Wireless World

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Showing the Public

THE 1952 National Radio Exhibition, opening today, is planned to follow a slightly different pattern from that of its immediate predecessors. As in recent years, it will be primarily a show of domestic broadcast receivers, with television in the foreground. Commercially, other branches of the industry will not be fully represented, but the organizers have arranged a number of non-commercial or semi-commercial exhibits aiming to show laymen some of the non-broadcast uses to which radio and radio-like devices can be put. There is also to be some emphasis on technical training, and space will be devoted to exhibits of an educational nature.

If all branches of the industry cannot be fully represented at the annual show, it is all to the good that the public should see that radio means something more than broadcasting.

Tax on Progress

THE Government has decided to impose a Purchase Tax of $66\frac{2}{3}$ per cent on apparatus used for broadcast relay reception. When radio receivers are subject to the same tax, that may be fair enough, but what is particularly unfortunate is that all loudspeakers, whether for relay or direct radio reception, are to be taxed. That section of the industry which protested against unfair differentiation in favour of the relays can hardly have expected this outcome.

To tax all loudspeakers seems to us to be putting a barrier in the way of progress. The loudspeaker is admitted to be the weakest link in the chain of sound reproduction, and so is most susceptible to radical improvement. A rich reward awaits anyone who finds a better way of converting electrical impulses into sound, but we imagine that those who hold the purse-strings will now think twice before allocating money to loudspeaker research.

British sound-reproduction equipment enjoys an excellent and well-deserved reputation abroad, and is already a substantial dollar-earner. Any Government action that tends to curb development in this highly promising field is especially to be deplored.

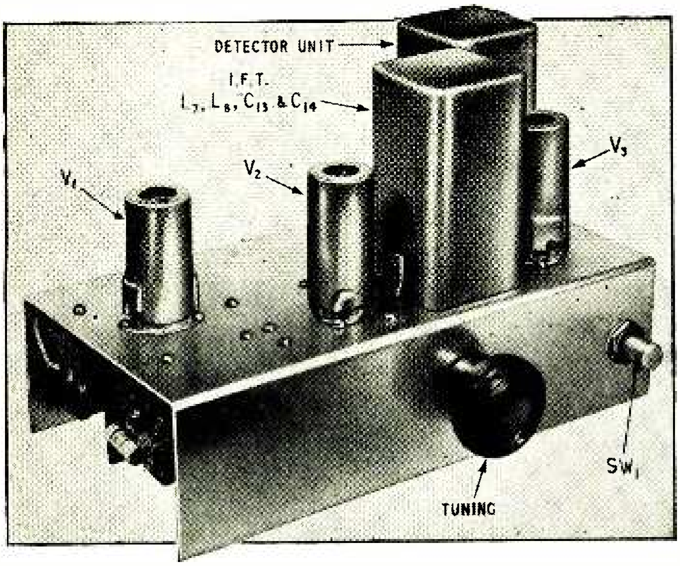
Administratively, there seems to be no convincing argument for dragging *all* loudspeakers into the Purchase Tax net. The number of broadcast relay companies is quite small, and it should be easy to collect the tax only on those speakers to be used for wire distribution networks.

The Heart of Our Affairs

UNTIL quite recently radio men were content to shunt messages along their ether channels in the form of signal elements called bauds. Nowadays, the new science of Information Theory, explained on another page, suggests that we must get to grips with the stuff of which the messages themselves are made. Information should now be measured properly, in units of its own; our crude bauds must become well-defined "bits". Hartley showed how information was *related* to the electrical properties of the channel, but Shannon tells us *how much* of it we can send.

The subject can hardly be ignored any longer, even by technical isolationists who have hitherto been in the habit of making the means—and not the end—of radio their sole concern. Radio engineers have already been forced to take into account the information-carrying capacity of their channels, the width of which is being more and more jealously restricted. The goods may have to be delivered at a certain—and sometimes quite high—rate (as in television, for example) and if the channel is too narrow to handle the traffic in a straightforward way, the technician must get to work to repack the goods—that is, to reshape the information itself.

According to the newer way of thinking, information is something more than goods in transit; it is the raw material of communication, to be processed before despatch. Of late this has been increasingly accepted, and a symposium of papers on the practical applications of Information Theory is being presented at the I.E.E. in September. From what the exponents of the new Theory tell us, it seems extraordinary that we have been able to ignore "information" for so long.



The valves, i.f. transformer and discriminator unit only are on top of the chassis.

F.M. FEEDER UNIT

Part 1.—Circuit Details of a Simple Inexpensive 3-valve Adaptor

By S. W. AMOS,* B.Sc. (Hons.), A.M.I.E.E., and G. G. JOHNSTONE,* B.Sc. (Hons.)

THE unit described in this article is designed to cover the v.h.f. broadcast band 87.5–100 Mc/s, and in particular to receive the B.B.C. experimental f.m. transmission radiated on 91.4 Mc/s from Wrotham, Kent. It delivers a signal suitable for operating an audio amplifier and requires an h.t. supply of approximately 30 mA at 250 V (but will operate with an h.t. as low as 150 V) and an l.t. supply of 0.8 A at 6.3 V. The feeder unit could be used in conjunction with an existing receiver by connecting the a.f. output to the gramophone input terminals, but a separate mains unit will then most likely be required. The aerial input is suitable for an unbalanced 80-ohm input, and is made via a co-axial plug and socket; the a.f. output is obtained from a similar socket. The power supplies are made via a multi-pin plug and socket, all three sockets being at the rear of the chassis.

The feeder unit is constructed on a chassis of 16 s.w.g. aluminium measuring 7½in by 4in by 2in and has two controls only, namely a tuning control covering the range 87.5–100 Mc/s and a spring-loaded switch used to locate the correct tuning point. No manual gain control was thought necessary because such a control is usually incorporated in the following audio amplifier. Three B7G valves and two crystal diodes are employed and Aladdin formers (moulded bakelite type PP 5892) are used throughout.

The complete circuit diagram of the unit is given in Fig. 1. It employs a superheterodyne circuit with an EF95 (6AK5) as r.f. amplifier, an EF91 (6AM6, Z77 or 8D3) as frequency changer, a second EF91 or equivalent as i.f. amplifier at 10.7 Mc/s and two crystal diodes in a ratio detector circuit. A double diode valve of the EB91 type could be used in place of the two crystal diodes and the relative merits of valve and crystals are discussed more fully later.

In spite of its inferior sensitivity, the ratio detector was chosen in preference to the Seeley-Foster discriminator because it can be made unresponsive to amplitude-modulated signals[1, 2, 3] and this avoids the necessity for a separate limiter stage; the detector driver valve can thus operate at maximum gain. As pointed out by Maurice and Slaughter[4] the sensitivity of the i.f. valve and detector combination is higher using a ratio detector than using a Seeley-Foster discriminator.

The operation of this form of detector is described in detail elsewhere[1, 4], but a brief summary is given below. The centre tap of the secondary winding L_{11} of the second i.f. transformer is connected to a small winding L_{10} closely coupled to the primary winding L_9; when the transformer is properly aligned, at the midband i.f. frequency the r.f. potential across each half of the secondary winding is in quadrature with the p.d. developed across L_{10}. Thus the p.ds between each end of the secondary winding and earth are equal and both diodes consequently receive equal r.f. inputs. If the i.f. signal frequency differs slightly from the midband value the p.ds across each half of the secondary winding, though still equal, are no longer in quadrature with the p.d. across L_{10} and the diode inputs are no longer equal. The interconnection between primary and secondary is similar to that of a Seeley-Foster discriminator, but the significant point about the ratio detector is that the two diodes are connected in series aiding whereas in the Seeley-Foster circuit they are connected in series opposing. For a signal at midband frequency both diodes conduct and the p.ds developed across the load circuit R_{15}-R_{18} are directly proportional to the signal input. The midpoint of this load is earthed and the potential at the lower end of L_{10} is also that of earth. If the signal frequency

* B.B.C. Engineering Training Department.

1 The Ratio Detector. S. W. Seeley and J. Avins. *RCA Review*, June, 1947.
2 FM Ratio detectors. R. G. Peters. *Communications*, November, 1945.
3 Ratio Detector is insensitive to AM. *Electronic Industries*, November, 1945.
4 FM Reception. D. Maurice and R. J. H. Slaughter. *Wireless World*, March, 1948.

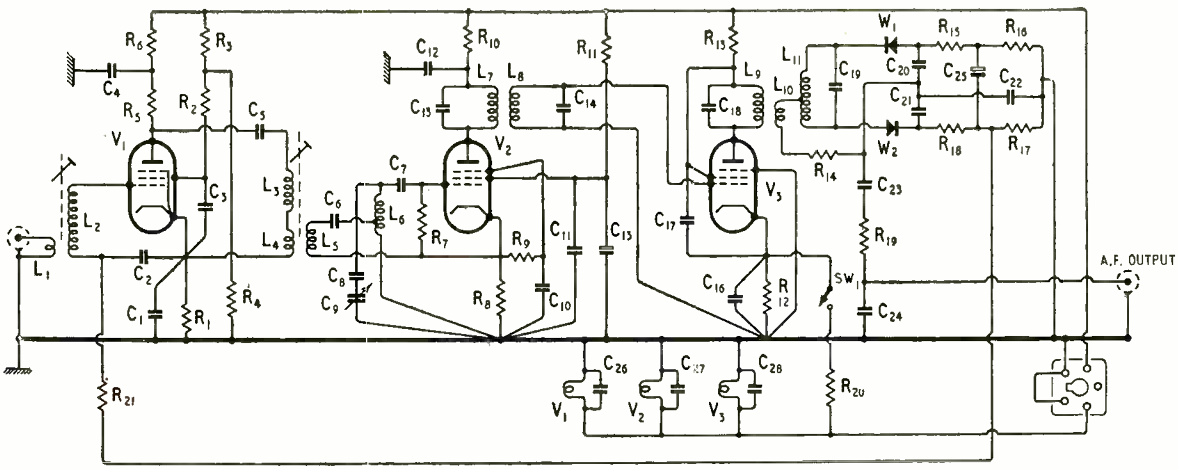
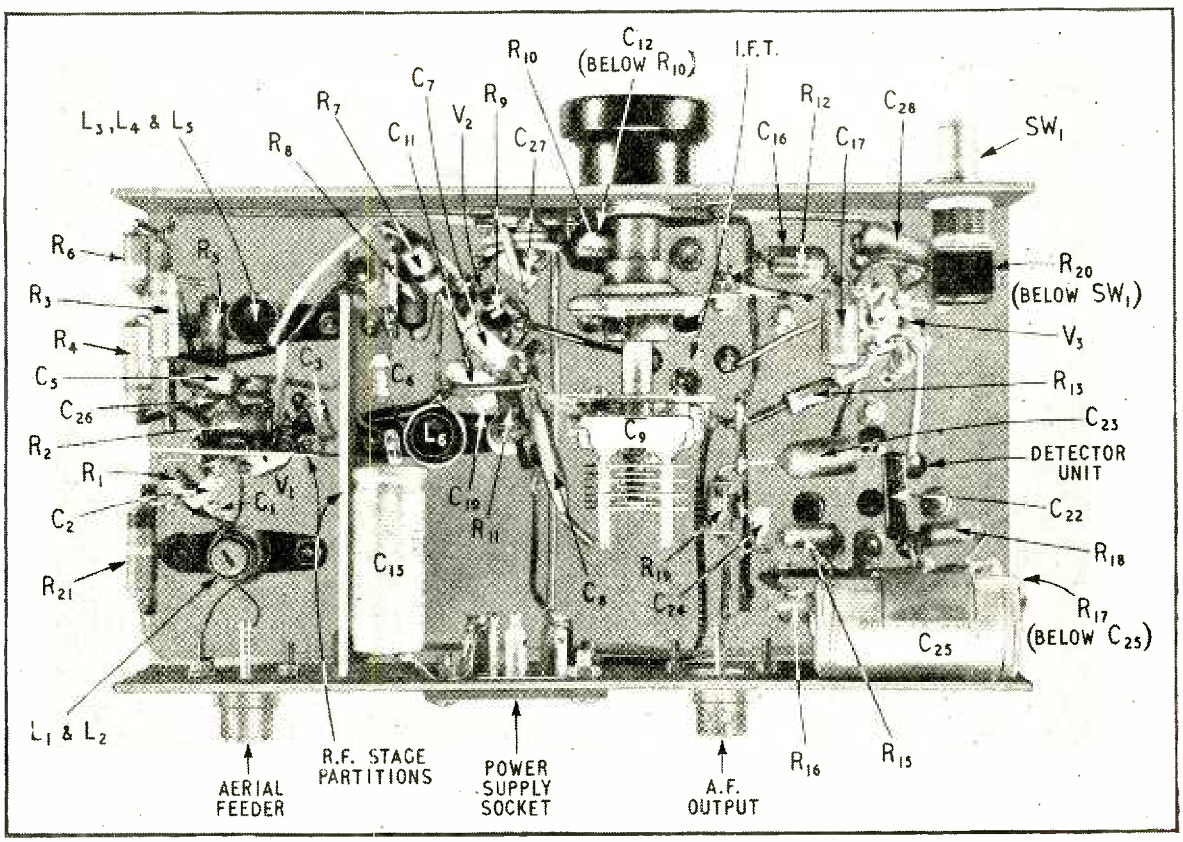


Fig. 1. Complete circuit diagram. Several of the components associated with the ratio detector are included in the screening can and cannot be found on the annotated illustrations. These will be discussed in the second part of the article.

alters the r.f. input to one diode increases and to the other decreases with the result that the potential at the lower end of L_{10} increases positively or negatively depending upon the direction of the frequency variation. When a frequency-modulated signal is applied, the output at the lower end of L_{10} is the modulation signal. For successful operation of the detector it is essential that the p.d. across the diode load should be constant in spite of frequency fluctuations of the incoming signal; this is achieved by shunting the load with a high-value capacitor to give a time constant long compared with the period of the lowest modulation frequency.

