multiplied by the distance through which it has acted, and this product is the total potential difference; if it is denoted by V volts the speed reached by the electron from a standing start is $593\sqrt{V}$ kilometres per second. The track of an electron in a given electric field pattern can be calculated from these principles, but the practical problem, which is the reverse—to find the shapes and voltages of electrodes needed to produce a field pattern that will make the electrons in a cathode ray follow a desired pattern of tracks—is more difficult, and is largely a matter of cut and try. A help towards visualizing the relationship between electric field patterns and electron tracks is the analogy in which electrons are represented by little balls, electric field by gravity, intensity of field by gradient of the surface along which the balls roll, p.d. by difference in height, and equipotential lines by contour lines.

The problem in any cathode-ray tube is to persuade the electrons, which tend to fly off in all directions by mutual repulsion, to converge to a particular point somewhere on the fluorescent screen. If they were sent towards this point slowly, their mutual repulsion would again have time to work and they could not be crowded together to produce a sufficiently small and intense spot. But if they are shot towards it at many thousands of miles per second they are there before they have time to realize that they hate one another's faces. So that is why a high voltage is applied between cathode and anode—which is sometimes very appropriately called the accelerator.

The converging, or focusing, can be done by either electric or magnetic fields, or of course both. In most oscilloscope tubes focusing is done by electric fields. In most television tubes it is done magnetically, but there is a tendency now to revert to electric focusing in order to save the cost of the magnet.

Before we tackle a complete c.r. tube it may help to clarify our mental pictures if we review the simple process of making a broad stream of marbles converge towards a point. Suppose they are being delivered uniformly along the front AB in Fig. 1 and that we want them to arrive at C. To get them moving in that direction it is of course necessary to make the surface slope down towards it. The speed they develop (friction neglected) is $8\sqrt{H}$, where H is the total height in feet they lose in the process; this formula is analogous to $593\sqrt{V}$ for electrons. To obtain, in addition, convergence towards C the obvious method is to channel the slope into a sort of valley. The marbles respond best to this treatment near the

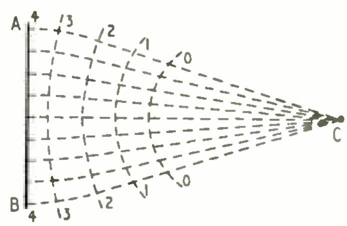



*Fig. 1. Contour map of a valley slope (Fig. 2) for making marbles roll from AB to C. The numbers attached to the contour lines are in inches above C level. The other dotted lines are the tracks of the marbles: note that by the time they have reached the last (zero) contour their momentum prevents them from rolling down exactly at right angles to the contour lines.*

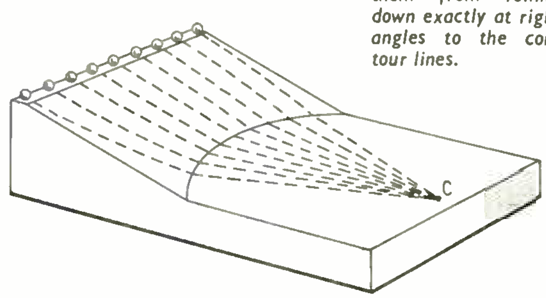



*Fig. 2. Model, of which Fig. 1 is the contour map. An electric field having equipotential lines of the same pattern as the contour lines of the model would make electrons follow similar tracks.*

start, before they have got up enough speed for their momentum to have much effect. Once their tracks have been directed towards C, it doesn't matter if the rest of the ground is flat. One procedure would be to make a model as in Fig. 2 and vary the shape of the channel until the balls actually did all arrive at C. Fig. 1 could then be derived from it, as a contour map of the model, the numbers on the contour lines being "inches above C level." Note that at first the tracks are almost at right angles to the contour, but nearer the foot the marble's momentum (neglected in the similar diagram last month) makes them swing out slightly.

Alternatively, if one were better at maths than at modelling, the contour lines required to obtain the converging tracks could be calculated and plotted as in Fig. 1, and these contour lines used to form an experimental model as in Fig. 2, by which the calculation could be checked. If now an electrode system were designed to produce equipotential lines shaped exactly like the contour lines in Fig. 1, electrons released along AB ought to converge on C, provided that their speed was sufficient for their mutual repulsion to be negligible. Of course the potentials of the equipotential lines must be proportional to *minus* the heights of the contours.

Gravity models have actually been used in the practical development of electron lenses, but a more usual device is the electrolytic tank, mentioned last month.

### Typical Focusing System

Let us now follow the evolution of a typical electric focusing system or lens in a c.r. tube. To show what happens in the small holes through which the beam passes it is necessary to draw these parts larger than life, and if the whole tube were drawn on the same scale—well, the Editor would disapprove! So the diagrams that follow, which are longitudinal sections, are *not* accurately to scale.

The first requirement in the vacuum tube is a heated cathode, for emitting the electrons; and next, an anode for accelerating them in the desired direction. If the anode were simply a plate, the electrons would all crash into it and there would be no beam to light up the screen. So a hole is made in the centre of the anode, as in Fig. 3. Removing this bit of metal does not much affect the potential of the space it leaves, for that space is surrounded by metal at the anode potential. So electrons starting off from the cathode scarcely notice the difference. As we saw last month, the equipotential lines are closer together where the lines of force diverge from a relatively small electrode, which means that the electrical slope is steepest near the start, and the electrons accelerate very rapidly.

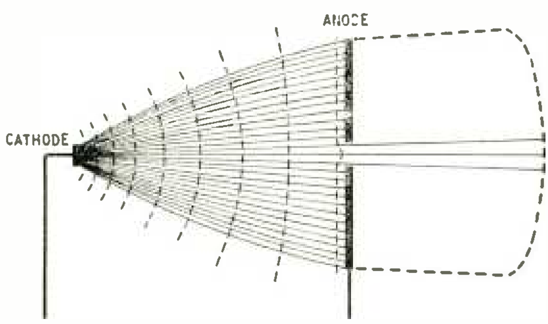



*Fig. 3. Equipotential lines (dotted) and electron tracks in a tube having only a cathode and perforated anode. The space enclosed by the dotted boundary on the right is supposed to be all at the same potential as the anode.*

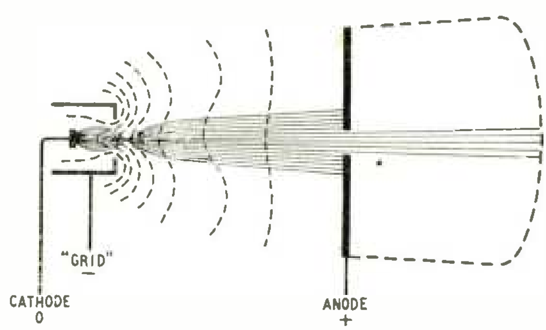



*Fig. 4. The addition of a cylindrical control electrode ("grid") at a slightly negative potential provides a more highly concentrated and controllable electron beam.*

Electrons right on the axis go clean through the hole, for although the anode attraction becomes increasingly sideways as they approach it, the sideways pulls are equal all round and cancel out. Even electrons slightly off the axis are travelling so fast by the time they are near the hole that only those very close to the edge would be deflected sufficiently to hit the anode. In Fig. 3 a contour line has been drawn very close to the anode to show how the field tends to follow the shape of the anode into the hole. The tendency for the electron tracks to be attracted towards the lines of force at right-angles to this line is small, and does little more than cause the beam that goes through the hole to spread out slightly. To prevent it from being spread out more by positive surroundings beyond the anode, or being repelled back to the anode by negative surroundings, the space beyond the anode is kept at or near anode potential so that the electrons that get through continue on in straight lines.

An obvious disadvantage of the system so far is that most of the electrons go to waste by colliding with the anode, leaving only a feeble beam to light the screen. One step towards remedying this is to start the electrons off on the right lines by making them run the gauntlet of a negatively charged cylinder, as in Fig. 4. If this is made too negative it neutralizes the strong but distant attraction of the anode and prevents any electrons from getting out, so it serves the double purpose of beam-forming and controlling the amount of beam current, and by analogy with a valve (rather than any physical resemblance) is usually called the grid. One of its effects is to focus the beam at a point just beyond where the beam emerges from the grid. In a well-designed tube the diameter of the beam at this point (called the cross-over) is smaller than the emitting surface of the cathode, so in effect the electrons are coming from a close approximation to the ideal point source, to the benefit of subsequent focusing.

If the screen were just beyond the anode the spot of light would be little bigger than the hole in the anode. But to leave room for deflecting the beam over a reasonable area the screen has to be a considerable distance beyond the anode, and even if the hole

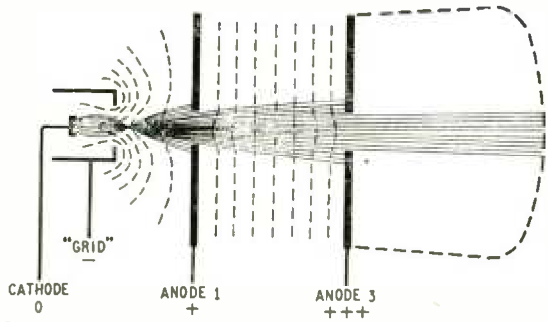



*Fig. 5. Although the addition of another disk anode at a higher potential does not improve the focusing it is a step towards an effective electron lens—Fig. 6.*

were extremely small the beam would spread too much to give fine definition, and, moreover (having come through such a small hole) it would be very weak. So the hole is made relatively large and the wide beam going through it is made to converge. The arrangement that does this is the electrons lens proper. There are innumerable varieties, but many of them comprise three anodes; in some, these anodes are kept at progressively higher potentials; in others, the first and third are highly positive and the second is less so, or even at or near cathode potential. Fig. 5 shows the sort of thing that would happen if the first and third anodes were disks with relatively large holes and the middle anode were omitted. The field between the anodes would be fairly uniform and would accelerate the beam but have little or no focusing effect.

Now put in a middle anode of cylindrical shape, as in Fig. 6. The metal wall of the cylinder short-circuits the electric field, for obviously it is all at the same potential, and so the equipotential lines are crowded together at the edges of the cylinder but are free to spread out in the centre. Remembering that the electrons tend to take the shortest cut from one equipotential line to another (but at the speed they are now doing they only *tend* to do so) we see that this pattern will make them converge. If it is found that the point to which they converge is, say, short of the screen, then by raising the potential of the middle anode some of the equipotential lines are transferred from the converging region to the diverging region, and the point of convergence is pushed farther away from the lens. This adjustment alone does not ensure that all rays converge on the *same* point to give a sharp focus; that depends to some extent on the voltages applied to the other anodes, but mainly on the shapes of all the anodes.

## Reversing Potential Gradient

A system basically like that just described is quite usual in oscilloscope tubes. The requirements for television are more exacting, and in a recent design there are four anodes: the first at only about +250 V, to attract the electrons gently through the grid orifice; the second and fourth forming a long cylinder with one section removed; and the third, between them, at about zero volts. The second and fourth are at about +10,000 V. One important thing to note about this and many other electric lenses is that the potential gradient reverses (in this example between the second and third anodes). After having fallen rapidly down a steep slope, the electrons have to go uphill for a short distance, like a switchback. If they strike this upward slope head-on, at right angles to the equipotential lines, all that happens is that they are decelerated. The final velocity corresponds to the net difference of potential between start and finish. But if they strike the upward slope at an angle, that angle is *increased* by the slope (instead of being diminished, as it would be if the slope were downward). One can easily check this by rolling balls up a slope. Of course, if the slope rises to a greater height than the original starting point, it fails to clear the summit and rolls back; but in the electron lens with the zero-potential third anode this condition is avoided by placing it so that it is largely screened by the 10 kV anodes.