The p.d. across the diode load, or more strictly one-half of it since the midpoint is earthed, can be used for a.g.c. and in this receiver is applied to the

Underside of the chassis showing the layout and position of the components. Comparison with the circuit diagram will enable them to be identified.



r.f. stage ; this is preferred to returning a.g.c. to the i.f. stage, for whilst it will cause mistuning in either case, in the latter it will also cause considerable distortion. Components $R_{19}C_{21}$ are for de-emphasis and also serve as additional r.f. decoupling in the audio output.

The ratio detector is not completely unresponsive to a.m. signals and the rejection properties derive from the steady voltage maintained across C_{25}. Whilst it was assumed above that the total diode output voltage should be stabilized, this is not the best condition for a.m. rejection. There is an optimum ratio of the d.c. output which should be stabilized and this depends upon a number of considerations. In this circuit approximately 0.85 of the detector output should be stabilized for optimum a.m. rejection, and this requires the sum of R_{15} and R_{18} to be 2.5 kΩ. If, however, the detector circuit is unbalanced due for example to crystal inequalities an improvement in a.m. rejection may be obtained by varying the values of R_{15} and R_{18}, keeping the total resistance constant. However this form of correction will not hold for all signal levels and should be adjusted under working conditions. This can be done conveniently by tuning the receiver to the Wrotham a.m. transmission on 93.8 Mc/s and

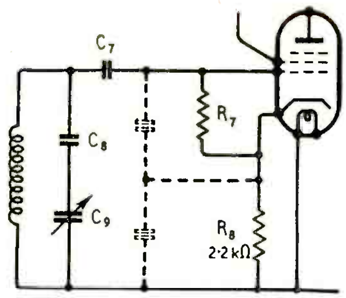


Fig. 2. Details of the oscillator circuit as described in the text.

adjusting the values of the resistors for minimum a.f. output. The resistor R_{11}, by modifying the diode peak currents, serves to effect a further improvement in a.m. rejection. Provided the receiver is properly aligned, a.m. rejection is best when the receiver is accurately tuned to the carrier; the rejection deteriorates as the receiver tuning is displaced to either side.

A double-diode valve or two crystals can be used in the detector. In general the valve gives a superior performance because the characteristics of the two halves are usually more stable, but crystals make for neater and more compact construction because they can be mounted with some of the low-value associated capacitors inside the detector unit. If crystal diodes are used they should, if possible, be well matched. The authors have experienced some trouble with crystal diodes particularly cheap surplus types due to variation in characteristics with mechanical shock and with time. Amongst others, CG1C and CG6M (B.T.H) have proved satisfactory but a pair costs about the same as a diode valve. For constructors intending to use a double diode valve there is sufficient space on the chassis without any changes in layout but the second i.f. transformer needs slight obvious changes in construction.

The winding details of the detector unit, as well as the circuit values in the detector itself are taken, with permission, from an article by Seeley and Avins[1].

The i.f. amplifier V_3 has a conventional circuit but three points are worthy of mention. The screen decoupling capacitor C_{17} is returned to the cathode pin to avoid possibility of instability. The components R_{12} and C_{16} are connected between the cathode pin and the i.f. transformer lead-out wire, the latter being earthed. The switch SW_1 is a spring-loaded push-button type used to locate the correct tuning point; when pressed it injects 50-c/s hum from the heater supply into the cathode circuit and amplitude modulates the i.f. input signal. This produces audible hum in the a.f. output of the receiver, which has a minimum value when the receiver is correctly tuned.

The first i.f. transformer is quite conventional and is tuned to the midband frequency of 10.7 Mc/s. This particular value was chosen because it enables the bandwidth necessary (about 300 kc/s) to be obtained readily whilst still permitting a stage gain of nearly 100 using a valve of the EF91 type. To obtain a high L/C ratio the coils are tuned partly by the valve interelectrode capacitances, 10 pF of fixed physical capacitance only being used. This results in some variation in i.f. tuning due to changes in valve interelectrode capacitances particularly during the warming-up period. This effect is not severe but the i.f. alignment should be carried out after the receiver has been operating for at least ten minutes.

The frequency changer is an EF91 connected in an

LIST OF COMPONENTS

Resistors

R_1 180 Ω	R_8 2.2 kΩ	R_{15} 1.2 kΩ*
R_2 270 Ω	R_9 47 kΩ $\frac{1}{10}$ W	R_{16} 6.8 kΩ†
R_3 22 kΩ	R_{10} 1 kΩ	R_{17} 6.8 kΩ†
R_4 47 kΩ 1 W	R_{11} 5 kΩ	R_{18} 1.2 kΩ*
R_5 10 kΩ 1 W	R_{12} 180 Ω	R_{19} 39 kΩ
R_6 1 kΩ	R_{13} 1 kΩ	R_{20} 470 Ω
R_7 33 kΩ	R_{14} 47 Ω	R_{21} 10 kΩ

* Adjusted for best a.m. rejection: sum of $R_{15}+R_{18}$ to equal 2.5 kΩ always.

† Close tolerance

All resistors ¼ W unless otherwise stated.

Capacitors

C_1 0.001 μF miniature ceramic	C_9 Air space variable 15 pF max.	C_{18} 10 pF
C_2 0.001 μF miniature ceramic	C_{10} 0.001 μF miniature ceramic	C_{19} 35 pF
C_3 0.001 μF miniature ceramic	C_{11} 0.001 μF miniature ceramic.	C_{20} 300 pF
C_4 0.001 μF miniature ceramic	C_{12} 0.001 μF 350 V d.c.	C_{21} 300 pF
C_5 50 pF	C_{13} 10 pF	C_{22} 300 pF
C_6 0.001 μF miniature ceramic	C_{14} 10 pF	C_{23} 0.01 μF 350 V d.c.
C_7 50 pF	C_{15} 4 μF Electrolytic.	C_{24} 0.002 μF
C_8 20 pF*	C_{16} 0.01 μF 350 V d.c.	C_{25} 8 μF Electrolytic.
	C_{17} 0.01 μF 350 V d.c.	C_{26} 0.001 μF miniature ceramic.
		C_{27} 0.001 μF miniature ceramic.
		C_{28} 0.001μF 350 V d.c.

* Adjusted to give correct tuning.

Valves
V_1 EF95, 6AK5.
V_2, V_3 EF91, 6AM6, Z77, 8D3.
W_1, W_2 Crystal diodes.

Chassis Fittings.
Aluminium chassis 7½ × 4 × 2in
Switch SW_1 Single-pole on-off spring-loaded push type.
3-B7G valveholders with screens.
2-Co-axial sockets.

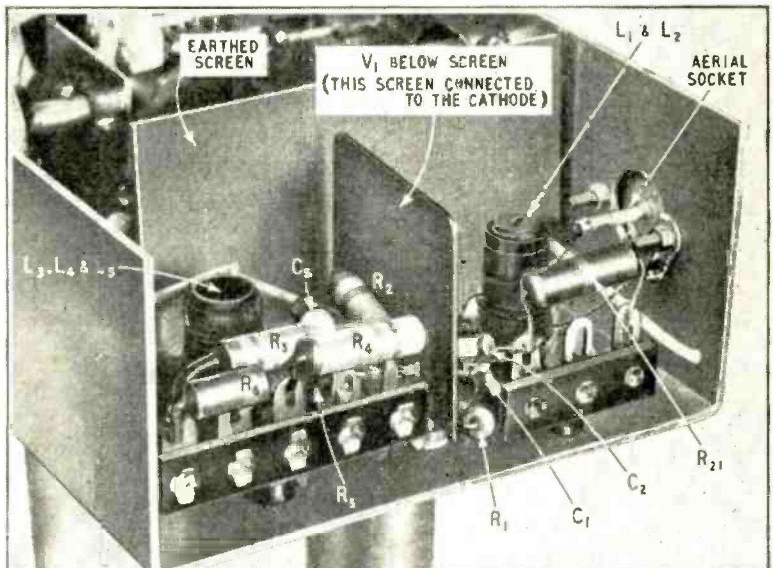
unconventional circuit, adopted after numerous experiments, because of its high conversion conductance; the stage gain of this frequency changer is, in fact, nearly ten times that of a more orthodox circuit used in early versions of the receiver. The oscillatory circuit L_6, C_8, C_9 is a cathode-coupled Colpitts arrangement operating below the signal frequency, positive feedback being obtained via the grid-cathode and cathode-heater capacitances of the valve, shown dotted in Fig. 2; this is a convenient form of oscillator because it makes use of the full g_m of the valve, i.e., the change in total space current per volt change of control grid potential. For this reason the oscillator gives good amplitude with an h.t. supply as low as 150 volts.

With this form of oscillator the cathode-earth capacitance is an essential part of the positive feedback circuit and the cathode cannot therefore be earthed. The d.c. cathode return is sometimes made via an r.f. choke but in this receiver a 2.2 kΩ resistor has proved satisfactory. Because of this resistance the cathode is approximately 20 V positive with respect to earth and the suppressor grid must not therefore be returned to earth, otherwise undesirable negative suppressor bias is obtained. The suppressor grid is returned to cathode as shown in Fig. 1. The tuning capacitor C_9 has approximately 15 pF maximum capacitance, but this is reduced by a fixed series 20-pF capacitor C_8 which limits the frequency swing of the oscillator to give the desired frequency coverage. The oscillator inductance is adjusted by the dust-iron core to fix the limits of the band. The tuning of the receiver is not at all critical and in all but the latest versions, the tuning capacitor was varied by direct rotation of the capacitor shaft, but an epicyclic slow-motion drive was fitted on the model illustrated. With this, the tuning is less critical than on most medium-wave receivers.

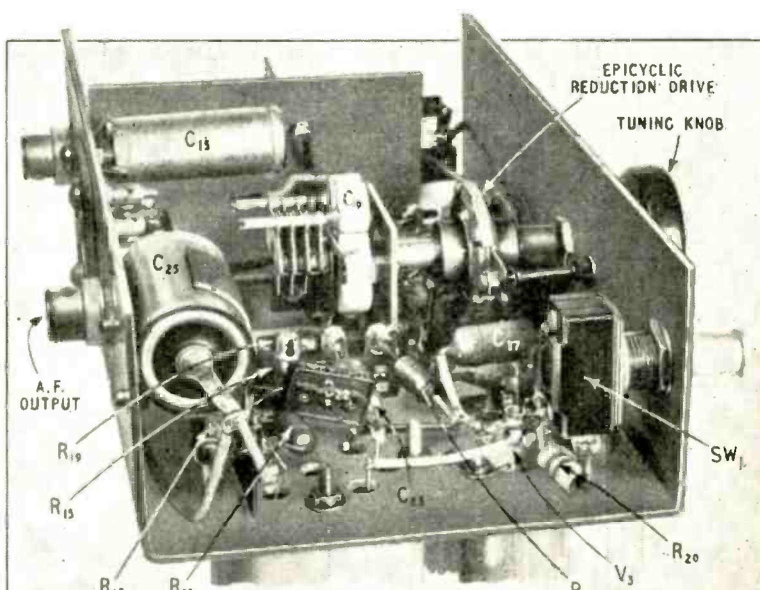
The signal-frequency input to the frequency changer is connected between the cathode of V_2 and a tapping point on the oscillator coil. This may be regarded as an approximation to a hybrid-coil arrangement and the correct tapping point is that for which the oscillator output measured between the tapping point and V_2 cathode is a minimum. If the position of the tapping point is correctly chosen, variation of the tuning of V_1 anode circuit has virtually no mistuning effect on the oscillator circuit. For the receiver illustrated the oscillator amplitude was 12 V peak between grid and earth and the minimum p.d. obtainable between the tapping point and cathode was just over 1 V peak; this tapping point was 1¼ turns from earth, the coil having a total of 4 turns. To facilitate making tapping points, the oscillator coil was wound with tinned copper wire (18 s.w.g.). The position of the tapping point does not seem to depend very greatly on the type of frequency changer valve used and a 6AM6, an 8D3 and a Z77 have been used with very little change in performance.

H.T. smoothing (C15) is included in the screen supply to V_2 to suppress a slight hum which was audible in the a.f. output; this was traced to frequency modulation of the oscillator by ripple on the h.t. supply. The smoothing circuit may not be necessary if the unit is fed from a well-smoothed h.t. supply.

The signal frequency input to the frequency



Above is shown a close-up view of the input end of the chassis and, below, a photograph of the output end. It should be noted that the small screen connected to cathode (top photograph) must not touch the adjacent earthed screen.



changer has both "legs" at r.f. potential and is obtained from V_1 anode by a 1 to 1 r.f. transformer, the details of which are given in a later part of this article. Tight coupling is required between these windings, and the dust iron core is arranged to be at the centre of the transformer. A considerable improvement in r.f. transfer from the anode of V_1 to the grid of V_2 was obtained by feeding the primary of the r.f. transformer, L_4, via a series inductor L_3. The series inductor must be tuned to give maximum transfer and this is achieved by winding the coil as a continuation of L_4, with a suitable spacing between. Full details are given later.

An EF95 was chosen as r.f. amplifier because experiments showed it capable of substantially greater gain at 90 Mc/s than the EF91-type used in the other two stages; the improvement is due to the higher input impedance of the EF95. The EF95 is provided with two cathode pins (2 and 7) and a copper sheet 1½in square is soldered to the corresponding valve-holder lugs and the small cylindrical screen at the centre to act as a shield between the anode and grid circuits. It must be remembered that the copper screen, although at zero r.f. potential, is approximately 2 V positive with respect to earth, and must not come into contact with any earthed conductor. Both grid and anode compartments are screened from the frequency changer by an aluminium shield bolted to the chassis, and nearly equal to the width of the chassis.

To avoid any possibility of oscillation, the screen grid and control grid circuits of the r.f. amplifier are decoupled to cathode as shown in Fig. 1. The screen grid is fed from a potential divider consisting of a 22-kΩ resistor R_3 and a 47-kΩ resistor R_1 connected across the h.t. supply; these are necessary to prevent the screen potential rising unduly (and possibly causing excessive screen dissipation) when the r.f. valve is biased back by a.g.c. This potential divider gives an a.g.c. action superior to that of a single series resistor. R_2 is included to prevent parasitic oscillations, which might otherwise be caused by the long screen supply lead. A.G.C. causes a certain amount of mistuning of the grid circuit when the receiver is tuned to a strong signal, but this is not considered serious because the circuit is damped by the aerial matching circuit, and the valve input resistance. Some form of a.g.c. is essential if crystals are used in the detector, because these are usually rated for a certain maximum r.f. input which cannot be exceeded without risk of permanent damage to the crystals. It is easily possible to exceed this maximum input for certain types of crystals if the receiver has no a.g.c. and is tuned to a strong carrier. The a.g.c. also simulates the function of the limiter used with a discriminator by tending to make the output amplitude independent of input carrier amplitude.

The tuning of the r.f. valve grid and anode circuits is fixed at the mid-band frequency, and is adjusted by the dust-iron cores in L_1 and L_2. Both circuits resonate with valve capacitances, no fixed physical capacitance being used.

The aerial is connected to a 1-turn coil wound over the earthy end of L2 (5 turns); this gives maximum voltage transfer with an 80-ohm source, i.e., a single dipole aerial.

In the concluding part of this article details of all the coils will be given, and the alignment procedure will be described. There will be also information on suitable aerials, together with receiver performance details.

To be concluded.

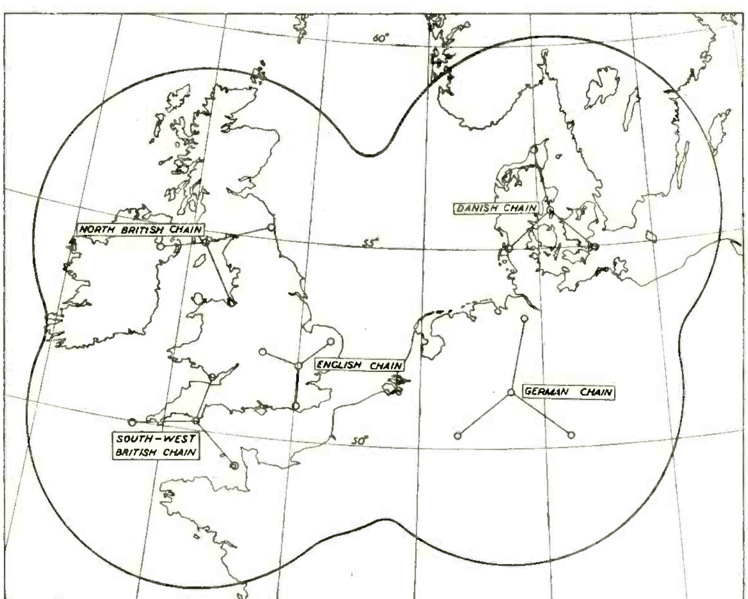
Decca Navigator

New British Chain Opened: European Coverage Extended

WITH the opening of the fifth chain of Decca Navigator stations—the South West British on 29th July—all the approaches to the British Isles and the major part of Europe are now covered by this position-fixing system for marine and air navigation.

The latest chain follows the accepted three-pointed star shape geographically, with the central station near Plymouth. The Red Slave station, so called because in conjunction with the Master station it generates the pattern of the position lines printed in red on the charts, is in Jersey. The Green and Purple Slaves are, respectively, on St. Mary Island in the Scillies, and at Llancarffan, near Cardiff.

As will be seen from the map the new chain covers the south-western approaches and closes the gap which previously existed between the North British and English chains. Although cited primarily as an aid to shipping it will add considerably to the Decca coverage for European air traffic.



Noise Limiters for Television Sound

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

Use of Germanium Rectifiers

SEVERAL forms of electrical equipment generate strong interference signals in the television frequency spectrum, but by far the commonest form is that radiated by the ignition system of a petrol engine. It is possible to reduce this form of interference by fitting suppressors in the high-tension leads to distributor and plugs, but even when this is done there is a residuum of interference which can be objectionable near a very busy highway, or in areas of weak field-strength. For this reason it is common practice to fit a " noise limiter " in the sound channel of the television receiver to reduce this form of interference to negligible proportions.

Neither suppression in the car nor limiting in the receiver is a completely satisfactory solution alone, but where both are employed no audible interference is noticeable. Even in a busy area and with unsuppressed vehicles a compound form of limiter will yield appreciable entertainment value where without it the programme would be completely masked by ignition interference.

Two basic types of limiter are commonly used, the " Series " type and the " Shunt." Where moderate values of suppression are judged sufficient the series circuit is employed, but where a very low signal/noise ratio exists, a combination of the two called the " Compound " limiter gives superior results. It is the purpose of this article to give data enabling such circuits to be designed around the germanium rectifier.

A major portion of the energy within the television frequency band which is radiated from a car is in the form of short, high-amplitude, pulses of radio-frequency energy. For a given energy content, the higher the amplitude and the shorter the duration of this pulse, the more effectively will a limiter reduce it relative to the wanted signal. The modulation envelope of such a pulse contains large components of frequencies greatly exceeding those carrying the audio signal, and unless the sound channel of the receiver is capable of transmitting this envelope without appreciable distortion from aerial to limiter, even the most efficient forms of limiter cannot give good performance. For this reason it is usual to design the sound channel to pass all modulation frequencies up to at least 100 kc/s, and to provide amplifying stages which will not produce inter-modulation of the audio components by the interference pulses. Since these high modulation frequencies must be passed right up to the limiter itself, it is advisable to fit the limiter immediately following the second-detector load.

Peak Limiting

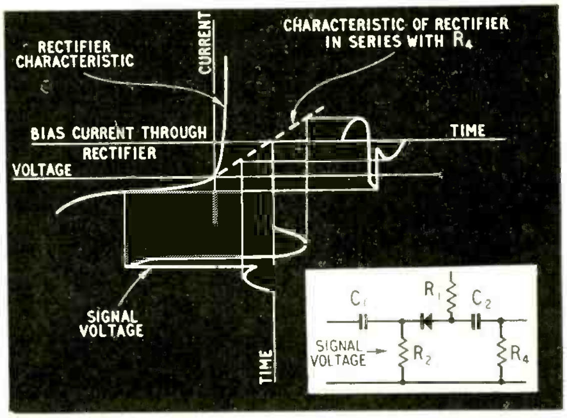
When an interference pulse greatly exceeds the maximum value of signal voltage, its nuisance effect may be reduced by limiting its value by means of a resistor and rectifier in series. The action of this circuit is shown in Fig. 1. The two resistors R_1 and R_2 are so high in value relative to R_4 that their shunting effect is negligible. The biasing current for the rectifier, which is drawn through R_1 and R_2, should be so high in value that it is slightly in excess of half the peak-to-peak value of maximum signal current which will flow through R_4, thus ensuring that the audio-frequency signal will never be " clipped " by excursions over the reverse characteristic of the rectifier. Although this circuit as described gives a fair reduction of interference, it still leaves an annoying level because pulses must necessarily exceed the audio signal in amplitude. A further improvement may be effected by taking advantage of the difference in frequency between the major components of audio signal and interference.

Frequency Discrimination

If a variable-frequency signal be applied across a resistor and capacitor in series, the voltage across the capacitor will decrease as frequency increases, over the frequency range where capacitor impedance is comparable with or lower than that of the resistor, but it will remain approximately constant over that portion of the range where capacitor impedance is much higher than that of the resistor. Thus if a value of capacitance be chosen which will not attenuate the audio-frequency spectrum, but which will attenuate the interference spectrum, the voltage output

* General Electric Company.

Fig. 1. Pulse limiting by rectifier. The circuit is that of the widely used series type of limiter.



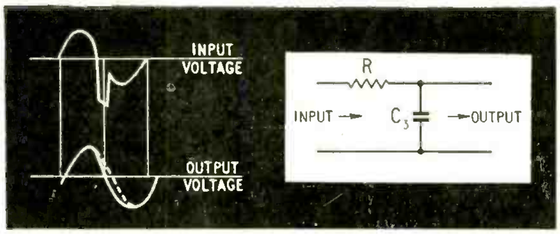
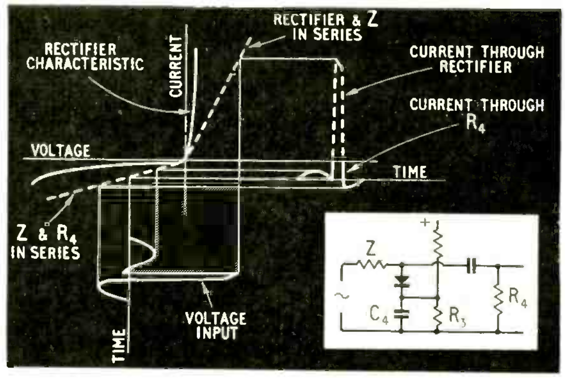


Fig. 2. Interference reduction by frequency discrimination.

Right: Fig. 3. Operation of the shunt limiter.



from the circuit of Fig. 1 may be still further improved as shown in Fig. 2. The dotted portion of output voltage indicates the waveform in the absence of the interference pulse, and it is evident that a further reduction has been accomplished.

In actual practice, an additional resistor "R" is not employed but the reverse resistance of the rectifier is made to fulfill this function, and C_3 is shunted across the output circuit following the rectifier in a series limiter. When so used, a much greater ratio of resistor impedance to capacitor impedance over the interference spectrum may be employed, since during conduction of signal current the effective value of R will be that of the second detector load, while during conduction of an interference pulse R is equal to the much higher value of the rectifier reverse impedance.

The Shunt Limiter

Although the rectifier used in the series limiter serves to "clip" the pulses to an amplitude only a little in excess of the peak audio signal, the rectifier, whatever its type, will have a finite reverse impedance, either resistive or capacitive; hence the clipping will not be perfect and an advantage is obtained by including an additional shunt limiter as a clipping stage ahead of the series limiter. When this is done, the rectifier in the series limiter ceases to "clip," but it is still advantageous to employ a rectifier in place of a resistor in series with C_3 because of its large increase of resistance for negative-going pulses of moderate amplitude.

The operation of a shunt limiter is shown diagramatically in Fig. 3. The effective source impedance (due to r.f. drive, second detector, and load) is represented by Z, and the rectifier is biased by current through R_3 to operate entirely over the reverse characteristic for all audio signals. The capacitor C_1 has such a value that negligible change of biasing voltage occurs due to interference pulses. It will be seen that the effect of this limiting circuit is to clip the interference pulses fed into the next stage to an amplitude a little greater than that of the maximum audio-frequency signal to be handled. While the impedance Z is mainly resistive, this is the maximum improvement which can be obtained from the shunt limiter, but if an inductance (used as a carrier filter choke) be inserted in series with Z, then a measure of frequency discrimination will be obtained which reduces still further the pulse amplitude. The measure of improvement obtained, however, will never be so great as that due to the series limiter, and for this reason, if only a single limiter is to be used it is usual to employ the series form.