I hope that by the time of the next Radio Show someone will have made a gravitational model for the educational stand. A better method than messing around with plaster of Paris is to mount a sheet of rubber in a horizontal frame and clamp portions of it (corresponding to sections of electrodes) at heights representing the potentials of those electrodes. It could be a simple matter for the heights to be variable, showing the effects of focusing adjustments and also of deflecting potentials, about which I have said nothing, because their principle ought by now to be obvious.

Of course, it must be realized that although such a model is three-dimensional it represents the electric field pattern in only two dimensions—a cross-section of the electron lens, as in Figs. 1-6 here. The lens is (or should be) symmetrical around its axis, so that the same diagrams or models hold good for all longitudinal sections. Equipotentials are always *surfaces*; it is only in section that they appear as lines.

The reason why this three-dimensional situation can be discussed on two-dimensional paper is that the direction in which electrons are accelerated by an electric field is the same as the direction of the field (lines of force). And the reason why the effects of magnetic fields are so much more difficult to visualize is that the direction of acceleration is at right angles both to the direction of the electron's movement and the direction of the field, so even when the problem is presented in its simplest form it still involves three dimensions. And in a solemn session of the Institution of Electrical Engineers I once heard one learned gentleman after another confess that visualizing anything in three dimensions was quite a headache. (Viewers of "3D" films will doubtless heartily agree.) However, it is a difficulty that is basic to electro-magnetism. In

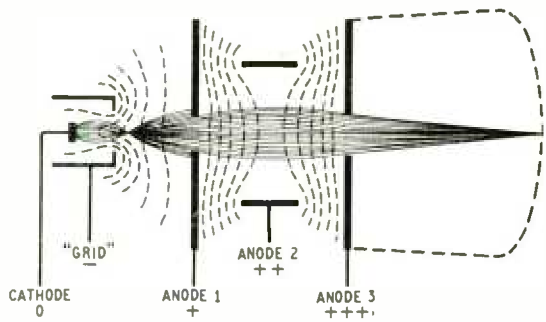



*Fig. 6. An intermediate anode of cylindrical shape bends the equipotential lines (which are actually sections of equipotential surfaces) as here, making the beam converge to a point on the fluorescent screen.*

ordinary electrical engineering—dynamos, motors, etc.—the problem is often a little easier because the electrons are confined to conductors, which are usually not free to move just anywhere. Electrons in a vacuum are not so bound. Their gyrations under the influence of combined electric and magnetic fields are the mathematicians' delight—but the non-mathematicians' despair.

However. Suppose we start with an electron gun something like that shown in Fig. 4, but with a larger hole, through which a slightly diverging beam of electrons is shot at high speed towards the screen. And suppose now that we wind a long coil around the beam, as in Fig. 7, producing a magnetic field pointing the same way as the electrons. What happens? To those electrons right at the centre of the beam, along its axis, nothing; for their path coincides exactly with the axial magnetic line of force, so they do not cut across the field, even slightly. So far as they are concerned there might not be a field. But those that are diverging do cut across the field, and so come under the law that makes electric motors motor. The appropriate memory-aider is the Left Hand Rule: if the thumb and first two fingers are stuck out all at right angles to one another, and the First finger is pointed in the direction of the magnetic Flux, and the seCond finger in the direction of the Current (which is opposite to the direction of the electrons) across the flux, the thuMb shows the direction in which the electrons tend to Move because of the electromagnetic force.

## Cathode's-eye View

Now in our c.r. tube the movement of the electrons, in so far as it is straight down the tube, parallel to its axis, is not across the flux at all, so merely confuses the issue; the proper viewpoint for seeing the movement across the flux without the axial movement is from the cathode. So here, Fig. 8, is a cathode's-eye view of the electron beam. Electrons along the axis remain at the centre all the time so do not appear to be moving at all; all others appear to be radiating outwards. Let us fix our attention on one particular electron just leaving the cross-over and diverging to the right. Since, for purposes of the left-hand rule, that is equivalent to a current in the opposite direction, the second finger should point to the left. The forefinger is pointing away, along the flux line, so the thumb shows that the force acting on the electron will make it accelerate downwards. If for simplicity we assumed (what in a real tube is not likely to be true) that the speed of divergence was constant, and also (what is certainly not true) that the direction of

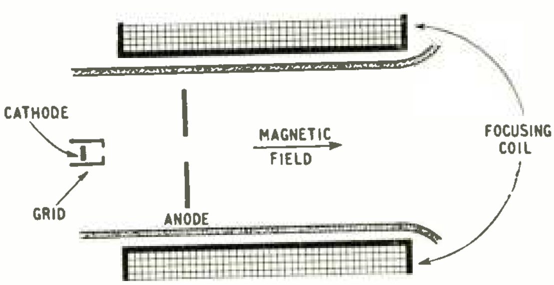



*Fig. 7. Section of electron gun, surrounded by a long coil designed to produce a nearly uniform magnetic field down the tube in the same direction as the electron beam.*

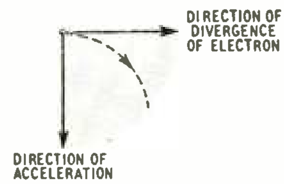



*Fig. 8. Cathode's-eye view of the beam, showing the effect of the magnetic field on an electron diverging to the right.*

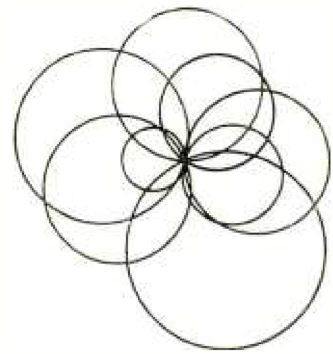


*Fig. 9. The divergent paths of electrons, as seen from the cathode, are curled round into circles by the magnetic field. The time taken to do a complete circle is the same for all electrons, slow or fast.*

acceleration continued to be downwards, then the path of the electron would be a curve as shown dotted. This is the same kind of curve as that traced by a ball thrown horizontally, and for the same reason—that the ball is given a constant speed horizontally, combined with a steadily growing speed downwards.

In practice, during the first stage of the electron's flight, from cross-over to anode, it is not going at uniform speed but is being accelerated by an electric field; it is only from the anode onwards that its horizontal motion is at constant speed. However, this complication is largely offset by the fact that the electromagnetic force causing the electron to accelerate downward is proportional to the speed of the electron as well as to the strength of the magnetic field. The real complication is the second one—that the downward acceleration doesn't keep on being downward. It is always at right angles to the electron, so directly the electron starts curving downward as in Fig. 8 the magnetic acceleration veers round to the leftwards. This makes the electron curve all the quicker, which keeps the acceleration veering, and so on. When the ordinary mind tries to follow the electron it is therefore likely to become very dizzy. Even the chap who rather fancies his proficiency with the calculus and tackles the thing mathematically may quite possibly get himself into a mess.

But the situation is exactly similar to a very familiar one—a weight being whirled round at the end of a string, or, if you prefer, the earth revolving round the sun. The weight, let us suppose, is given a constant speed in a certain direction—say the original direction of the electron in Fig. 8. But being attached to the string it cannot go out in a straight line; it goes round in a circle centred at the point where the other end of the string is fixed. To keep it in this orbit, the string has to exert a tensional force. This force is obviously always at right angles to the direc-

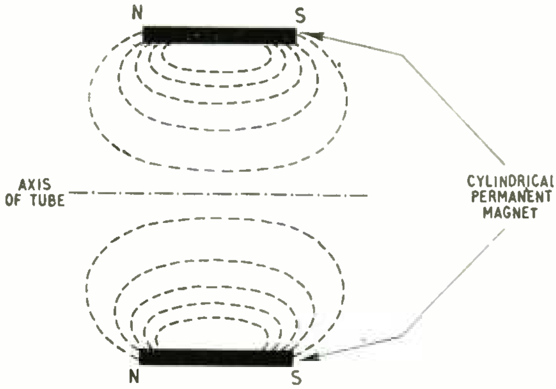


*Fig. 10. In practice a short magnet is used, and the effect on the electrons is more complicated.*

*Fig. 11. One effect of shortening the magnet is to change the circles of Fig. 9 into shapes more like this. The final result can still be satisfactory, and much more conveniently obtained.*

tion the weight is going. And if the speed of the weight is constant, so too is the force. Since these are exactly the conditions that govern the movement of the electron, it is reasonable to suppose (and it can be confirmed mathematically) that the electron whirls round in a circle.

### Corkscrew Electron Tracks

All electrons have the same mass and charge, and we are assuming that the magnetic field is the same for all, so for a given speed they all experience the same force. Actually, of course, the speeds with which they cross the field are different; those only just off the axis diverge much more slowly than those on the outside of the beam. But if the equation for centrifugal force is applied to weights that are all the same, and force proportional to speed, it shows that the time for one complete revolution is the same for all, regardless of speed. The faster speeds are handicapped by having to take bigger circles. The same applies to electrons. So after a certain time all electrons that started off from the centre together, whether fast or slow, have done one revolution and arrive back on the axis again simultaneously. In the meantime, of course, they have been travelling down the tube, so the electron tracks are actually like a corkscrew—or a helix, to be more scientific. Fig. 9 shows one curl each of a few electron tracks as seen from the cathode. The small circles are made by slowly diverging electrons; the larger circles by the faster ones.

Increasing the strength of the magnetic field increases the centre-wards force on all the electrons, so tightens their curls and reduces the time they take to execute each complete turn. To get a well-focused spot it is obvious that the strength of the magnet must be adjusted so that one of the times when all the electrons meet again is the moment they reach the fluorescent screen—which is a grand place for a reunion; they all get beautifully lit up.

Obvious it may be, but quite unpractical. To keep the electrons corkscrewing all the way to the screen it would be necessary to maintain the uniform magnetic field all the way there—a point that seems to have been overlooked in some of the drawings I have seen, purporting to explain magnetic focusing. Even to provide a magnet as long as the one in Fig. 7, extending as far as where the tube begins to open out, is too expensive and inconvenient, let alone one enveloping the entire tube, screen and all! So in practice a very short magnet is used, producing a curved field pattern something like Fig. 10. If you have been thinking that the theory of magnetic focusing has already been complicated enough, even with our beautifully uniform but quite unpractical field, you (and I) may well quail at the prospect of having to trace precisely what happens to diverging electrons in a field that varies rapidly both in strength and direction. But the operative word is "precisely." We can make a guess at roughly what happens.

At first, before an electron gets into the magnetic field, it is diverging quite happily in a straight line. But before it has had time to go too far, at the comparatively slow speed of this first stage of the journey, it finds itself going through the magnet ring, with a strong magnetic pull making it wheel round sharply. The magnet has been made of such a strength that by the time the electron is beyond its influence it has done an about-turn and is converging towards the axis again, as in the view from the cathode in Fig. 11. It is now also shooting towards the screen at really high speed, and, if everything has been done right, hits it just as it (and all its mates that left the cathode at the same moment) are on the axis again. Of course this is assuming the beam is not being deflected. If it is, then they meet elsewhere, but as all are equally deflected they do meet.

But don't ask me to produce a mechanical analogy to demonstrate all this! The proof of the thing is on your TV screen.

## Awards for Technical Authors

THE Radio Industry Council's premiums for technical writers for the year 1953 are now announced; as will be recalled, these awards are made with the object of encouraging the publication of clearly written expositions of British achievements in radio and electronics.

Premiums of 25 guineas each are awarded to the authors of the following articles:—

"Spectrum Equalization," by G. G. Gouriet (*Wireless Engineer*, May).