The Compound Limiter

When the two circuits are combined to form a compound limiter as shown in Fig. 4 a very efficient combination results. The component values are restricted by operating conditions, and the final choice must be a compromise between conflicting requirements. R_5 is a rudimentary carrier-elimination filter, working in conjunction with the input capacitance of the audio amplifier. It is inadvisable to allow much more than 0.5-MΩ grid-cathode resistance because of "backlash" current to the grid, and a suitable choice would be 0.1 MΩ for R_5 and 0.47 MΩ for R_4. R_4 may be a potentiometer with R_5 connected to the slider to give volume control. The audio-feed capacitors C_1 and C_2 should present a negligible impedance to the lowest audio frequencies relative to R_4, and for a high-fidelity amplifier this will necessitate a value as high as 0.1 μF for each of them, giving a 0.5-db fall at 50 c/s. A smaller capacitance may be used if the decrease in low-frequency response can be tolerated, 0.01 μF resulting in 4.2 db loss at 50 c/s. The values of R_1 and R_2 should be approximately equal to give minimum shunting of R_4, and the total resistance must be chosen to give the desired value of biasing current through D_3. The value of this current depends entirely upon the maximum level at which the channel will operate, and if V_a is the peak audio-frequency voltage to be handled by the audio amplifier, a useful guide to value of current I, is given by the equation:—

$$I = \frac{1.1\,V_a\,(R_2 + R_4)}{R_2\,R_4} \qquad \text{(1a)}$$

If $R_1 = R_2$ and V_h = h.t. voltage.

$$R_2 = R_4\left(\frac{V_h}{2.2V_a} - 1\right) \qquad \text{(1b)}$$

The value of second-detector load R_L will be circumscribed by the design of the input transformer and by the bandwidth to be passed. A further limitation on its maximum value exists however, due to the shunting effect of R_4. If the effective audio-frequency impedance of the complete load is considerably smaller than the impedance to direct current, distortion of deeply modulated signals occurs. The actual value chosen is a compromise, but it is suggested that for high-fidelity systems the reduction should be less than 10% and where some distortion can be tolerated, less than 30%. Assuming again, that

R_1 and R_2 are approximately equal in value, these two limits result in the following equations :—

High Fidelity :—

$$R_L \ll \frac{0.1\ R_2\ R_1}{R_2 + 2\ R_1} \quad .. \quad .. \quad .. \quad (2a)$$

Moderate Fidelity :—

$$R_L \ll \frac{0.4\ R_2\ R_1}{R_2 + 2\ R_1} \quad .. \quad .. \quad .. \quad (2b)$$

Although the value of C_L is strictly a problem related to the design of the detector circuit, it is included here since efficient noise limiting depends upon the frequency response of this circuit. The time constant of R_L and C_L should be in the neighbourhood of 2.5 microseconds, which gives for the magnitude of the capacitance :—

$$C_L = \frac{2.5 \times 10^6}{R_L}\ \text{pF} \quad .. \quad .. \quad .. \quad (3)$$

For the suppression of pulses, C_3 should be as large as possible, but to preserve audio-frequency response, as small as possible. As C_3 increases in value, the attenuation of the higher audio frequencies increases due to its "shunting" of R_L. As a compromise, for high-fidelity systems, it is suggested that its reactance at 10 kc/s should equal the resistance of R_L, but that where noise is extremely bad and field strength low, a sacrifice of top-notes be made by increasing C_3 until it equals R_L at 3 kc/s. The value under these two conditions may be calculated from the equations:—

High Fidelity :—

$$C_3 = \frac{10^8}{2\pi R_L}\ \text{pF} \quad .. \quad .. \quad .. \quad .. \quad (4a)$$

Low Fidelity :—

$$C_3 = \frac{10^9}{6\pi R_L}\ \text{pF} \quad .. \quad .. \quad .. \quad .. \quad (4b)$$

In deriving equation (1a) the value of R_3 has been ignored. This was possible because over the practicable range of values which may be used in a television receiver, its inclusion would have a negligible effect on the value of R_2 as calculated from equation (1b). The function of R_3 is to provide a biasing voltage for D_2 which shall be slightly in excess of the peak audio signal to be handled. In this case, to avoid distortion by working on the "bend" of the rectifier characteristic, it is suggested that the biasing voltage be 1.3 times the maximum audio peak, and using the relationship in equation (1a) the following law is obtained :—

$$R_3 = \frac{1.2\ R_2\ R_1}{R_2 + R_1} \quad .. \quad .. \quad .. \quad .. \quad (5)$$

The value of C_1 is not critical providing it gives a time constant together with R_3 which is long relative to the duration of an interference pulse. A value of 0.05 μF is adequate for this purpose.

For the suppression of pulses a large inductance is desirable for L_1, but for good high-frequency response of the sound channel a low value is essential. This value also will be a compromise between the conflicting requirements of fidelity and suppression, and it is suggested that its impedance at 50 kc/s should be made equal to that of R_L, which gives as a relationship :—

$$L_1 = \frac{10R_L}{\pi}\ \mu\text{H} \quad .. \quad .. \quad .. \quad .. \quad (6)$$

Some disturbance of the audio response occurs due to the effect of L_1 and C_3 in series, but resonance only occurs above the band which may be received. What is more serious is that this resonance, which is ineffective in the case of "impulsive" noise due to the "cut-off" effect of D_3, becomes serious in the case of some other forms of interference. The best advice is to try the circuit in a particular location both with and without L_1 in circuit, and to choose the condition which gives greatest improvement on the type of interference in that neighbourhood.

For the guidance of those who may wish to construct the complete circuit and fit it as a unit into an existing receiver, suitable component values are given in Table 1.

Overall Performance

Due to variation in the modulation envelope of received noise, there is little point in attempting to calculate attenuation for certain theoretical forms. Such calculations are only of service to compare the performance of different rectifiers in a given circuit, but for the comparison of different circuit behaviours a noise generator and measuring equipment are desirable.

Extensive measurements have been made on the audio-frequency harmonic distortion introduced by the circuits described, and it has been found negligible (less than 1%) in the circuits here described when suitable rectifiers are used. Two types which have been used with success are the GEX.34 as series

Fig. 4. Circuit of sound-channel rectifier and compound limiter.

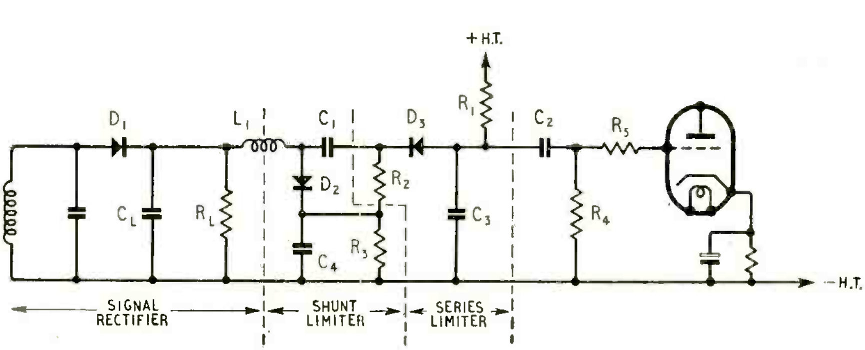


TABLE 1

Typical Component values for circuit shown in Fig. 4.

R_1, R_2	= 4.7 MΩ
R_3, R_4	= 0.47 MΩ
R_5	= 0.1 MΩ
R_L	= 68 kΩ
L_1	= 200 mH
D_1, D_3	= GEX.34
D_2	= GEX.03
C_1, C_2	= 0.1 μF
C_3	= 300 pF
C_4	= 0.05 μF
C_L	= 47 pF

limiter, and the GEX.03 as shunt limiter. In each case, for the approximate calculation of performance, the forward characteristic may be considered a linear slope of 100 ohms cutting the voltage axis at +0.3 volt, and the reverse characteristic as a linear slope of 350,000 ohms passing through the origin. The small portion (0 to +0.3V) not so described is a curve passing through the origin and "running into" the linear forward characteristic. This characteristic is only an approximation to a more complicated form, but it will be found adequate for assessing the operating conditions and performance.

When choosing a rectifier for the series-limiter circuit great care must be taken to obtain a low shunt capacitance, since a high capacitance will vitiate the frequency discrimination required for successful operation. In this connection the germanium rectifier has the lowest self-capacitance (less than 1.0 pF) of any available component, and providing care is taken when "wiring up" the circuit to minimize circuit strays, full advantage will be taken of this feature. For the shunt limiter, on the other hand, a very low forward impedance is the essential characteristic, and in this feature also the germanium rectifier is unequalled among the various components available for the function.

Compound limiters similar to the one described have been tried out in many fringe areas, and found adequate in performance, even when the aerial has to be directed along a main highway to "view" the transmitting station. It may be taken as a general guide that where regular entertainment value may be obtained from the picture, the compound limiter will be adequate to give acceptable sound reception. The only exception to this rule is in areas where interference other than that from ignition systems is the major limitation to reception; unless the interference is mainly of "impulsive" type, this form of limiter will not be found of great value, but fortunately for most viewers their interference will be found such that a compound limiter will render it inaudible.

Acknowledgments

Acknowledgement must be made to the General Electric Company Limited who have allowed information gained from work in their laboratories to be used in the preparation of this article, and to several colleagues whose labours have provided the data for it.

Book on Interference Suppression

MOST radio people tend to regard interference suppression as something of a mystical art, only to be practised by certain individuals gifted with a special kind of occult understanding. This is partly the fault of the scant literature on the subject, which in general amounts to little more than a collection of cookery-book recipes, with nothing in the way of consistent explanation to hold them together—perhaps because the authors don't want to give away too many trade secrets! In such circumstances, then, it is very encouraging to see a new approach to the subject—a book whose main object is to make clear the underlying principles of suppression technique, so providing the reader with a good basis from which to tackle the particular problems that come his way.

That is not to say "Radio Interference Suppression," just published for *Wireless World*, is a vague or academic book. Far from it. The author, G. L. Stephens, is an engineer with extensive experience in this field, and he writes for practical men. Thus, after explaining the origins of interference and principles of suppression, he goes on to give many practical examples of the technique. Some of the interfering appliances he discusses are engine ignition systems, switches, thermostats and contactors, electric motors and generators, rotary converters, lifts, neon signs, fluorescent and other types of discharge lighting, trams, trolleybuses and electric trains, radio-frequency heaters, welding apparatus, oil-fired boilers, television receivers, spectrographic equipment, and valve rectifiers.

Throughout the book particular attention has been paid to the problem of interference on television frequencies. Special attention is also given to suppression methods on motor vehicles and on board ship. Other chapters deal with the design and choice of suppressor components, methods of locating the source of interference, and suppression at the receiver itself. Reference data given in the appendices includes some useful information on screened rooms.

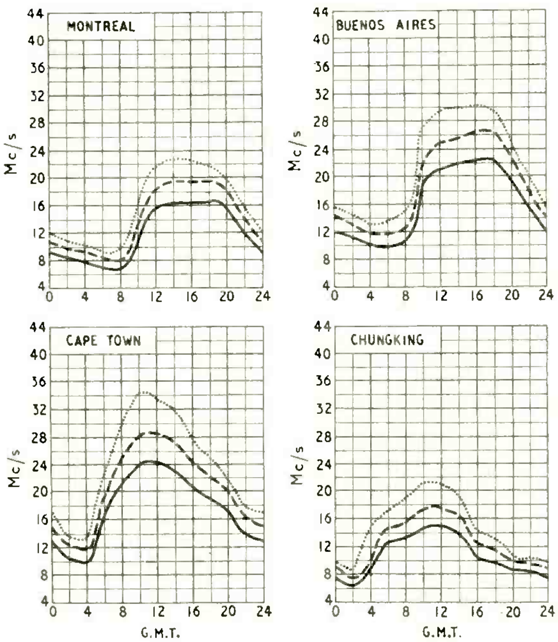
"Radio Interference Suppression" is published for *Wireless World* by Iliffe & Sons Ltd. It can be obtained from any bookseller, price 10s 6d, or direct from our Publishers at 10s 11d by post.