"Triode Transformation Groups," by A. W. Keen (*Wireless Engineer*, October).

"A Cylindrical Magnetron Ionization Gauge," by A. H. Beck and A. D. Brisbane (*Vacuum*, April).

"The Scanning Electron Microscope and the Electron-Optical Examination of Surfaces," by D. McMullan (*Electronic Engineering*, February).

"A Linear Sweep Cathode-Ray Polarograph," by H. M. Davis and Miss J. E. Seaborn (*Electronic Engineering*, August).

"Selective Calling for Radio-Telephone Systems," by J. R. Pollard (*Electronic Engineering*, December).

# Improved Radio Altimeter

*Servo Principle Giving Greater Freedom From Noise*

By A. BLOCH,* K. E. BUECKS† and A. G. HEATON‡

THE radio altimeter has now become quite a well-known instrument for giving the pilot of an aircraft an indication of his clearance height above the terrain. Like many distance-measuring devices it works on the echo or radar principle, only instead of pulses it makes use of frequency modulation to obtain the actual measurement. A frequency-modulated continuous wave is transmitted downwards from the aircraft and is reflected back from the ground. By the time it reaches the aircraft again the transmitter frequency has changed, so there is a difference between the frequency of the received wave and that of the transmitted wave. This frequency difference is, of course, proportional to the time delay experienced by the returning wave, and so to the height of the aircraft above ground, and in the instrument it is obtained simply by heterodyning the two waves and taking the resultant difference frequency.

A new instrument has now been designed which works on this familiar principle but has improved sensitivity. It will give a reliable indication of height up to 5,000ft with an accuracy of $\pm 3\%$ $\pm 5$ft and over all types of ground—including dry desert which reflects only 3% of the incident power. At the same time the new instrument avoids certain complications, such as range-switching, which were necessary in previous designs. It uses a continuous-wave transmission, the frequency of which is varied linearly with time between 1,605 and 1,655 Mc/s.

One method of obtaining the greater sensitivity has been by the use of the superheterodyne principle. This achieves the required large amplification of the received signal without introducing difficulties brought about by microphonic noise created in the amplifier by the vibration of the aircraft. The wave returned from the ground may have an amplitude of only one millionth or less of the amplitude of the wave transmitted and may thus require an amplification of $10^7$ times in order to operate a robust indicator.

Instead of the returned wave being heterodyned with the transmitted wave, it is heterodyned with an auxiliary wave, the frequency of which is always 110 Mc/s higher than the transmitted wave. This auxiliary frequency is created by mixing part of the output of the transmitting oscillator with the output of a 110-Mc/s oscillator and filtering out the desired component. If the returned wave had been heterodyned with the transmitted wave directly the resultant beat frequency would have been an audio frequency. Here, however, it is 110 Mc/s plus or minus this audio frequency, which is, of course, quite low compared with 110 Mc/s, so that for brevity we can still speak

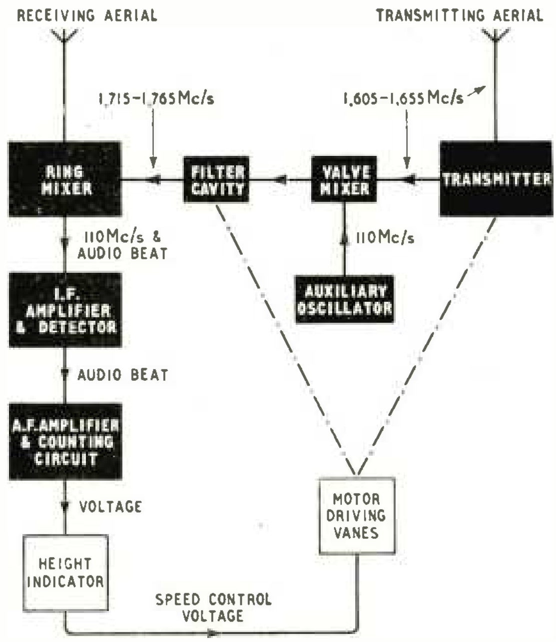
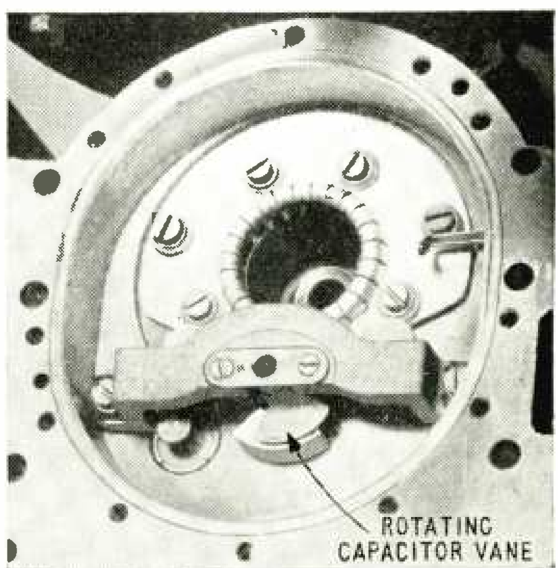



*Fig. 1. Simplified block schematic illustrating the principle of the altimeter.*

*Fig. 2. The cavity resonator of the transmitting oscillator, showing the small rotating capacitor vane.*




* Research Laboratories, General Electric Company.
† Royal Aircraft Establishment.
‡ Salford Electrical Instruments.

of an intermediate frequency of 110 Mc/s. This intermediate frequency is amplified about a thousand times and then mixed with the output of the auxiliary 110-Mc/s oscillator. As a result, beats are produced of the same audio frequency as if the returned wave had been heterodyned directly with the transmitted wave. These beats are subsequently amplified and sent to an indicating mechanism, which will be described below. The exact frequency of the 110-Mc/s oscillator is immaterial, as long as it stays within the pass band of the i.f. amplifier.

Additional protection against noise is obtained by an application of the principles of servo mechanisms to keep the bandwidth of the amplifier smaller than it would be normally. In order to get a sufficiently accurate indication of heights below 900ft the constants of the altimeter are chosen so that for this height a beat frequency of just 10 kc/s is produced. Under the same conditions at 5,000ft a beat frequency of over 50 kc/s would be produced, so that an amplifier of this bandwidth would be required, which would pass five times as much noise as an amplifier with a bandwidth of only 10 kc/s. In order to avoid this the following scheme has been adopted. The frequency variation of the transmitting oscillator is produced by a rotating capacitor vane driven by a small motor. Once a height of 900ft has been reached, any further increase in height is arranged to cause a reduction of the voltage supplied to the driving motor, slowing down the motor until a beat frequency of 10 kc/s is restored. Obviously, the amount of slowing down of the motor is just as much a measure of the height reached as is the frequency attained with constant motor speed. The additional advantage of this scheme is that from a height of 900ft upwards the beat frequency produced is always 10 kc/s, and it is possible to make the audio amplifier most sensitive to this particular frequency. Thus the weaker signals, i.e., signals received at heights greater than 900ft, get maximum amplification.

## Circuit Arrangement

Fig. 1 shows the layout of the instrument and the relation of its various parts. The transmitting oscillator consists of a triode operating in a cavity resonator (Fig. 2). This resonator is modulated through the range 1,605-1,655 Mc/s by a small rotating capacitor vane driven by a special d.c. motor. (In this motor the speed of rotation is an accurate measure of the voltage applied to the terminals of the motor, a property required in the operation of the servo mechanism.) The larger part of the oscillator output is fed to the transmitting aerial. A small part is fed to the valve mixer, where it is mixed with the output of an auxiliary 110-Mc/s oscillator. This mixer valve, a triode, also operates in a cavity resonator which is of similar dimensions to the transmitting oscillator cavity and is always kept in tune with the required frequency (110 Mc/s above the transmitter frequency) by a rotating capacitor vane mounted on the same shaft as the vane of the transmitting cavity. The output of this filter cavity is used as the "local oscillation" and is mixed with the received signal in the ring mixer.

The ring mixer is a so-called balanced mixer, i.e., a type in which two mixing elements (here silicon crystals) are operated simultaneously in such a way that the effect of any amplitude modulation of the local oscillator frequency is cancelled in their combined output as far as possible (Figs. 3 and 4). The output of the ring mixer consists of a 110-Mc/s intermediate frequency with a superimposed audio beat corresponding to the height of the aircraft. This is passed through an i.f. amplifier, which has a bandwidth of 1.5 Mc/s, and then on to a detector where the audio beat frequency is obtained. After amplification the audio beat goes to a counting circuit which produces an output voltage proportional to the rate of the beat.

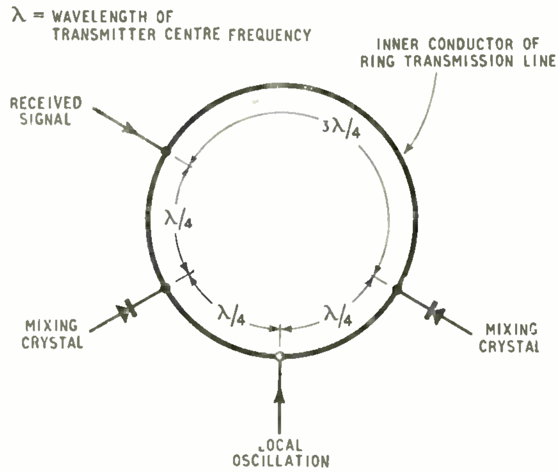



*Fig. 3. Principle of the ring mixer. The local oscillation is fed to the crystals in phase while the returned signal is fed to them 180 out of phase. The i.f. outputs from the crystals are then in opposite phase and as they are combined by subtraction any unwanted amplitude modulation of the local oscillation is cancelled out.*

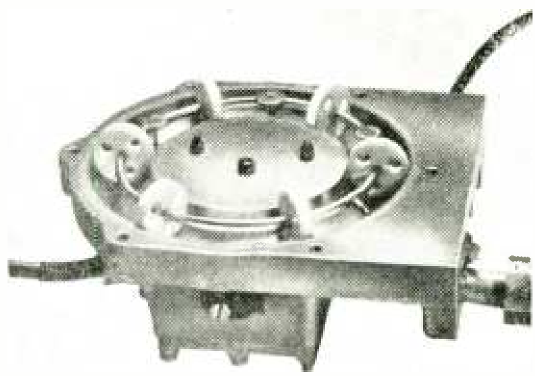
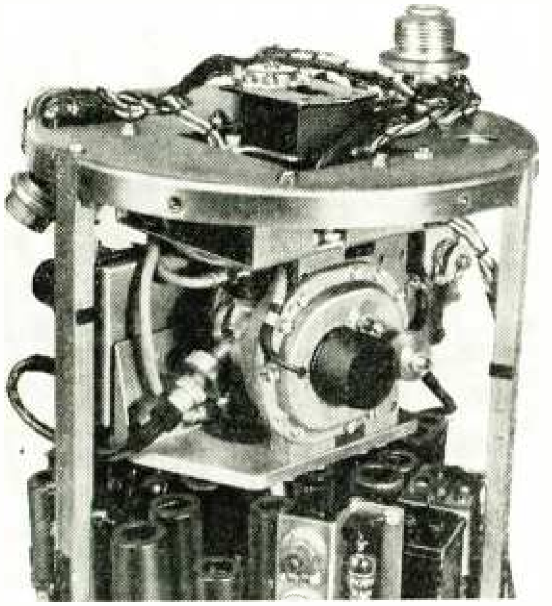


*Fig. 4. The ring mixer consists of a coaxial transmission line, 1.5 wavelengths long, formed into a circle. This is an opened-up view.*

It has already been mentioned that the altimeter has two different modes of operation: one, below 900ft, where the modulating motor is run at constant speed and the frequency of the beats is taken as a measure of height; and another one, for heights above 900ft, where the beat frequency is kept constant at 10 kc/s and the motor speed is taken as a measure of height. The altimeter must therefore include some mechanism which will automatically change from one mode of operation to the other one without an external switching operation.



One end of the chassis showing the cavity resonator of the valve mixer and the capacitor-vane driving wheels.

The voltage from the counting circuit is compared with a voltage derived from a potentiometer that is mechanically coupled to the height indicator. Any unbalance detected is used to control the motor which sets the potentiometer and indicator in such a way as to eliminate the unbalance. For heights below 900ft the voltage derived from the counter is (because of the constant speed of the modulating motor) proportional to the height of the aircraft. The voltage derived from the potentiometer is proportional to the height shown by the indicator. Thus the position of the indicator will always reflect the rate at which the beats are produced and therefore show the correct height (Fig. 5).

### Second Mode of Operation

The potentiometer is constructed in such a way, however, that once the indicator setting exceeds 900ft it provides constant output, irrespective of height. Evidently its output can then only be balanced if the modulating motor is slowed down. For this purpose there is mechanically coupled to the first potentiometer a second potentiometer which supplies the voltage for the modulating motor. If the indicator shows a height of less than 900ft this second potentiometer is in a "flat" portion of its range and thus supplies the required constant voltage for the modulating motor. But if the indicator goes to a height of more than 900ft the potentiometer is in an appropriately graded part of its range and supplies to the motor a voltage which decreases with the height shown by the indicator. Hence, when the aircraft rises to a height of more than 900ft the indicator motor—not being able to establish a balance on any setting of the indicator of less than 900ft—will run on, drive the first potentiometer on to its "flat" portion and the second potentiometer on to its graded portion. It will thereby reduce the speed of the modulating motor until there is again


*Fig. 5. Face of the height indicator. The full scale represents 1,000 ft, so the pointer makes five revolutions for 5,000 ft. Integral thousands are clocked-up in the window at the bottom.*

a balance between the output of the counter and the voltage supplied by the first potentiometer (now constant, corresponding to a beat frequency of 10 kc/s). With proper grading of the second potentiometer the setting of the indicator at which balance is obtained and the indicator motor stops corresponds again to the height of the aircraft.

This second mode of operation continues for heights up to 5,000ft. For heights exceeding this figure the motor speed stays constant and an indication is given that the aircraft is above the limiting height. This "hold off" presentation continues above 5,000ft, even if the signal should fade into noise, as sufficient gain is provided before the counting circuit for this to be operated by noise. Such noise represents a signal above 10 kc/s, since the audio amplifier characteristic extends beyond 20 kc/s. It will be apparent that if an output corresponding to a frequency greater than 10 kc/s is produced by the counter, the indicator will run up beyond 5,000ft in an endeavour to find a balance point.

### Automatic Change of Characteristics

An additional feature of the altimeter is a system which indicates to the pilot that he is flying at a preselected height and warns him if he drops below this height.

An interesting point about the audio amplifier which magnifies the beat frequency is that it has a system for automatically changing its frequency characteristic to suit the mode of operation of the altimeter. Two input channels are provided. The first is in operation when the signal strength is below a certain level and its characteristic is of the peaked form referred to already. As the signal strength increases a bias is produced which closes this channel and the signal is now transferred to the second channel, which has a flatter characteristic. This arrangement has been chosen because when working at low altitudes; i.e., at low beat frequencies, a peak in the frequency response characteristic at 10 kc/s would cause an undesirable deterioration in the signal/noise ratio.

The aerials used are identical for receiver and transmitter. They are arranged on the aircraft in such a position that the direct transfer of energy from transmitter to receiver is kept at a minimum. An installation on either side of a tail plane is usually sufficient for this purpose. The directivity of these aerials is prescribed by operational requirements such as angles of bank, dive, or climb during which the reflected signal must be received.

# Attenuators for High Frequencies

By R. F. PRIVETT,* M.Sc.

*Basis for a Design Using Standard Components*

MANY r.f. measurements, such as the measurement of receiver gain, require that a known voltage be produced at the input terminals of the unit under test. The input voltage may be too low to permit it to be measured directly, and it is then usual to generate the signal at a level convenient for measurement, to attenuate it to the required level and to transmit it via a screened conductor to the unit under test. The combination of oscillator, monitor, attenuator and coaxial cable is called a standard signal generator. This article is intended to give the reader an understanding of that part of a signal generator which is in general the least understood—the output system.

"Cathode Ray"[1] has given an introduction to the subject in which he stresses the importance of matching and illustrates "ladder" attenuators and attenuators which contain "T-section" pads of fixed attenuation, which are selected by the operation of two-pole, two-way, changeover switches. The latter system is the one described in this article, and, as designed, the attenuator can provide any attenuation variable in increments of 1 db, up to a total of 80 db, by the combination of pads of 1, 2, 5 and 10 db loss.

To appreciate the importance of each factor involved in attenuator design it is necessary to consider the following topics: (1) Precautions required in the transmission of r.f. energy and in particular propagation along coaxial cables. (2) The r.f. behaviour of resistors, and the variation of pad attenuation with changes of resistance. (3) The effects of switch capacitance and lead inductance.

In a signal generator one must also consider how best to measure the attenuator input.

## The R.F. Transmission Circuit

An output system is illustrated in Fig. 1. The open circuit voltage E of the generator may be measured and held constant and the voltage presented to the unit under test is the voltage $e$ developed across the cable termination $Z_T$. This diagram has been simplified and shows the generator as a source of open-circuit voltage E and internal impedance $Z_s$, the attenuator as comprising one "T-section" and the termination as an impedance $Z_T$ separate from the unit under test (in practice this unit may provide a part, or all of this terminating impedance).

We will now concern ourselves solely with the requirements placed by the cable on $Z_T$ and $Z_s$. The physical form of the generator and the behaviour of the attenuator will be discussed later. So let us connect the generator directly to the cable by putting $R_1 = R_3 = 0$ and $R_2 = \infty$.

The characteristic impedance $Z_0$, of a cable may be defined as the input impedance presented by an infinite length. A lossless cable has a $Z_0$ which is purely resistive and can be calculated in terms of the geometry of the conductors and the dielectric constant of the insulation. Conductor resistance and dielectric loss cause $Z_0$ to have a reactive component and cause attenuation along the length of the cable, which, however, can be minimized by the choice of an optimum value for $Z_0$. The standard polythene-insulated cable is designed for this optimum and has a $Z_0$ which may be taken as resistive, and is nominally 75 ohms with a manufacturing tolerance of a few ohms. For our purpose the cable will be considered lossless.

A length of cable can nevertheless affect the output by introducing impedance transformations; for example a cable of length one quarter of a wavelength $\left(l = \frac{\lambda}{4}\right)$ can behave as a transformer causing our generator of impedance $Z_s$ to appear at the other end of the cable as a generator of impedance $Z' = \frac{Z_0^2}{Z_s}$. The open circuit voltage E would be transformed as the square root of the impedance, i.e. $E' = E\sqrt{\frac{Z'}{Z_s}}$. From the above it follows that the variations of the output voltage $e$ due to changes with frequency in the electrical length of the cable (defined as $\frac{2\pi l}{\lambda}$) can be reduced to zero by making $Z_s = Z_0$. The generator is then matched to the cable and the value of the load $Z_T$ is unimportant. By a similar process one may show that the generator impedance $Z_s$ is unimportant if $Z_T = Z_0$.

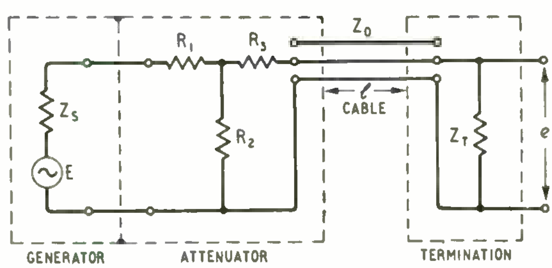



*Fig. 1. Simplified circuit of the output system of a signal generator.*

* General Electric Company (Research Laboratories).
[1] "Wireless World," March 1953, p. 131.

In practice the cable may not be uniform and the source or generator may not be perfectly matched. Then it is best to have the cable approximately matched at *both* ends.

It is possible to design the generator impedance to match the cable, and imperfections are more likely to be present at the termination. Part or all of the terminating impedance may be provided by the unit under test, and the effects of mismatches introduced by the unit must be minimized.

As an example of the use of a matched generator in minimizing the effects, consider the problem of providing a constant voltage at the input terminals of an amplifier which has a small input capacitance C. If these terminals are shunted by a resistor the cable can be terminated correctly at low frequencies, but the capacitance will introduce a moderate mismatch at high frequencies. The voltage developed across the terminals has been calculated, by methods outlined in the Appendix, for the case of a matched generator, and for that of a zero impedance or constant-voltage generator. The results for the particular values of C = 10pF, cable $Z_0 = 75$ ohms and length $l =$ 1 metre are plotted on Fig. 2. The dotted curve, calculated for a generator of 75 ohms output impedance, shows a loss increasing with frequency to a value of 0.86 db at 200 Mc/s, whereas the full curve, calculated for a zero impedance source, shows large fluctuations with frequency; even at 30 Mc/s the output has risen by 0.5 db.

We may conclude that a generator of the correct output impedance is essential, unless measurement is restricted to frequencies at which the cable has a length less than one-eighth of a wavelength, or to frequencies at which the unit under test can be assumed to match the impedance of the cable.

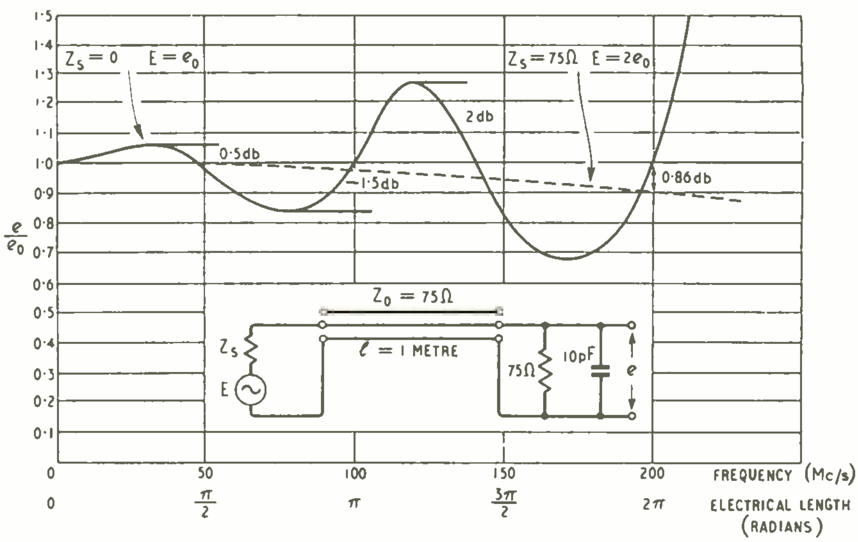



*Fig. 2. Effect of source impedance on output voltage from a 1-metre coaxial cable feeding a resistance equal to the characteristic impedance shunted by 10pF.*

**R.F. Behaviour of Resistors and Resistance Networks.**—The low-frequency accuracy of an attenuator using resistance networks is limited by the stability of the component resistors. D.c. measurements of resistance and successive adjustments may be employed to approximate to the required value of resistance with any accuracy likely to be desired, until the error remaining is of the order of the errors expected to arise with age, temperature, humidity, etc.