Short-wave Conditions

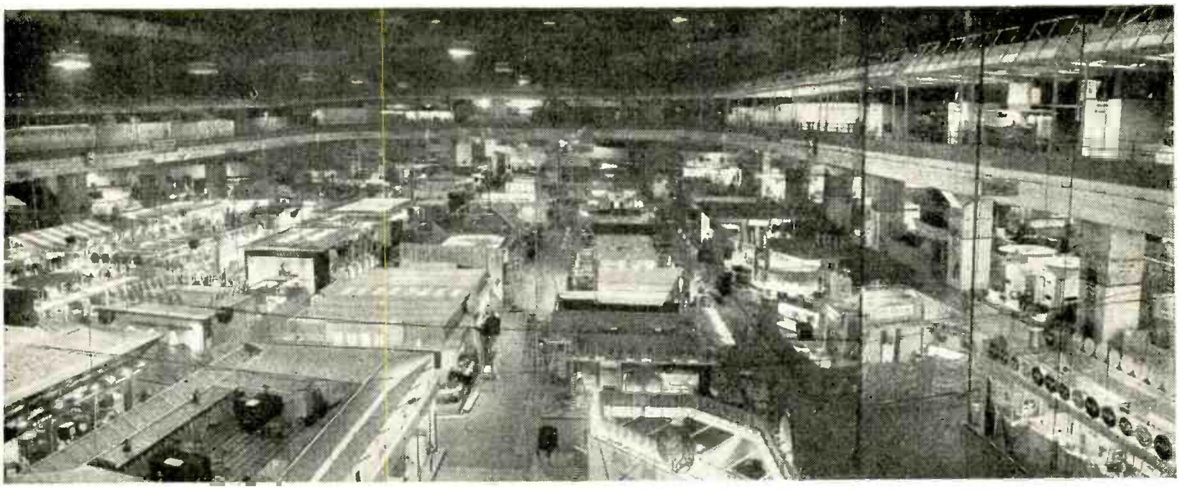
Predictions for September

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 September.

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



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



19th National Radio Exhibition

Classified Guide to the Principal Classes of Exhibits

TO-DAY, 26th August, the 19th National Radio Exhibition at Earls Court is being viewed by specially invited guests and members of the public prepared to pay 5s. To-morrow (27th August) it will be officially opened at 12 noon by Lord Burghley, president of the Radio Industry Council who are sponsoring the Show which continues until 6th September.

The price of admission on all days, except 26th August, is to be 2s 6d for adults and 1s for children. Parties of from 25 to 50 are to be admitted at 2s each and parties of 50 or more at 1s 9d each.

Of the 108 exhibitors, 32 are manufacturers of broadcast and television receivers and in the Hall of Television 29 manufacturers are demonstrating 80 receivers. In addition, as will be seen from the list of standholders, a number of manufacturers have their own demonstration rooms.

Believing that the primary function of a guide is to present information in an easily assimilated form, we have again prepared our pre-view as classified and tabulated lists of the principal exhibits. The exhibitors are listed alphabetically under their trade names or abridged names by which they are best known and also numerically by stand numbers. This, we think, enables the makers of any particular class or item of equipment to be found and, with the aid of the plan, readily located in the exhibition.

Not all the exhibits readily fall into the categories chosen for our tabulated lists, among them being printed circuits (Hunt), radio relay receivers (E.M.I.) and electronic musical instruments (Selmer). Also there are not sufficient examples of the heavier side of radio—transmitters and navigational gear—to justify a section, but mention should be made of the v.h.f. mobile gear shown by G.E.C. and television transmitters exhibited by Pye.

"How it works" is the keynote of the Show and ingenious devices have been utilized to this end by some of the manufacturers. The R.I.C., too, has made use of some of the wide open spaces (which last year called forth the criticism that they created a sepulchral gloom) to house special exhibits of electronic apparatus in use. These electronic "side shows" include demonstrations of underwater television, radio-frequency heating and an electronic stencil cutter for duplicating purposes. The process employed in the stencil cutter is similar in principle to that used for the radio transmission of photographs; the scanning rate is 500 lines to an inch.

At the present time considerable stress is being laid on the demands of the Forces on the radio industry and each of the three Services is showing something of the part played by radio in communications, navigation, defence and attack. A replica of the radar and wireless office in a submarine is included on the Navy's stand, where ratings of the Electrical Branch (which is responsible for the maintenance of all radio, radar and electrical equipment in the Fleet) will be seen repairing equipment in an electronics maintenance room similar to that in a modern battleship. The R.N.V.(W.)R. is also represented on the stand.

The two main users of radio and electronic gear in the Army—the Royal Corps of Signals and the Royal Electrical and Mechanical Engineers—are sharing the Army's stand. The centrepiece of the R.E.M.E. section is a radio-guided missile. Gun-laying radar is shown in use and laid out bread-board fashion for instructing trainees in circuitry.

To demonstrate the use of radio for the control of aircraft the R.A.F. is staging a flying display of models made by members of the R.A.F. Model Aircraft Association. The aircraft, which are electrically driven, fly in a circuit (they are tethered to a central post by a thin cable carrying the power supply) and the retraction of the undercarriage, opening of bomb doors, etc., is controlled by radio.

All R.A.F. apprentices who enter for the radio and radar trades are trained at No. 6 Radio School, Cranwell and some of the 1,000 at present undergoing training, preparatory to becoming junior technicians in the trades of air or ground radio fitters, are to be seen demonstrating some of the phases in the three-year course.

The central feature of the B.B.C.'s contribution to the Exhibition is, of course, the studio, which is about twice the size of last year's, incorporating an auditorium with seating for nearly 1,000. The studio is equipped with a mobile television control room, a three-camera channel unit, and a 3-ton motor-driven camera crane. For the sound transmissions from the studio an echo room has been provided with all the paraphernalia for sound effects.

During the show (on 2nd September) the first annual dealers' conference, organized by the British Radio Equipment Manufacturers' Association (a constituent body of the R.I.C.) will be held and will cover such subjects as maintenance schemes for receivers and sales promotion. The Radio and Television Retailers' Association has presented season tickets to each of its members.

For the first time a technical training display is included in the Show to back up the efforts of both the industry and the educational authorities to make good the shortage of technicians in the industry. A number of educational bodies have co-operated with the R.I.C. in presenting demonstrations, which should increase technical interest in the show and at the same time encourage some visitors to seek further information on the possibilities of technical careers in the industry, about which a leaflet has been prepared. Among the colleges and institutions providing demonstrations are Imperial College, Norwood Technical College, Northampton Polytechnic, E.M.I. Institutes, Marconi College and College of Aeronautics.

Arrangements for the relaying of both sound and vision programmes to the Hall of Television and to the stands and demonstration rooms are similar to last year's. The television waveform, which conforms to standard B.B.C. practice, will be piped on channel 4 (61.75 and 58.25 Mc/s) and each outlet in the show feeds one receiver with a signal level of $1\,\text{mV} \pm 3\text{db}$ into 70 ohms unbalanced. The distribution centre for both the sound and vision transmissions is the Control Room on the first floor, which can be seen by visitors through glass windows. The television programme is virtually continuous throughout each day, being made up of normal B.B.C. transmissions (which are radiated from Alexandra Palace by radio on a special channel), a 35-mm film scanner in the Control Room, shows in the exhibition studio and features from the celebrity dais on the ground floor.

An information bureau at which details of the services offered by the various sections of the Board of Trade and the Patent Office is provided at Stand 2. A feature of the Television Society's stand is the various units designed by members for incorporation in the Society's television transmitter (G3CTS/T) which it is hoped to put into service shortly. The Electrical Trades Union has an information bureau at which particulars of the union's activities in the radio and electrical industries may be obtained.

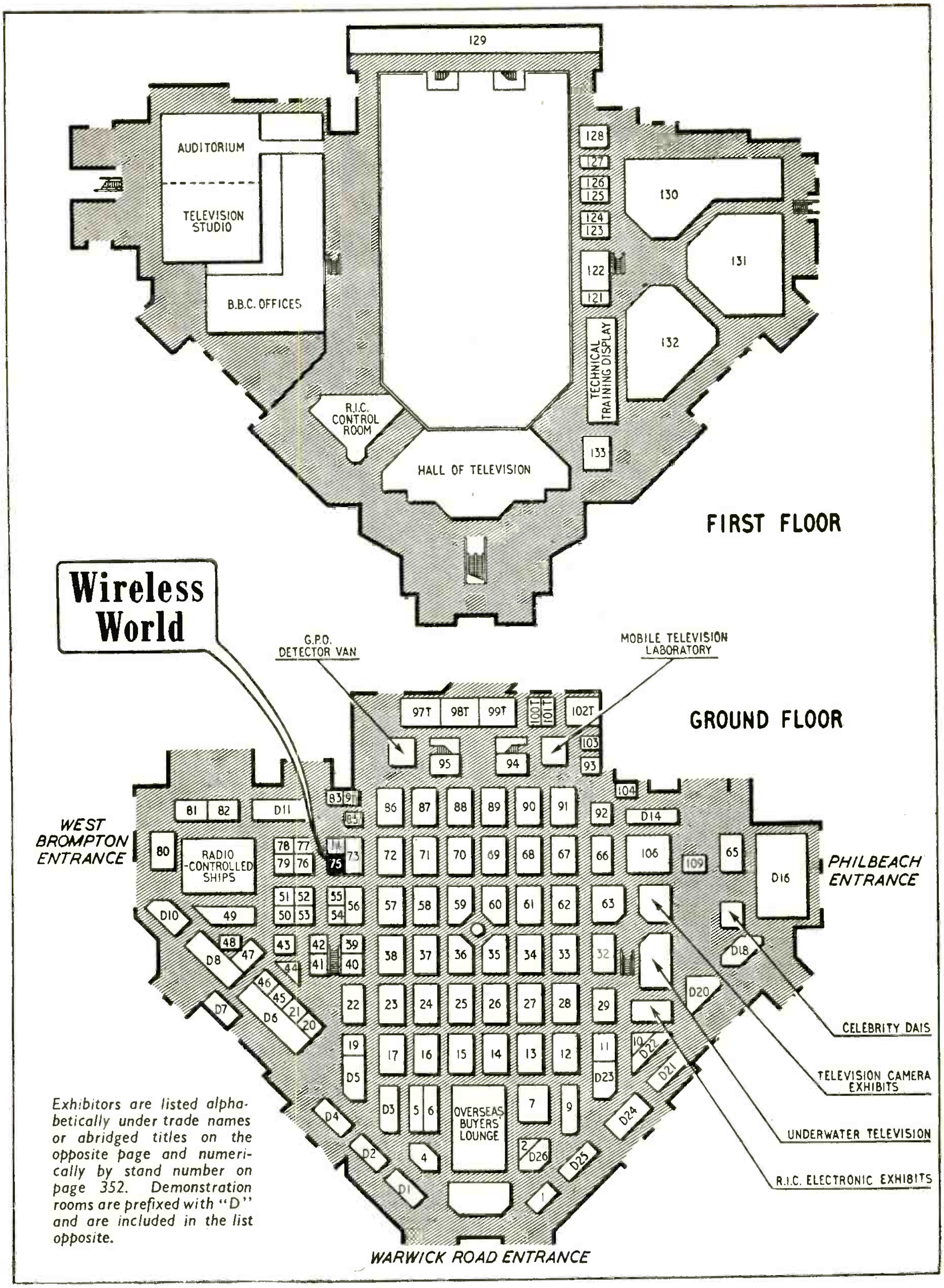
ALPHABETICAL LIST OF EXHIBITORS AND GUIDE TO STANDS

Name	Stand
A.R.B.M.	86
Ace	66
Aerialite	50
Alba (Balcombe)	35
Amplion	54
Antiference	22
Army	132
Avo (Automatic Coil Winder)	46
B.B.C.	129
Baird	33
Barclays Bank	51
Belling-Lee	25
Bernards	127
Board of Trade	2
Brimar (S.T.C.)	6
"British Radio & Television"	44
British Railways	4
Brown Brothers	97T
Bulgin	1
Bush	16(D3)*
Champion	133
Collaro	91
Cossor	37(D25)
Decca Records	61(D2)
Defiant (Co-op)	12(D18)
Dubilier	79
Dynatron	40
E.M.I.	68
E.T.U.	125
Econasign	21
Eddystone (Stratton)	124
Ediswan	62(D1)
Eelex (Eastick)	102T
Ekco	24(D8, D10)
"Electrical & Radio Trading"	74
Elpico (Lee)	77
English Electric	67
Ever Ready	57
Exide & Drydex (Chloride)	94

Name	Stand
Ferguson	88(D23, D24)
Ferranti	14(D26)
G.E.C.	26, 78 (D6)
Garrard	92
Goodmans	41(D7)
H.M.V. (Gramophone Co.)	89, 109(D16)
Hobday	99T
Hunt	56
Imhof	19
Invicta	71
J.B. Cabinets	9
J.G. Publications	43
K.B.	28
Kerry's	98T
L.E.S.	101T
Linguaphone	96
Livingston Laboratories	93
Lloyds Bank	81
McCarthy (Felgate)	7
McMichael	69
Marconiphone	87(D14)
Masteradio	63
Mullard	17(D5)
Multicore	32
Murphy	15(D4)
National Provincial Bank	82
Navy	130
Pamphonic	85
Peto Scott	23
Petter	100T
Philco	38
Philips	59, 60 (D11)
Pilot	58

Name	Stand
Plessey	80
Portogram	20
"Practical Wireless" and "Practical Television"	52
Prowse	104
Pye	36 (D21)
R.A.F.	131
R.G.D.	29
Regentone	13
Roberts	39
Rola-Celestion	73
Sculptured Sound (Sali)	121
Selmer	10(D22)
Sentercel (S.T.C.)	55
Simon	47
Skarsten	48
Sobell	34
"Star"	65
Stella	27
T.C.C.	72
Taylor	53
Telcon	42
Telequipment	83
Telerection	11
Television Society	126
Turnidge	123
Ultra	70(D20)
Valradio	122
Vidor	90
W.B. (Whiteley)	95
Waveforms	103
Westinghouse	49
Westminster Bank	5
White-Ibbotson	128
"Wireless Trader"	45
"Wireless World" and "Wireless Engineer"	75
Wolsey	76

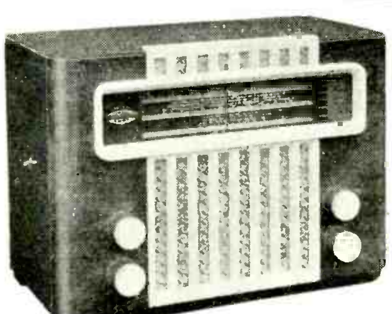
*Demonstration rooms and offices prefixed with "D"



Exhibitors are listed alphabetically under trade names or abridged titles on the opposite page and numerically by stand number on page 352. Demonstration rooms are prefixed with "D" and are included in the list opposite.