Unfortunately the resistors of the higher stability generally become extremely reactive at high frequencies, and attenuator design has shown signs of division into two classes. The first class is exemplified by the precision instrument accurate to a hundredth of one db which contains wire-wound resistors, and the second by the instrument of medium d.c. accuracy which is maintained at high frequencies. Research is in progress to improve the high-frequency performance of the former class and the accuracy of the latter. The attenuator described falls into the latter class and employs the "cracked" carbon high-stability type of resistor. As a useful attenuator can be constructed using the familiar resin-bonded carbon type of resistor both types will be considered.

The resistance values required for attenuator pads of 75 ohms characteristic impedance are given in Table I. Each pad is symmetrical so that, in the nomenclature of Fig. 1, $R_1 = R_3$.

A pad in which all the resistances are the same has attractions economically and, as will be shown later, electrically. This pad gives an attenuation of 11.44 db. The values are calculated from the formulæ :—

$$R_1 = Z_0\left(\frac{N-1}{N+1}\right)$$

$$R_2 = Z_0\left(\frac{2N}{N^2-1}\right)$$

where N is the ratio of input current to output current, which in the case of a 3 db pad is $\sqrt{2}$.

The resin-bonded carbon resistor can be obtained in miniature form with ample dissipation for attenuator inputs of a few volts r.m.s., and the required value of resistor can be approximated to within $\pm$ 5 per cent by selection from the preferred standard values of the 5-per cent tolerance range.

For example, half the resistors nominally 20 ohms or 22 ohms should be within 5 per cent of the 21-ohm value required by the 5db pad. With a temperature coefficient averaging 0.05 per cent per degree C and a shelf-life stability of $\pm$ 2 per cent, selection to $\pm$ 3 per cent would be profitable.

The errors in attenuation between correct values of source and load impedance due to pad resistances of 90 per cent of the correct values are given in Table II. The values in brackets are those obtained with a zero-impedance source and it can be seen that a correct source impedance is important in reducing the effect of errors. The change in attenuation due to a proportionate change in all resistances is then low, and this has a bearing on high-frequency response (as will be shown).

"High-stability" resistors, stable to $\pm$ 1 per cent,

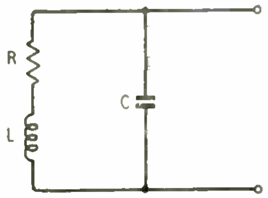



*Fig. 3. Equivalent circuit of a carbon resistor.*

*Right: Fig. 4. Underside of attenuator using wafer switches. Foil instead of wire is used for cross leads to reduce inductance.*

TABLE I

| Attenuation (db) | 20 | 11.44 | 10 | 5 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| $R_1$ .. | 61 36 | 43.30 | 38.96 | 21.01 | 12.8 | 8.66 | 4.31 |
| $R_2$ .. | 15.15 | 43.30 | 52.71 | 123.4 | 212 | 323 | 650 |

TABLE II

| Nominal attenuation (db) | Increase in attenuation (db) due to −10 per cent resistance change | | | |
|---|---|---|---|---|
| | $R_1$ only | $R_1$ and $R_3$ | $R_2$ only | $R_1$, $R_2$ and $R_3$ |
| 3 | −0.05 | −0.15 | +0.17 | +0.02 |
| 11.44 | −0.26 | −0.51 | +0.54 | +0.02 |
| | | (−0.8) | (+0.4) | (−0.28) |
| 20 | −0.38 | −0.72 | +0.76 | +0.02 |

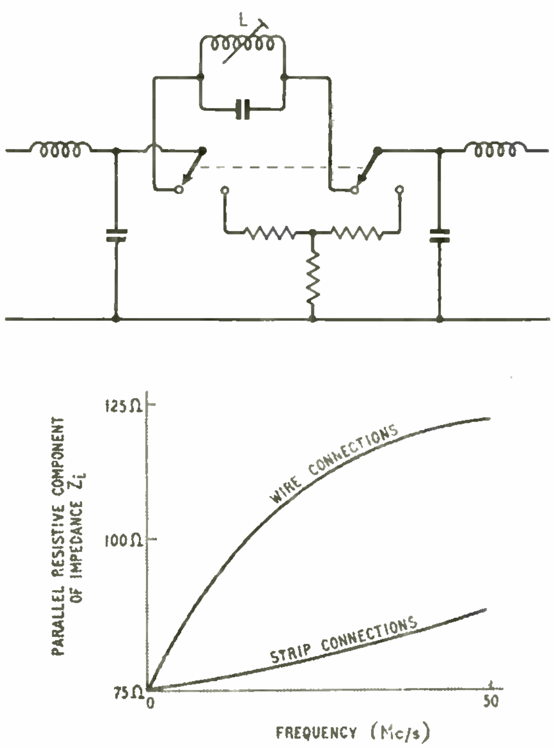



*Fig. 5. Equivalent circuit of switch and wiring and variation of losses with frequency.*

can be obtained with a nominal dissipation of ⅛W. They are slightly larger than the conventional resistors described, but in spite of this, and the spiralling of the resistive track which is necessary to control the value of resistance, they have high-frequency properties which are very similar. An equivalent circuit which approximates to both types of resistor in the resistance range of 10 to 1,000Ω is shown in Fig. 3.

The shunt capacitance C is usually below 1 pF and the series inductance will vary with lead length, but should be under 0.02μH. It thus appears that the behaviour of a resistor will vary with its resistance value R and it is found that the impedance of a 1,000-Ω resistor will fall at high frequency and that of a 10-Ω resistor will rise. Resistors in the range 40 to 200Ω can be expected to retain a resistance close to their d.c. value.

Reference to Tables I and II will now show why it is advisable to avoid low values of resistance, especially when included in a pad of high attenuation, e.g. the 15-Ω resistor in the 20-db pad. The advantages of using pads with equal resistors, having the same behaviour of high frequencies, are now obvious. This suggests that the bulk of the attenuation should be provided by pads of 11.44 db attenuation and to approximate to this value it was decided to standardize on a 10-db pad.

**Switches and Interconnections.**—Two-pole two-way switches are required to control the insertion of the pads and many varieties of toggle and wafer switches are available. The wafer type has the lowest capacitances to earth and across the contacts, but its use leads to a large attenuator compartment. Fig. 4 gives an underneath view of an attenuator using wafer switches and containing 20, 10 and 5 db pads, giving a total attenuation of 75 db variable in increments of 5 db. Such a design using pads of 10 db maximum attenuation and giving increments of one db would result in a very bulky unit, but it is possible that 20 db pads in which the 15-Ω resistor is replaced by 3 resistors each of 45Ω, would be satisfactory when used in conjunction with wafer switches. Space could be saved by using toggle switches to control the insertion of the pads of lower attenuation.

Some attention was given to the performance of the attenuator at its zero attenuation setting, as heavy losses due to the switches and connecting leads would render the attenuator useless for incorporation in a signal generator. Measurements were made of the input impedance $Z_i$ of the wafer-switch type of attenuator at its zero setting with a 75-Ω load across the output terminals. The results of these measurements together with the equivalent circuit of a switch and its connections are shown in Fig. 5.

The reduction of the inductance L of the connection across the switches, which was achieved by replacing

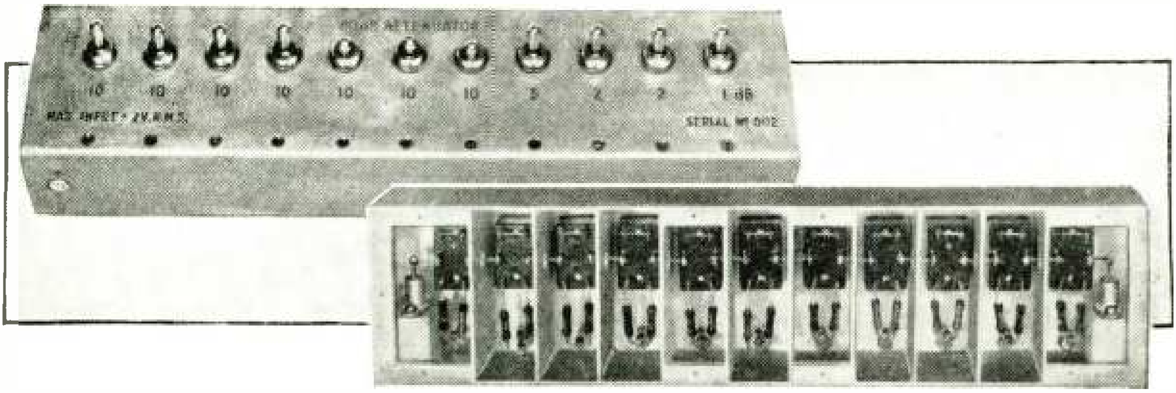


*Fig. 6. Attenuator unit for frequencies up to 100 Mc/s using standard toggle switches.*

the original copper wires by strips of copper foil, resulted in an input impedance which varied slowly with frequency. These strips can be seen in Fig. 4 and the theoretical explanation of this behaviour is that the series inductances and shunt capacitances form a low-pass filter which by the reduction of inductance has been brought to a characteristic impedance, analogous to that of a cable, of approximately 75 Ω. The cut-off frequency of this filter is of the order of 500 Mc/s so that at frequencies up to 100 Mc/s the attenuator at zero setting behaves very much as a length of 75-Ω cable.

With the application of these principles attenuators were constructed using "Arrow," "Bulgin" and "N.S.F." toggle switches, and the type produced in small quantities is that illustrated in Fig. 6. The resistors used were supplied by special arrangement to be within ± 1 per cent of the required values and are high-stability components. Standard P.O. type connectors were used while the box was fabricated from sheet brass.

One of the units was sent to the National Physical

## APPENDIX

A generator of impedance $Z_s$ is connected by a cable of characteristic impedance $Z_0$, and length $l$, to a termination consisting of a resistance $Z_0$ shunted by a capacitance C. If the generator impedance $Z_s = Z_0$ the output voltage $e$ developed across the termination will be independent of $l$ and the circuit has the simple equivalent form shown in Fig. A1.

We then have $\frac{e}{e_0} = \frac{1}{1 + j\omega C Z_0/2}$ and taking the modulus or "amplitude of $e$"

$$\left|\frac{e}{e_0}\right| = \frac{2}{\sqrt{4 + \omega^2 C^2 Z_0^2}}$$

If the generator impedance $Z_s = 0$ we have the equivalent circuit of Fig. A2.

The equivalent output impedance is reactive and the open-circuit voltage is transformed in the ratio $\sqrt{1 + y^2} : 1$ where $y = \tan\frac{2\pi l}{\lambda}$. The term $\frac{2\pi l}{\lambda}$ is called the electrical length of the cable and the wavelength in the cable is $\lambda = \frac{\lambda_0}{\sqrt{\kappa}}$ where $\lambda_0$ is the wavelength in air and $\kappa$ is the dielectric constant of the insulation. (For polythene $\kappa = 2.23$ and $\lambda \simeq \frac{2\lambda_0}{3}$)

From the above circuit

$$\left|\frac{e}{e_0}\right| = \frac{\sqrt{1 + y^2}}{\sqrt{(1 - y Z_0 \omega C)^2 + y^2}}$$

When $y = 0$ $\left(l = \frac{n\lambda}{2}\right)$ $\frac{e}{e_0} = 1$, and for a cable of length one metre this occurs at 0, 100, 200, 300 Mc/s etc. Note that $e = e_0$ at all frequencies if $l = 0$, and that $e = e_0$ for all $l$ if C = 0.

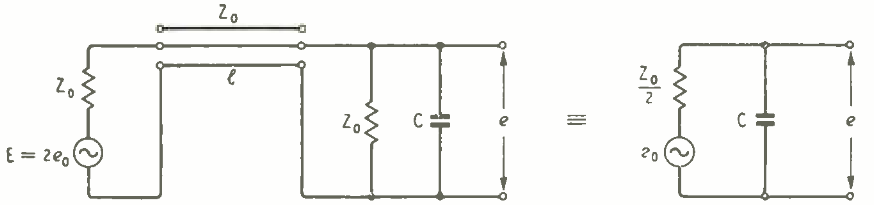



Fig. A1.

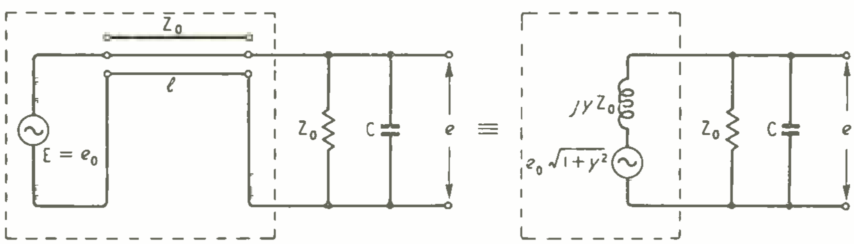



Fig. A2.

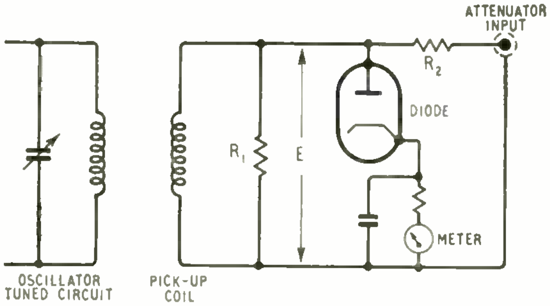



*Fig. 7. Typical coupling circuit between oscillator and attenuator.*

**TABLE III**

| Pads in circuit | Nominal attenuation (db) | Attenuation in db relative to 1-Mc/s value at frequencies of: | | | |
|---|---|---|---|---|---|
| | | 25 Mc/s | 50 Mc/s | 75 Mc/s | 100 Mc/s |
| 1 × 10.. .. | 10 | 0 | 0.05 | 0.025 | 0.05 |
| 1 + 2 + 2 + 5 | 10 | 0 | 0.05 | 0.10 | 0.125 |
| 5 × 10.. .. | 50 | 0 | 0.10 | 0.25 | 0.10 |
| 1+2+2+5+ (4 × 10) .. | 50 | −0.05 | +0.075 | 0.3 | 0.2 |
| All .. | 80 | −0.15 | −0.125 | — | — |
| "Zero level" insertion loss .. | 0 | 0.15 | 0.25 | 0.45 | 0.65 |

Laboratory for calibration at high frequencies and the results are summarized in Table III. The change in attenuation relative to the value measured at 1 Mc/s is given for various combinations of pads at frequencies of 25, 50, 75 and 100 Mc/s. At the higher frequencies the measurements were limited to a maximum attenuation of 50 db. Also the attenuation introduced by the presence of the attenuator at its zero setting was measured.

**Measurement of Attenuator Input.**—Consider the circuit coupling an oscillator to the input of the attenuator and in particular the arrangement in Fig. 7. Here a pick-up coil, which is lightly coupled to the oscillator, and is damped by resistance $R_1$, develops a voltage across a diode voltmeter. It is normal practice to hold this voltage to a constant value at all frequencies, either by an operator who corrects errors shown on a meter by the adjustment of manual controls, or by a feedback network.

Whether the servo system is automatic or is completed by human agency it results in a constant voltage E being maintained across $R_1$. At the attenuator input the terminals yield an open-circuit voltage E and a short-circuit current $E/R_2$ and by Thévenin's theorem must appear as a source of resistance $R_2$. Thus to suit the attenuator described $R_2$ would be made 75 Ω. A low value of $R_1$ will minimize the adjustment necessary to compensate for changes of load presented by the attenuator, but too low a value will cause excessive loading of the oscillator circuit.

# MULTIPLEX F.M. BROADCASTING

## *Two Programmes in a Standard Channel*

With frequency modulation very much in the air as a result of the Television Advisory Committee's recent report on v.h.f. broadcasting, it is interesting to hear from America about a system of f.m. multiplexing whereby a standard 200-kc/s channel can be used for carrying two programmes simultaneously. It is the work of the late Maj. E. H. Armstrong, the pioneer of f.m. transmission, and J. Bose of Columbia University, and has been undergoing tests for several years at Maj. Armstrong's experimental f.m. station in New Jersey. The auxiliary channel is provided by a 27.5-kc/s sub-carrier, which frequency modulates the main carrier and is itself frequency modulated by the auxiliary programme.

Previous attempts have been made at f.m. multiplexing for broadcasting but have not been very successful, mainly because of cross-modulation between the main and auxiliary channels and the transfer of noise from one to the other. Armstrong and Bose have published claims to have overcome this trouble by arranging for the modulation processes of the two channels to be performed in separate parts of the transmission system, so that they are protected from each other. The phase-shift method of modulation is used, with frequency multipliers to increase the small deviation obtained from it to the required value. A crystal oscillator providing the drive is followed by a phase-shift modulator into which is fed the a.f. modulating signal of the main programme. The resulting modulated carrier then passes through a chain of three frequency multipliers and interposed band-pass filters to a power amplifier and the aerial, where the final maximum deviation is about 50 kc/s. Between the second and third multipliers is inserted a second phase-shift modulator and here the 27.5-kc/s sub-carrier with its auxiliary programme is superimposed on the main carrier. The deviation produced by this sub-carrier is of the order of ±20 kc/s, while its own deviation by the modulation is about ±5 kc/s.

The phase-shift modulation system is also used within the auxiliary channel for impressing the audio input on the sub-carrier. To obtain the necessary deviation, however, the frequency multipliers have to increase the modulated sub-carrier to something like 11 Mc/s, so a frequency converter is used to bring this down to the required 27.5 kc/s.

Demonstrations of the system have been given with different programmes on the two channels, and in spite of the fact that the modulation in the auxiliary channel is limited to 7.5 kc/s, compared with the main channel's 15 kc/s, listeners at the receiving end have reported "no audible difference in quality between the two programmes." Other demonstrations have been given with the two channels carrying the same programme; with binaural audio inputs; and with the receiving loudspeaker listening to the silent auxiliary channel to show the absence of cross-modulation from the main channel.

# *Vibratory Gyroscope*

## *Electronic Indicating System*

THE familiar tuning-fork, once used for controlling the frequency of wireless transmitters, now figures as the stabilizing element in a new kind of gyroscope devised by the Sperry company. It performs the same function as the spinning flywheel of an ordinary gyroscope, but in rather a different way. Actually it operates on much the same principle as the physiological balancing mechanism of the common house-fly, which has club-shaped vibrating rods situated just behind the wings. The main advantage of this type of instrument is, of course, that it has no rotating parts or bearings to cause trouble. In addition, its sensitivity to different rates of turn is claimed to cover a very wide range—from as slow as the earth's rotation to as fast as 100 r.p.m.

In operation the two prongs of the tuning fork (Fig. 1) can be regarded as segments of two ordinary gyro flywheels pivoted at somewhere near the heel of the fork. Since the prongs are vibrating towards and away from each other, the imaginary flywheels would be continually reversing their direction of rotation in a similar manner, one going clockwise to the other's anti-clockwise. If the "flywheels" were rotating continuously as in an ordinary gyroscope they would provide a steady reaction against any external force that tried to turn the tuning fork about its vertical centre line. Since, however, their motion is actually alternating, the reaction to an applied turning force is also alternating, and it appears as a vibratory twisting motion in the shaft of the fork. The greater the rate of turn applied to the fork the greater the amplitude of this torsional vibration. As for the direction of turn, clockwise or anti-clockwise, this is indicated by the phase of the torsional vibration. With clockwise turning, an inward swing of the vibrating prongs causes the torsion blade to approach the left-hand pick-up coil, while with anti-clockwise turning an inward swing sends it towards the right-hand coil. In the actual instrument the shaft of the fork is mechanically tuned so that it resonates torsionally at the natural vibration frequency.

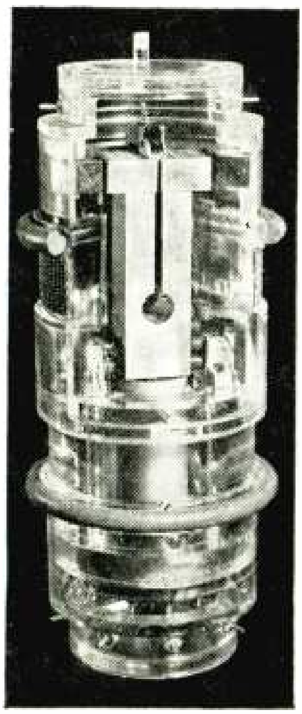


*Fig. 2. Cut-away model showing the actual form of the instrument. Underneath the prongs is the tuned torsion shaft, and at the base of this are the torsion pick-up coils.*

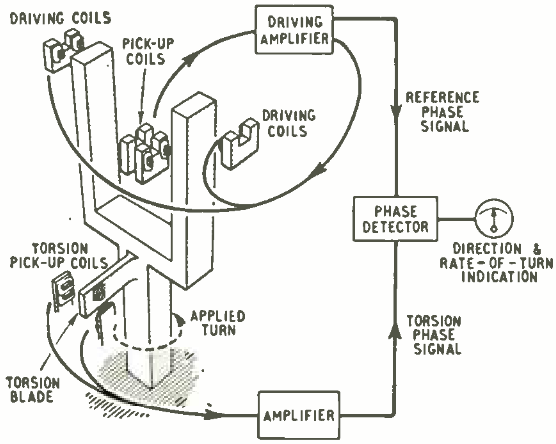



*Fig. 1. Essentials of the experimental vibratory gyroscope.*

As can be seen from the diagram, the prongs of the fork are kept in vibration (actually at 1,850 c/s) by a feedback arrangement comprising driving coils, pick-up coils and an amplifier. The resultant torsional vibration is detected by a blade on the shaft and two more pick-up coils. The electrical signal from these is amplified and applied to a phase detector, which also has an input signal from the vibrating prongs to provide a reference phase. Thus the phase detector gives the phase of the torsional vibration relative to the prong vibration and hence the direction of turn, as already explained. Its output is in the form of a d.c. signal which indicates by its polarity the direction of turn and by its amplitude the rate of turn. These indications are shown by appropriate pointer movements on a centre-zero meter.

## POWER TRANSISTOR

ACCORDING to a description in the December, 1953, *Electronics* a 20-watt transistor, which exceeds the normal power level by about 100 times, is being produced by the Minneapolis-Honeywell Regulator Company. It is a diffused-junction germanium transistor hermetically sealed in glass and metal and having a screw mounting for direct connection to a metal chassis, or other support, which will act as a conduction cooling medium.

For the present they are being used in aircraft fuel gauges only but some may become available for commercial use later. No mention is made of their frequency characteristics but a 20-watt transistor excites the imagination and conjures up visions of economical and compact power amplifiers.