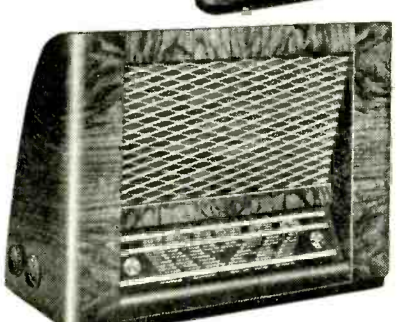
RECEIVERS : Broadcast, Television, Communications and Special-purpose

FIRM	(Stand)	Broadcast								Television								
		Mains	Battery	Mains/battery	Portable	Personal portable	Radio-gramophone	Chassis	Kits	Direct-viewing	Projection	Television-broadcast	Chassis	Kits	V.H.F., domestic	V.H.F., communication	Communications	Car
Aiba	(35)	●	●	●	●	—	●	—	—	●	—	●	—	—	—	—	—	—
Baird	(33)	—	—	—	—	—	—	—	—	●	●	—	—	—	—	—	—	—
Bush	(16)	●	—	—	—	—	●	—	—	●	—	—	—	—	—	—	—	—
Champion	(133)	●	—	●	—	—	●	—	—	●	—	—	—	—	—	—	—	—
Cossor	(37)	●	—	●	—	—	●	—	—	●	—	—	—	—	—	—	—	—
Decca	(61)	—	—	—	—	—	●	—	—	—	●	●	—	—	—	—	—	—
Defiant	(12)	●	—	—	—	—	●	—	—	●	—	—	—	—	—	—	—	—
Dynatron	(40)	●	—	—	—	—	●	●	—	●	—	—	—	—	—	—	—	—
Eddystone	(124)	●	●	—	—	—	—	—	—	—	—	—	—	—	—	●	●	—
Ekco	(24)	●	—	●	●	—	●	—	—	●	—	—	—	—	—	—	—	●
Elpico	(77)	—	—	—	—	—	—	●	●	—	—	—	—	—	—	—	—	—
English Electric	(67)	—	—	—	—	—	—	—	—	●	—	—	●	—	—	—	—	—
Ever Ready	(57)	—	●	—	●	—	—	—	—	—	—	—	—	—	—	—	—	—
Ferguson	(88)	●	●	●	●	—	●	—	—	●	—	—	—	—	—	—	—	—
Ferranti	(14)	●	●	●	●	—	●	—	—	●	●	—	—	—	—	—	—	—
G.E.C.	(26, 78)	●	●	—	●	—	●	—	—	●	—	●	—	—	—	—	—	—
H.M.V.	(39, 109)	●	—	—	—	—	●	—	—	●	—	●	—	—	—	—	—	—
Invicta	(71)	●	●	●	●	—	●	—	—	●	—	—	—	—	—	—	—	—
K.B.	(28)	●	●	●	●	●	●	—	—	●	—	—	—	—	—	—	—	—
McCarthy	(7)	●	●	—	●	—	●	—	—	●	—	—	—	—	●	—	—	—
McMichael	(69)	●	—	●	●	—	●	—	—	●	—	●	—	—	—	—	—	—
Marconiphone	(87)	●	—	●	●	—	●	—	—	●	—	●	—	—	—	—	—	—
Masteradio	(63)	●	—	—	—	—	●	—	—	●	—	—	—	—	—	—	—	●
Murphy	(15)	●	—	●	—	—	●	—	—	●	—	—	—	—	—	—	—	—
Pamphonic	(85)	—	—	—	—	—	●	—	—	●	—	●	—	—	—	—	—	—
Peto Scott	(23)	—	—	—	—	—	●	—	—	●	●	—	—	—	—	—	—	—
Petter	(100T)	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—
Philco	(38)	●	—	—	●	—	●	—	—	●	—	—	—	—	—	—	—	—
Philips	(59, 60)	●	—	—	—	—	●	—	—	●	●	—	—	—	—	—	—	—
Pilot	(58)	●	●	●	●	—	●	—	—	●	—	—	—	—	—	—	—	—
Portogram	(20)	●	—	—	—	—	●	—	—	—	—	—	—	—	—	—	—	—
Pye	(36)	●	●	●	●	●	●	—	—	●	—	—	—	—	—	—	—	●
Regentone	(13)	●	●	—	—	—	●	—	—	●	—	—	—	—	—	—	—	—
R.G.D.	(29)	—	—	—	—	—	●	—	—	●	●	—	—	—	—	—	—	—
Roberts	(39)	—	●	●	●	—	—	—	—	—	—	—	—	—	—	—	—	—
Sculptured Sound	(121)	●	—	—	—	—	●	—	—	●	●	●	—	—	—	—	—	—
Sobell	(34)	●	—	—	—	—	●	—	—	●	—	—	—	—	—	—	—	—
Stella	(27)	●	—	—	—	—	●	—	—	●	●	—	—	—	—	—	—	—
Ultra	(70)	●	—	●	—	—	●	—	—	●	—	●	—	—	—	—	—	—
Valradio	(122)	—	—	—	—	—	—	—	—	—	●	—	—	—	—	—	—	—
Vidor	(90)	●	●	●	●	—	—	—	—	●	—	—	—	—	—	—	—	—
W.B.	(95)	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—
White-Ibbotson	(128)	—	—	—	—	—	—	—	—	—	●	—	—	—	—	—	—	—

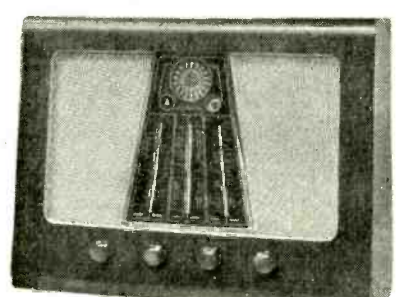


Portogram Model U52 three-waveband a.c. mains receiver.

Kolster-Brandes 3-band table mains receiver, Model HR10.

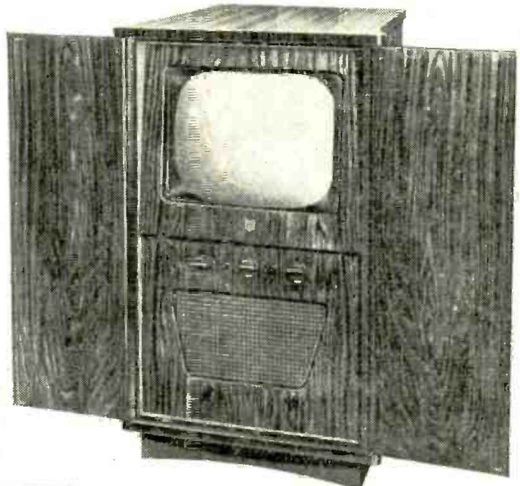


Left : Pilot "75" table model receiver (mains).

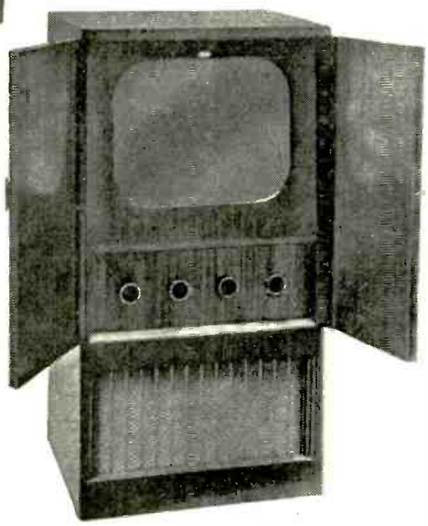


Right : Bush export Model EBS24 with 5 short and one medium wavebands.

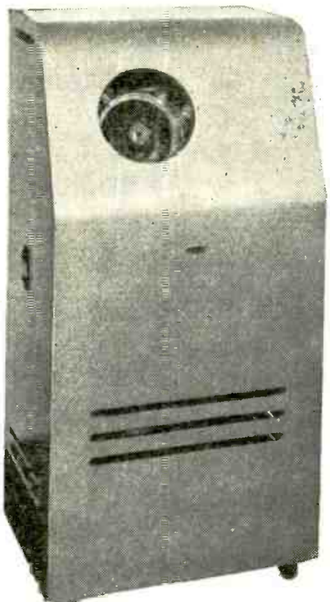
Left: Dynatron "Fulmer" television receiver with 17-in tube.



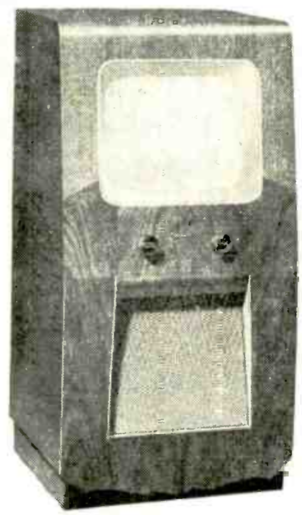
Ekco Model TC174 16-in tube television receiver with grey filter and spot wobble.



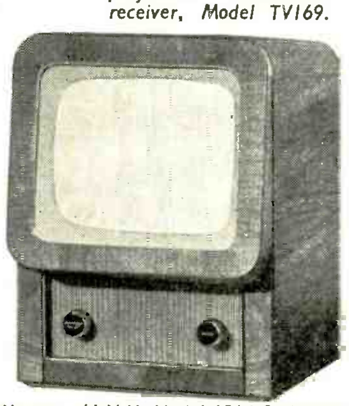
Peto Scott flat-screen projection television receiver, Model TV169.



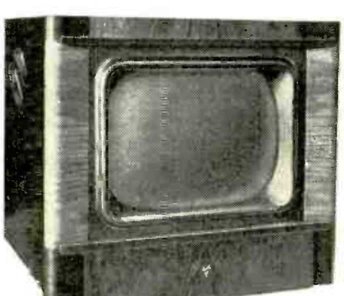
Valradio large screen projection television receiver Type V3C giving picture 3 x 4ft.



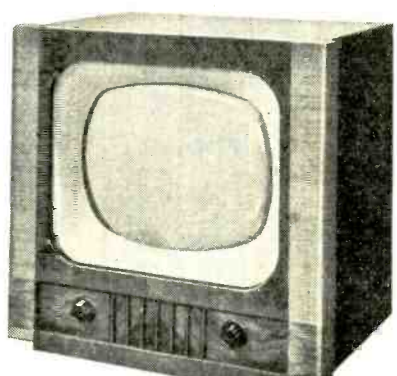
Marconiphone 12-in tube 5-channel television receiver for a.c./d.c. Model VC59DA.



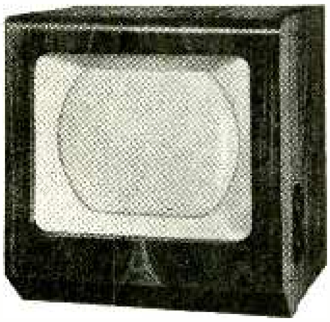
Above: H.M.V. Model 1814 5-channel television receiver.



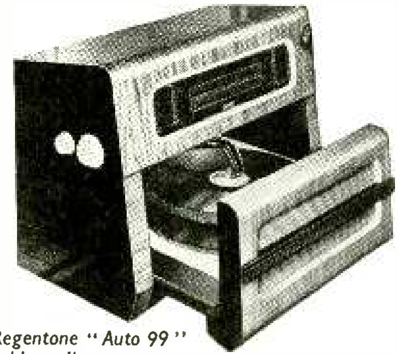
Left: Vidor table model television receiver.