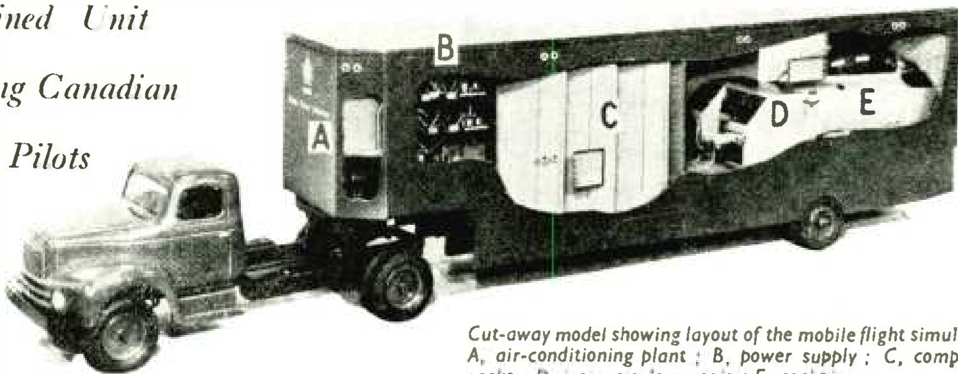
## Ionosphere Review—1953

### *A Correction*

THE two graphs on page 67 in last month's issue were unfortunately transposed. The lower graph is Fig. 1 (twelve-month running averages of sunspot numbers, etc.), while the upper is Fig. 2 (monthly mean sunspot numbers, etc.).

# Mobile Flight Simulator

*Self-contained Unit for Training Canadian "Sabre" Pilots*




*Cut-away model showing layout of the mobile flight simulator. A, air-conditioning plant ; B, power supply ; C, computor racks ; D, instructor's console ; E, cockpit.*

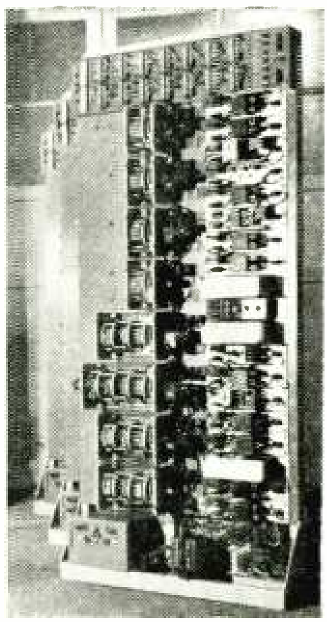
THE first of the ten flight simulators ordered by the Canadian Department of Defence Production was handed over at a ceremony in London recently by the designers and makers, Redifon, Ltd., Broomhill Road, London, S.W.18.

This equipment is for the training of "Sabre" jet fighter pilots, and can reproduce all the effects of flight on instrument readings and the "feel" of the controls, with appropriate sound effects. In everything but the accelerations resulting from change of course and speed the pilot feels that he is airborne, and can be set problems in navigation, artificial emergencies due to such causes as icing, engine defects, etc., any of which might have serious consequences for an inexperienced trainee if he were in actual flight. The instructor can watch the pupil's reactions and correct errors in safety, and, last but not least, at low cost. Taking everything into account the simulator costs about £3 per hour to run, whereas the overall cost of flight training would be £50 per hour. Not the least of the advantages of flight simulators is the saving of training time which might otherwise be lost through bad flying weather. They can also be used to re-examine qualified pilots periodically, and tests can be devised which are far more searching than those which would normally be given in the air.

As in the simulators previously described (*Wireless World*, April 1951, p. 130) the details of flight characteristics, engine performance, etc., are translated into electrical quantities through the medium of potentiometers, each with specially graded cards. This information is integrated by electro-mechanical servos operating on the "velodyne" principle used for wartime radar control, but with a.c. instead of d.c. inputs. The "processed" information is then sent to instrument dials, flight control motors, etc., any single factor, such as the force required to move the elevators, being controlled by air speed, flight altitude, weight of fuel remaining and any other relevant data supplied by the setting of the various panel instruments.

To have packed this complex mechanism into a single articulated road vehicle, while leaving sufficient space for access to the servo and amplifier racks, is no small achievement.

*On the right are shown recorders for plotting simulated flight path. These also generate long-range d.f. signals.*



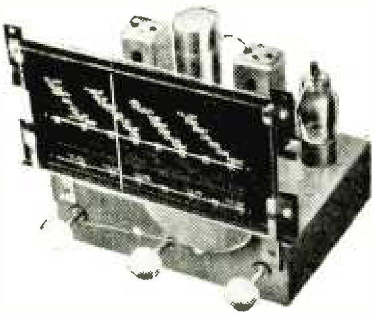
*One of the computor-amplifier racks is shown in the photograph on the extreme right. Six of these are mounted "herring bone" fashion in the middle section of the van.*

# Manufacturers' Products

NEW EQUIPMENT AND ACCESSORIES FOR RADIO AND ELECTRONICS

## *Tuner Unit*

THE detector circuit in the "Elpico" Model RF/716 superheterodyne tuner unit makes use of a double triode, the first half of which



*"Elpico" Model RF/716 tuner unit.*

functions as a diode and the second as a cathode follower. By this means capacitive couplings and shunts have been eliminated and the d.c. and a.c. load conditions are the same. It is claimed that the circuit will accept, without adding distortion, the maximum modulation level used by the B.B.C. Diodes for a.g.c. are combined with the pentode i.f. valve.

Long, medium and short wavelengths are covered and the unit, which is made by Lee Products, 63, Great Eastern Street, London, E.C.2, costs £14 14s.

## *Sapphire Needles*

THE installation of automatic grinding and polishing machines has enabled the makers of "Windsor" sapphire-tipped needles to produce a range retailing at 2s 6d each. These are all of 0.0025in tip radius for 78 r.p.m. records and are available in standard diameter or "midget" shanks, or in the "trailer" type for use with older heavy magnetic pickups.

The makers, Sapphire Bearings, Ltd., 16, Catherine Place, London, S.W.1, state that every needle is inspected by shadowgraph for sphericity and radius of point, and surface polish.

## *Miniature Trimmers*

COMPRESSION capacitors of the "postage stamp" variety for circuit trimming are now obtainable from the British Distributing Company, 591, Green Lanes, London, N.8, in capacitances ranging from 5/60 pF (min and max) to 150/400 pF. They are assembled on ceramic bases designed for use separately or in banks of any number and mixture of capacitances. The dielectric is mica. Individual units measure $\frac{3}{4} \times \frac{3}{8} \times \frac{3}{8}$in and the test voltage is 300 d.c.

## *Germanium Crystal Coil*

AMONG the small r.f. coils made by The Teletron Company, 266, Nightingale Road, Edmonton, London, N.9, is one designed especially for a germanium crystal receiver. Described as the Type HAX it has three separate windings on a 0.45-in moulded former with an adjustable dust-iron core. The tuned winding is Litz-wound and covers the medium broadcast waveband with a 0.0003-mfd variable capacitor.

The other windings are for aerial and crystal respectively, the couplings being set for optimum performance with an average aerial. The coil costs 3s.

## *Potted Transformers*

A HARD-SETTING resin compound is used for casing a new range of miniature audio transformers introduced by John Bell and Croyden, 117, High Street, Oxford. With this type of finish fixing screws can be moulded into the block where required and become an integral part of the component. Rigid tags or pins can replace loose connecting wires and be inserted where required for particular purposes. Non-standard shapes and sizes are more easily provided by potting than by most other types of finish.

## *Electrostatic "Tweeter"*

THE introduction of new materials and methods has brought about a revival of interest in the electrostatic loudspeaker, particularly in Germany. The two outstanding advantages of this type are the simplicity of application (it is connected across the output transformer primary with a simple filter to keep out low frequencies), and the virtual absence of directional properties through 180 degrees in the horizontal plane.

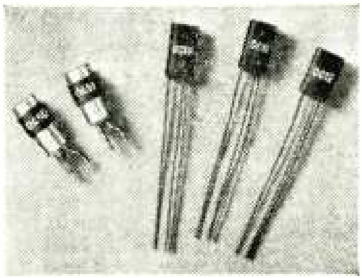
One example, the Körting, is now available in this country through E. D. Parchment, 69, Clapham Road, London, S.W.9. It consists of a curved perforated back-plate with a stretched diaphram of plastic film, coated on the outside with a metallic film. The whole is housed in a moulded plastic frame measuring approximately $4\frac{3}{4}$in × $3\frac{3}{4}$in × $\frac{5}{8}$in.

The normal polarizing voltage is 250 (test 1,000V) and the capacitance 0.001μF. The frequency response, according to the makers' published curve, is 7,000-15,000 c/s, ±5db.

*Körting electrostatic high-frequency loudspeaker.*

## *Transistors*

A RANGE of transistors is now available from Mullard to equipment designers who wish to carry out experimental work. These are two-point contact types, the OC50 and



*New transistors from Mullard.*

OC51, and three junction types, the OC10, OC11 and OC12.

The point-contact types are readily available at a price comparable with that of mains subminiature valves. Their point spacings have been made different so that the two transistors have markedly different characteristics. The OC51 has a better high frequency characteristic than the OC50. The OC50, however, operates more satisfactorily than the OC51 in the "collector bottomed" condition.

The junction transistors, OC10, OC11 and OC12 are designed for economy in power supplies and, in both amplifier and oscillator circuits, they will operate from h.t. supplies as low as 1.5 volts, with current consumptions of a similarly low order. Under suitable conditions they will work with h.t. supplies of only a fraction of a volt.

The OC11 is a general-purpose amplifier which, in an earthed emitter circuit, gives a current amplification factor of 17. Under similar conditions, the OC12 gives a current amplification factor of 30, and is intended primarily as an output transistor, although it can also be used in amplifier circuits. The OC10 is a low-noise version of the OC11 and is intended for use in the early stages of high-gain amplifiers.

Mullard's address is Century House, Shaftesbury Avenue, London, W.C.2.

## *Nickel for Valves*

TWO new grades of nickel in wrought form are now available for valve manufacturers from Henry Wiggin & Co., Birmingham, 16. Both grades have a minimum nickel content of 99.5 per cent and are low in the volatile elements such as magnesium. Grade H.P.A., which has a low silicon content (0.03 per cent max.), is useful for the cathodes of valves which must have a very long life with low emission current. In Grade H.P.B. the silicon content is 0.15 to 0.25 per cent with the object of increasing activation and emission. The makers warn that care must be used with H.P.B. nickel, as under certain conditions high interface impedances may build up between the cathode sleeve and the coating material.

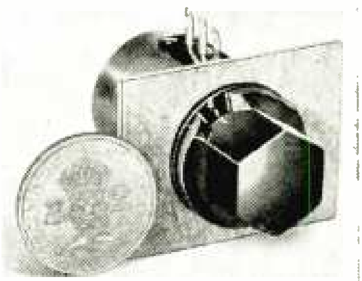
| Element | H.P.A. (per cent) | H.P.B. (per cent) |
|---|---|---|
| C | 0.10 max | 0.10 max |
| Cu | 0.04 max | 0.04 max |
| Fe | 0.05 max | 0.05-1.0 |
| Mn | 0.02 max | 0.10 max |
| Mg | 0.01 max | 0.01 max |
| Si | 0.03 max | 0.15-0.25 |
| Al | 0.01-0.05 | 0.02 max |
| S | 0.005 max | 0.005 max |
| Ni and Co | 99.5 min | 99.5 min |

## *Miniature Attenuator*

THE illustration shows a miniature stud-type attenuator no larger than a two-shilling piece (1⅛ in) and measuring 1⅛ in in depth behind the panel.

It is described as the Type M and is intended primarily for audio applications in portable equipment and where space is at a premium. In certain circumstances it could be employed in medium- or carrier-frequency circuits up to about 4 Mc/s.

Painton ¼-W high-stability carbon resistors are fitted and the attenuator can be arranged as either a 10-step twin-arm network (bridge T) or a 20-step single-arm network (unbalanced potentiometer). Alternatively, it can be arranged as a fader control.



*Painton miniature stud attenuator, Type M.*

The knob and dial are so designed that only the portion of the network in circuit is indicated by the figures uncovered by the skirt of the knob.

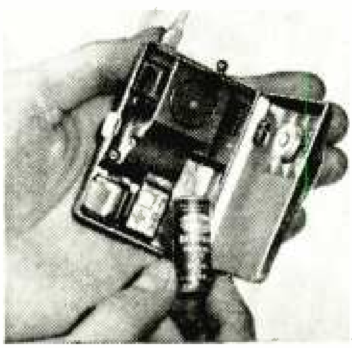
The makers are Painton & Co., Ltd., Kingsthorpe, Northampton.

## *Hearing Aid with Transistor*

CONSIDERABLE saving in h.t. battery consumption has been effected in the Amplivox Model J2 hearing aid by the use of a junction transistor in the output stage. Low-consumption valves are used in the voltage-amplifying stages, but the greater part of the normal h.t. current is saved by using the transistor; actually a reduction from 0.35mA in the all-valve Model J to 0.04mA in the J2, or a ratio of 120/1,000 hours life. A single Mallory mercury cell (1.3V) is used for l.t. and here the economy is useful, but less spectacular, 20mA to 12.5mA or 50 to 80 hours. The air-to-air gain of the J2 is 47db with E9L high-sensitivity earphone, compared with 53db in the all-valve J hearing aid.

The price of the J2 is £44 2s and the makers are Amplivox, Ltd., 2, Bentinck Street, London, W.1.

*Amplivox Model J2 hearing aid with junction transistor output stage.*



# RANDOM RADIATIONS

By "DIALLIST"

## *At Long Last!*

UNLESS ANYTHING so entirely monstrous as the shelving of the Television Advisory Committee's all-but-unanimous report should take place, f.m. is at long last recognized as the victor in the great (and far too protracted) controversy over the best modulation system for v.h.f. broadcasting. No one who had been receiving the Wrotham broadcasts, as no doubt all members of the technical sub-committee had, could have failed to realize the vast superiority of frequency modulation as a defence against motor-car-ignition interference, which is the only really important kind of interference on the v.h. frequencies. Given a receiver so arranged that a quick switch-over from one system of modulation to another can be made, two or three short periods of listening should convince most people that a.m. with limiter is a bad second to f.m., with plain a.m. very much an also-ran. Since it has been shown that a nation-wide f.m. service could be installed at little more than one-third the cost of a similar a.m. service, and that the latter would call for 44 per cent more stations, with a power output more than $3\frac{1}{2}$ times as great and costing $2\frac{1}{2}$ times as much to run, I can't help feeling very much in sympathy with the Committee's majority report.

## *Shaggy Dog Story*

UNLIKE MOST of the others, this Shaggy Dog Story is true, cross my heart; see that wet, see that dry. Hailing me as I was passing her house the other day, my friend Mrs. X wafted me into her drawing room. "Have you ever heard," she asked, "of a dog that was radio-active or something?"

??????

"Well, I think Wuffles must be." Wuffles is an Old English Bobtail. "Yesterday afternoon, when the children and I were watching Muffin, he just gave himself a shake over there and the television set immediately went mad."

"What happened?"

"First, the picture shrank to half-size; then it blacked right out. I tried twiddling knobs and things, but that didn't do any good. There were so many flashes and crackles that I switched off and 'phoned the serviceman. He took the set away this morning, saying that its innards looked as if it had been struck by lightning."

I asked whether by any chance Wuffles was wet when he performed that devastating shake. He was! He'd been brought in at the back door by her husband, after a walk in the rain, and had escaped and made his way into the drawing room before he could be dried off. Most of him was behind the television set when he shook himself. One could picture large drops of water being propelled through the louvres while a mist of droplets was borne in by convection currents. Wet dogs, it seems, should be kept far from TV receivers; the shaggier the farther.

## *A C.R.T. Weak Spot*

A CAUSE of television c.r. tube breakdown which seems to be growing increasingly common is the development of a "short" between heater and cathode. The fault is often intermittent—and that kind is the most exasperating of all. It can be cleared in suitable cases by the use of an isolating transformer; and the fact that special transformers are readily available shows that these shorts are not exactly rarities. When one considers the cost, including purchase tax and labour charges, of replacing one of the large tubes so popular today, one can't help feeling that a very special effort should be made to overcome any known weaknesses in them. Here is one which calls urgently for attention. For it is clearly not always possible to use an isolating transformer; and even when it is possible there are dealers here and there who can't, or won't, undertake the job.

## *But We Liked it*

IF YOU WANT some fun, get some friends who are old hands at wireless to ransack their junk boxes and lumber rooms and join with them in building a receiver as nearly as possible like those used to reproduce broadcasting in its early days in this country. Then, having made the set, you may spend entertaining hours in listening to its performances and in wondering how people in those days could possibly have thought them endurable, let alone beautiful. Some friends and I did just that a year or two ago. We were able between us to bring together a fine collection of period-piece components. My own contribution was three typical triodes, which had actually had very little use. The triode was in those days the most complex valve available; and when I say typical I mean that $r_a$ was of the order of

40,000Ω and $g_m$ round about 0.225 mA/V. One man proudly produced a loudspeaker famous in its day for the quality of its reproduction: an Amplion "Lion," with a conical metal horn, about 12in long and 4in in diameter at the output end, fixed to the case of a rather large telephone receiver. Others contributed an assortment of coils, transformers, condensers and resistances (to call the last two capacitors and resistors would be an anachronism) and we were all set to go.

## *Loud and Clear!*

The circuit, selected from a handbook of the period, consisted of a tuned-grid, tuned-anode r.f. amplifier, held down by the application of positive grid bias *via* a potentiometer; a leaky-grid detector, with reaction of the variably coupled coil type; and an a.f. stage, coupled to the detector by a 5:1 transformer and working with about 2 volts negative grid bias, which was as much as it would stand with the historically correct 90-V h.t. But, younger readers may exclaim, what about the output stage? Dear younger readers, that a.f. stage *was* the output stage! The small power valve didn't come along until broadcasting had been going on for some time. The same Marconi "R," or Mullard "Ora" or Cossor "Tin-hat" valves had to serve in each and every stage of early broadcast receivers. Also included in our collection were several numbers of the popular radio magazines of the early 1920s. These confirmed our recollection that the two qualities then most esteemed in a broadcast receiver were the number of stations that it would "get" and the volume with which it would bring in the local station: "Even at 50 yards from the speaker," wrote one enthusiast in the correspondence columns, "every note is clear and free from distortion!" Bearing in mind the conditions prevailing in that output stage—and indeed in all those stages—you may feel that this writer had been a little over-enthusiastic. Make up a set on the lines suggested and you'd wonder how anyone could have endured its output for a moment, even with the volume turned right down. Will my successor in the *Wireless World* of thirty years hence, I wonder, make similar experiments by reconstituting a 1954 wireless or television set? And, if he does, will he marvel in the same way at the crudities which our eyes and ears must have accepted without protest?

# UNBIASED | By FREE GRID

## *Alice in Solidconductorland*

*"A current of electricity from A to B consists of electrons moving from B to A and/or positive ions moving from A to B. If the current is flowing in solid material, the ions are the fixed material itself, so cannot move and the current consists wholly of electrons."*

THE ABOVE definition of an electric current *in a solid conductor,* which is quoted from the article in the January issue of *W.W.* dealing with the speed of electricity is accurate beyond the shadow of a doubt. It does, however, have a seeming oddness if considered carefully and my warped mind has sometimes wondered if this is not due to the fact that in pre-electronic days an unlucky guess was made about the direction of electric current flow and we still cling stubbornly to it.

"What is going on?" said Alice to the Red Duchess as she pointed to a rather disorderly mob of soldiers streaming out of one of the castle towers which had a big B over the gate and entering another tower labelled A. "Oh," said the Duchess, "just troop movements; I have decided to evacuate tower A and house all the troops in tower B." "But," protested Alice, "They're not obeying your orders; they are evacuating B and marching over to A." "Nonsense, child," said the Duchess following the direction of Alice's pointing finger. "What you see are merely soldiers; the troops which are moving in the opposite direction are not really moving at all."

"Then do troop movements from tower A to tower B consist of soldiers marching from B to A and nothing moving from A to B?" asked Alice. "Certainly" said the Duchess. "What a strange thing" commented Alice. "Wouldn't it make things easier to call the soldiers troops, and then troops and soldiers would always be marching in the same direction because they would, in fact, be one and the same thing?"

"Maybe to your simple mind it would make things easier" said the Duchess with some asperity, "but you have no respect for tradition; a century or more ago when troops were first discovered my great-grandfather, who, being blind, mistook the directions in which they were marching and gave orders that the castle entrances were to be labelled exits and *vice-versa.* As everybody else was blind too" continued the Duchess, "it didn't matter much and the troops didn't care anyway as they knew the way in and the way out by the same sort of natural law or homing instinct which enables a male hippopotamus, even when he is blindfolded, to distinguish a female hippopotamus from another male hippopotamus."

"But nobody is blind now" protested Alice. "Of course not, child," said the Duchess chidingly, "but out of respect for my great-grandfather's

*"What is going on?"*

memory we still like to pretend he was right even though it gets us into all sorts of difficulties, so when soldiers are moving from B to A we always pretend that troops are moving from A to B even though troops don't really move; at any rate not in Solidconductorland in which we live.

"Well" said Alice "I call it silly; we have nothing like it in our country." "Rubbish" snapped the Duchess beckoning to her executioner, "What about your summer time? What is obviously midday you pretend it is one hour past midday although everybody knows full well that it really isn't." "Off with her head," she shouted to the executioner.

## *A Unique Opportunity*

NOBODY SEEMS to have pointed out what a magnificent opportunity the proposed introduction of competitive television would offer for starting the higher definition of which we have heard so much from those who criticize the B.B.C.'s 405-line system. Now at last a unique opportunity arises for confounding these critics or justifying their views.

Before any competitive service could start we would all, in any case, have to buy adaptors or new sets if we want to receive the programmes. Those who could not or would not go to the expense of this would be no worse off than they are at present, for they would still be able to receive the B.B.C. programmes. But if people were willing to go to the expense of buying an adaptor or a new set to receive the alternative programmes, then why not give them full value for their money in the shape of a picture of the highest definition which modern technique can provide?

Naturally this would be very hard lines on the B.B.C.—about 625 of them, I suppose—and the Corporation would be torn between its desire to radiate a picture of equally high definition and the necessity of keeping faith with owners of existing sets who didn't want to spend money on new receiving gear. But I feel that owners of existing sets would be so jealous of the technically better picture of "competitive" viewers that they would soon alter their views and their viewing apparatus, thus freeing the B.B.C. from its obligations and enabling it to compete on equal technical terms with, or even to go one better than, its competitor by radiating stereoscopic TV, to say nothing of colour.

## *No Suppressors Needed*

AT THIS TIME of the year the big toy shops in all our large towns usually make an intensive drive to sell model electrically-operated railways, which they show in operation. These are prolific sources of interference to neighbouring TV sets as, so far as I can see, no attempt is made to fit suppressors.

It may be argued, of course, that these trains are not being demonstrated in normal television hours, but one cannot expect the average modern child to discontinue the use of his model railway when TV starts. At least, such was my opinion until recently, when I was discussing the problem with a specimen of the 1963 National Service class. To my surprise he pointed out with withering contempt that he and others of his age group were the backbone of the B.B.C.'s TV audience and would not foul their own nest. I felt completely silenced and suppressed.