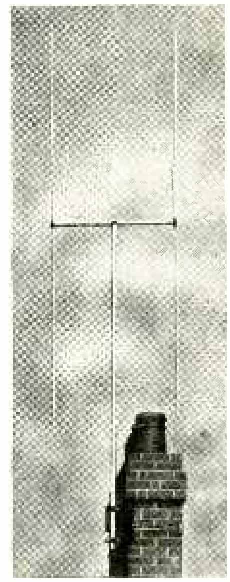
Right: R.G.D. Model 6015T table television receiver with 15-in tube.



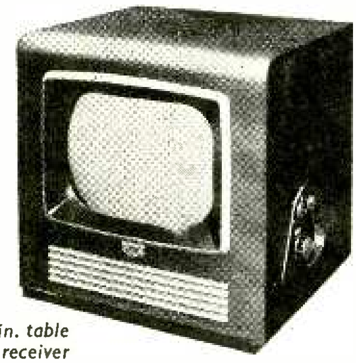
Cossor a.c./d.c. television set model 927 with 12-in. tube.



Regentone "Auto 99" table radiogram.



Belling-Lee "Junior H" television aerial on 9-ft. lightweight mast.



Ultra 12-in. table television receiver Model V80.

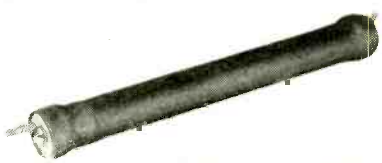
Left: McCarthy (Felgate) table radiogram with 3-speed record changer in roll-top compartment.

ACCESSORIES : Including Materials, Valves and Non-electronic Rectifiers

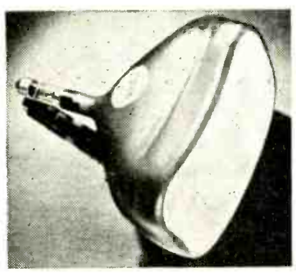
FIRM	(Stand)	Aerials: Broadcast	Aerials: Television and E.H.F.	Aerials: Anti-interference	Aerials: Car	Aerial accessories	Valves	C.R. tubes	Photocells	Metal rectifiers	Crystal valves	Battery chargers	Batteries	Power units, eliminators	Interference suppressors	Permanent magnets	Magnetic recording tape	Wire and cable	R.F. cable	Insulants	Coil formers	Solder	Television pre-amplifiers	Television optical accessories
A.R.B.M....	(86)	—	—	—	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—	—	—	—
Aerialite	(50)	•	•	•	•	•	—	—	—	—	—	—	—	—	•	—	—	•	•	—	—	—	—	—
Amplion...	(54)	—	—	—	—	—	—	—	—	—	—	•	—	•	—	—	—	—	—	—	—	—	—	—
Antiference	(22)	•	•	•	•	•	—	—	—	—	—	—	—	—	•	—	—	•	•	—	—	—	—	—
Belling-Lee	(25)	•	•	•	•	•	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	•	—
Brimar ...	(6)	—	—	—	—	—	•	•	—	•	•	—	—	—	—	—	—	—	—	—	—	—	—	—
Cossor ...	(37)	—	—	—	—	—	•	•	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dubilier ...	(79)	—	—	—	—	—	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—	—
E.M.I. ...	(68)	•	•	•	—	—	—	—	—	—	—	—	—	—	•	—	•	—	•	—	—	—	•	•
Eddystone	(124)	•	—	—	—	•	—	—	—	—	—	—	—	•	•	—	—	—	—	—	•	—	—	—
Ediswan ...	(62)	—	—	—	—	—	•	•	•	—	•	—	—	•	•	—	—	•	•	•	—	—	—	—
Ekco ...	(24)	—	—	—	•	•	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	•	—
Elpico ...	(77)	•	—	—	•	—	—	—	—	—	—	—	—	—	•	—	—	•	•	•	•	•	—	•
English Electric	(67)	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ever Ready	(57)	—	—	—	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—	—	—	—
Exide ...	(94)	—	—	—	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—	—	—	—
G.E.C. ...	(26, 78)	—	—	—	—	—	•	•	•	—	•	—	—	—	—	—	—	—	—	—	—	—	—	—
H.M.V. ...	(89, 109)	—	•	—	—	—	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	•	•
McMichael	(69)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	•	—
Marconiphone ...	(87)	—	•	—	—	—	•	•	—	—	—	—	—	—	•	—	—	—	—	—	—	—	•	•
Masteradio	(63)	—	—	—	•	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mullard ...	(17)	—	—	—	—	—	•	•	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—
Multicore	(32)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	•	—	—
Sentercel	(55)	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—	—	—	—	—	—	—
T.C.C. ...	(72)	—	—	—	—	—	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—	—
Telcon ...	(42)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	•	•	•	—	—	—	—
Telerection	(11)	—	•	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Valradio...	(122)	—	—	—	—	—	—	—	—	—	—	—	—	•	—	—	—	—	—	—	—	—	—	—
Vidor ...	(90)	—	—	—	—	—	—	—	—	—	—	—	•	•	—	—	—	—	—	—	—	—	—	—
W.B. ...	(95)	—	—	—	—	—	—	—	—	—	—	—	—	•	—	•	—	—	—	—	—	•	—	—
Westinghouse ...	(49)	—	—	—	—	—	—	—	—	•	•	—	—	•	—	—	—	—	—	—	—	—	—	—
Wolsey ...	(76)	•	•	—	—	•	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	•	—

COMPONENTS : Excluding Accessories

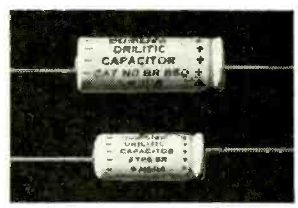
FIRM	(Stand)	Capacitors, fixed	Capacitors, variable	Trimmers	Resistors, fixed	Resistors, variable	Resistors, non-ohmic	Switches	Coils, R.F.	Coil Unit sub-assemblies	Transformers, mains	Transformers, audio	Chokes	Plugs, sockets, connectors, adaptors	Chassis fittings (valveholders, etc.)	Cabinets, racks, chassis	Dials, drives, knobs	Vibrators	Scanning components	Focus and ion-trap magnets
Amplion ...	(54)	—	—	—	—	●	—	—	●	●	—	—	—	—	—	—	—	—	—	—
Belling-Lee ...	(25)	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—	—	—
Brimar ...	(6)	—	—	—	—	—	●	—	—	—	—	—	—	—	—	—	—	—	—	—
Bulgin ...	(1)	●	—	●	●	●	—	●	—	—	—	●	●	●	●	—	●	—	—	—
Dubilier ...	(79)	●	●	●	●	●	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dynatron ...	(40)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—
E.M.I. ...	(68)	—	—	—	—	—	—	—	●	—	—	—	—	—	—	—	—	—	—	—
Eddystone ...	(124)	—	●	—	—	—	—	—	●	—	—	—	—	—	—	—	●	—	—	—
Ediswan ...	(62)	●	—	—	—	—	—	—	—	—	—	—	—	●	●	—	—	●	—	—
Elpico ...	(77)	—	●	—	●	—	—	●	●	●	●	●	●	●	●	●	●	—	—	—
Goodmans ...	(41)	—	—	—	—	—	—	—	—	—	—	●	●	—	—	—	—	—	—	—
Hunt ...	(56)	●	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Imhof ...	(19)	—	—	—	—	—	—	—	—	—	—	—	—	—	●	●	—	—	—	—
J.B. Cabinets ...	(9)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—
Mullard ...	(17)	—	—	●	—	—	●	—	—	—	—	—	—	—	—	—	—	—	—	●
Rola-Celestion ...	(73)	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—	—	—	—	—
Sculptured Sound ...	(121)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—
T.C.C. ...	(72)	●	—	●	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Telcon ...	(42)	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—	—	—
Valradio ...	(122)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—
W.B. ...	(95)	—	—	—	—	—	—	—	●	—	●	●	●	●	●	●	●	—	●	●
Wolsey ...	(76)	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—	—	—



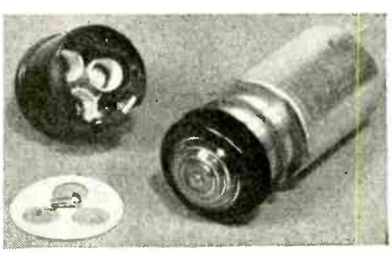
One of the new Westinghouse sealed E.H.T. rectifiers.



Mullard rectangular television tube Type MW36-22.

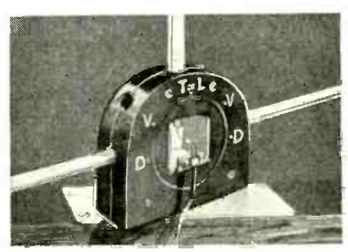


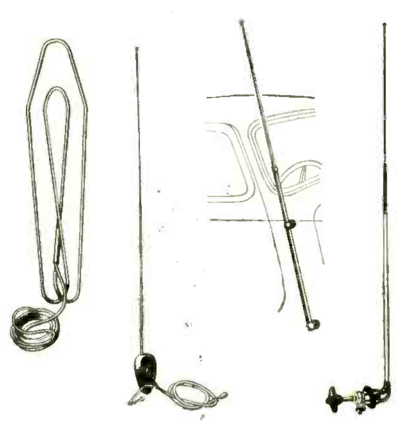
New "BR" 8-mfds Dubilier Drilitic (lower) compared in size with earlier type.



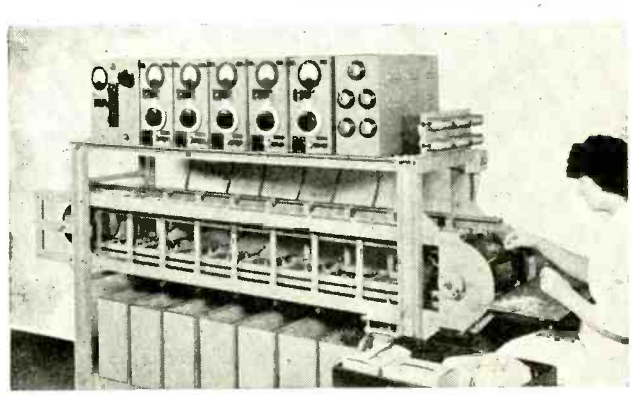
Bulgin 3-colour panel-type signal lamp.

Right: Wolsey indoor television aerial unit with switching for different arrangements.





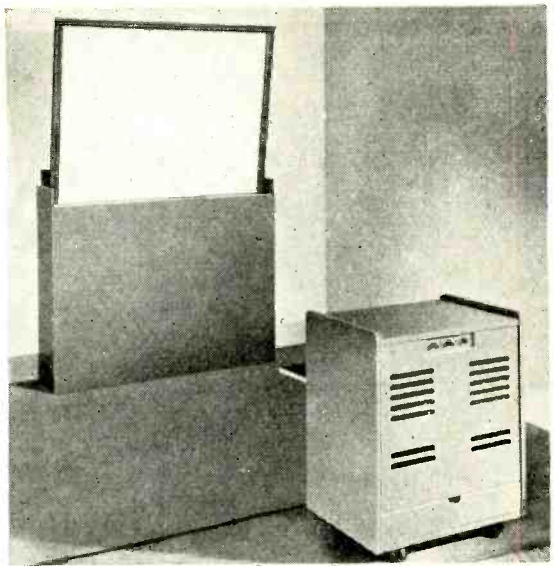
Selection of Aerialite car radio aerials.



Automatic capacitor testing and grading machine developed by T.C.C.

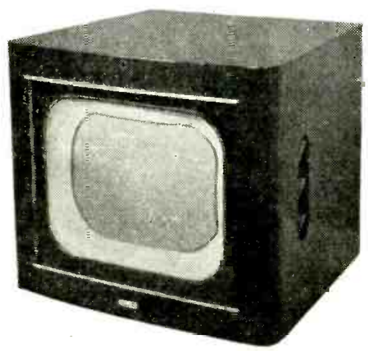
TEST AND MEASURING GEAR : Including Signal Sources

FIRM (Stand)	Single-range pointer meters	Multi-range meters	Bridges and accessories	Valve voltmeters	Test sets	Signal sources	Television signal sources	Oscilloscopes	Wavemeters
Amplion ... ... (54)	—	●	—	—	—	—	—	—	—
Avo ... ... (46)	—	●	●	●	●	●	●	—	—
Cossor ... ... (37)	—	—	—	—	—	—	●	●	—
E.M.I. ... ... (68)	—	—	●	—	●	●	●	●	—
Eddystone ... (124)	—	—	—	—	—	—	—	—	●
English Electric... (67)	—	—	—	—	—	●	—	—	—
Livingston Labs. (93)	●	●	●	●	●	●	●	●	—
Taylor ... ... (53)	●	●	—	●	●	●	●	—	—
Telequipment ... (83)	—	—	—	—	—	—	●	●	—
W.B. ... ... (95)	—	—	—	—	●	—	—	—	—
Waveforms ... (103)	●	—	—	—	●	●	●	—	—

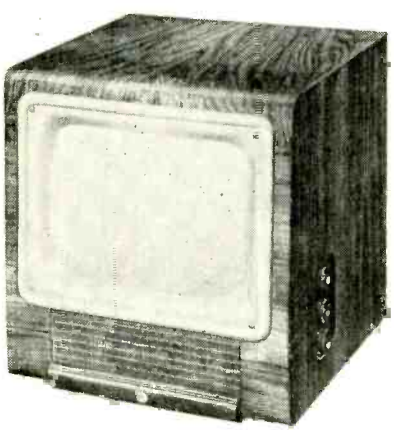


Decca large screen (3 x 4ft) projection television receiver.

Eddystone Model 680X communications receiver.



Murphy 12-in Model V200A television receiver with interchangeable r.f. unit.



Baird " Table-Fifteen " television receiver.

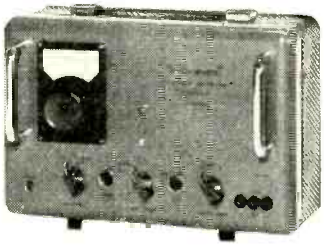
SCIENTIFIC, INDUSTRIAL AND MEDICAL APPARATUS

FIRM (Stand)	Control devices	Counters	Radiation monitors	Medical apparatus	Hearing aids
Dynatron... ... ... (40)	—	●	●	—	—
Ediswan ... ... (62)	—	—	—	●	—
K.B. ... ... (28)	—	—	—	—	●
Westinghouse ... ... (49)	●	—	—	—	—

SOUND REPRODUCING EQUIPMENT : Audio Amplifiers and Electro-Acoustic Apparatus

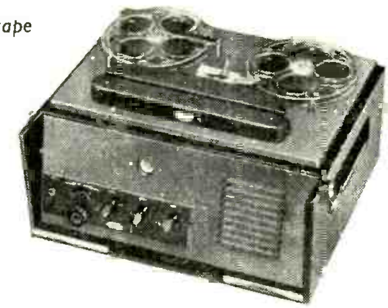
FIRM (Stand)	Microphones	Pickups	Amplifiers	Loudspeakers	Gramophone motors	Record changers	Record players	Electric gramophones	Disc recorders	Tape recorders
Amplion ... (54)	—	—	—	D	—	—	●	—	—	—
Baird ... (33)	—	—	—	—	—	—	—	—	—	●
Collaro ... (91)	—	—	●	—	●	●	●	●	—	—
Decca ... (61)	—	●	●	D	●	—	●	●	—	—
E.M.I. ... (68)	●	●	●	D, R	—	—	—	—	●	●
Ediswan ... (62)	—	●	—	—	—	●	—	—	—	—
Elpico ... (77)	—	—	●	—	—	—	●	—	—	—
G.E.C. (26, 78)	o	—	●	R	—	—	—	—	—	—
Garrard ... (92)	—	●	—	—	●	●	—	—	—	—
H.M.V. (89, 109)	—	—	—	—	—	●	●	●	—	—
K.B.... ... (28)	—	—	—	—	—	—	●	—	—	—
Pamphonic (85)	●	—	●	D, R	—	●	●	—	—	●
Petter ...(100T)	—	—	—	—	—	—	—	—	—	●
Portogram (20)	—	—	●	D	—	—	●	—	—	—
Rola-Celestion (73)	—	—	—	D, R	—	—	—	—	—	●
Sculptured Sound ... (121)	—	—	—	D, R	—	—	—	—	—	—
Simon ... (47)	—	—	—	—	—	—	—	—	●	●
W.B. ... (95)	●	—	●	D	—	—	—	—	—	—
Westinghouse (49)	—	—	—	—	—	—	—	—	—	●

D, domestic loudspeakers ; R, sound reinforcement loudspeakers.

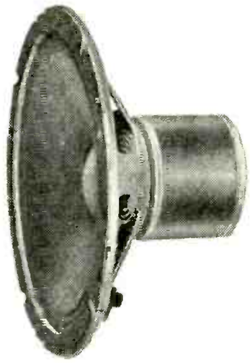


Telequipment television waveform generator.

Right: Simon magnetic tape recorder Type TR1A.

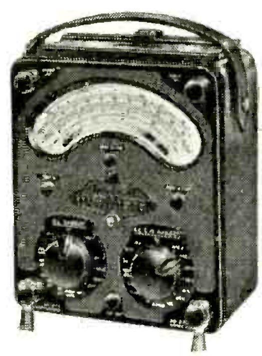


Below: Goodmans "Axion 102" 8-in loudspeaker with flux density of 16,000 gauss.

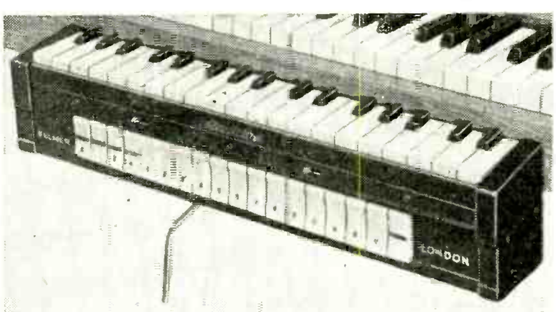


Collaro Microgram portable electric gramophone.

Pamphonic record player with pre-amplifier and tone control.



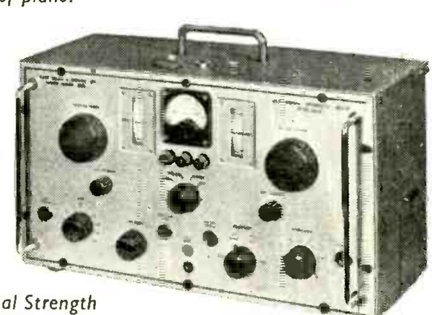
Latest pattern "Model 8" Avometer.



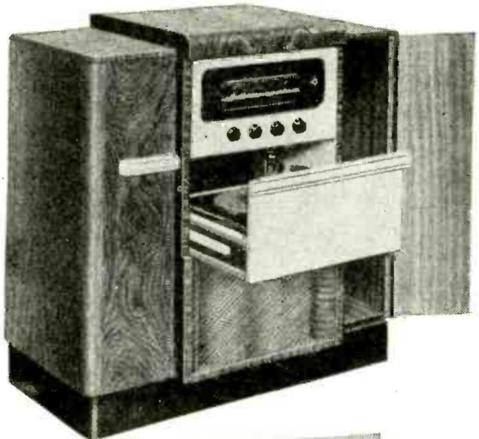
Right: Taylor insulation tester Type 130A.

Left: Selmer "Clavioline" electronic manual attached to keyboard of piano.

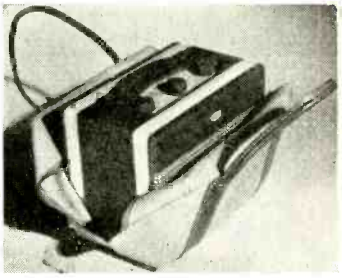
Left: Truvox (Rola) new "Minor" re-entrant horn loudspeaker.



E.M.I. v.h.f. "Signal Strength Meter" Type QD151.

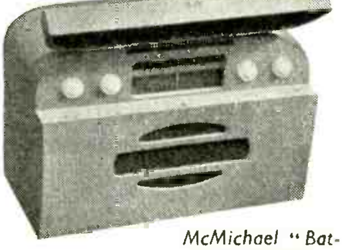


Left: Champion "Coronation" radiogram with 3-speed automatic record changer.



Right: Roberts' new "Junior" all-dry portable.

Below: Alba portable radiogram with spring motor for mains or battery operation.



McMichael "Batman" portable.

G.E.C. Model BC4444 portable receiver.

NUMERICAL LIST OF STANDHOLDERS

1 **A. F. Bulgin & Co.**, Bye-Pass Rd., Barking, Essex,
2 **Board of Trade**, Lacon House, Theobalds Rd., London, W.C.1.
4 **British Railways**, 222, Marylebone Rd., London, N.W.1.
5 **Westminster Bank**, 51, Threadneedle St., London, E.C.2.
6 **Standard Telephones & Cables**, Footscray, Sidcup, Kent.
7 **Felgate Radio**, Felgate House, Studland St., London, W.6.
9 **J.B. Manufacturing (Cabinets) Co.**, 86, Palmerston Road, Walthamstow, London, E.17.
10 **Henri Selmer & Co.**, 114/116, Charing Cross Rd., London, W.C.2.
11 **Telerection**, Antenna Works, St. Pauls, Cheltenham, Glos.
12 **Co-operative Wholesale Society**, 99, Leman St., London, E.1.
13 **Regentone Products**, Eastern Avenue, Romford, Essex.
14 **Ferranti**, Hollinwood, Lancs.
15 **Murphy Radio**, Welwyn Garden City, Herts.
16 **Bush Radio**, Power Rd., Chiswick, London, W.4.
17 **Mullard**, Century House, Shaftesbury Avenue, London, W.C.2.
19 **Alfred Imhof**, 112, New Oxford St., London, W.C.1.
20 **Portogram Radio Electrical Industries**, Preil Works, St. Rule St., London, S.W.8.
21 **Econasign Co.**, 92, Victoria St., London, S.W.1.
22 **Antiference**, 67, Bryanston St., Marble Arch, London, W.1.
23 **Peto Scott Electrical Instruments**, Addlestone Rd., Weybridge, Surrey.
24 **E.K. Cole**, Ekco Works, Southend-on-Sea, Essex.
25 **Belling & Lee**, Cambridge Arterial Rd., Enfield, Middx.
26 **General Electric Co.**, Magnet House, Kingsway, London, W.C.2.
27 **Stella Radio & Television Co.**, Oxford House, 9/15, Oxford St., London, W.1.
28 **Kolster-Brandes**, Footscray, Sidcup, Kent.
29 **Radio Gramophone Development Co.**, 3, Hampton Court Parade, East Molesey, Surrey.
32 **Multicore Solders**, Maylands Avenue, Hemel Hempstead, Herts.
33 **Baird Television**, Lancelot Rd., Wembley, Middx.
34 **Sobell Industries**, Langley Park, Nr. Slough, Bucks.
35 **A. J. Balcombe**, 52, Tabernacle St., London, E.C.2.
36 **Pye**, Radio Works, Cambridge.
37 **A.C. Cossor**, Cossor House, Highbury Grove, London, N.5.
38 **Philco (Overseas)**, Lion House, Richmond, Surrey.
39 **Roberts' Radio Co.**, Creek Rd., East Molesey, Surrey.
40 **Dynatron Radio**, Perfecta Works, Ray Lea Rd., Maidenhead, Berks.
41 **Goodmans Industries**, Axiom Works, Wembley, Middx.
42 **Telegraph Construction & Maintenance Co.**, Telcon Works, Greenwich, London, S.E.10.
43 **J.G. Publications**, 32, Vauxhall Bridge Rd., London, S.W.1.
44 **"British Radio & Television,"** 92, Fleet St., London, E.C.4.
45 **Trader Publishing Co.**, Dorset House, Stamford St., London, S.E.1.
46 **Automatic Coil Winder & Electrical Equipment Co.**, Winder House, Douglas St., London, S.W.1.
47 **Simon Sound Service**, 48/50, George St., London, W.1.
48 **Skarsten Manufacturing Co.**, 21, Hyde Way, Welwyn Garden City, Herts.
49 **Westinghouse Brake & Signal Co.**, 82, York Way, Kings Cross, London, N.1.
50 **Aerialite**, Castle Works, Stalybridge, Cheshire.
51 **Barclays Bank**, 54, Lombard St., London, E.C.3.
52 **Geo. Newnes**, Tower House, Southampton St., London, W.C.2.
53 **Taylor Electrical Instruments**, 419, Montrose Avenue, Slough, Bucks.
54 **Amplion**, 230, Tottenham Court Rd., London, W.1.
55 **Standard Telephones & Cables**, Connaught House, Aldwych, London, W.C.2.
56 **A. H. Hunt (Capacitors)**, Bendon Valley, Garratt Lane, London, S.W.18.
57 **Ever Ready Co.**, Hercules Place, Holloway, London, N.7.
58 **Pilot Radio**, 31/37, Park Royal Rd., London, N.W.10.
59, 60 **Philips Electrical**, Century House, Shaftesbury Avenue, London, W.C.2.
61 **Decca Record Co.**, 1/3, Brixton Rd., London, S.W.9.
62 **Edison Swan Electric Co.**, 155, Charing Cross Rd., London, W.C.2.
63 **Masteradio**, 10/20, Fitzroy Place, London, N.W.1.
65 **"The Star,"** 12/22, Bouverie St., London, E.C.4.
66 **Ace Radio**, Tower Works, Pound Lane, Willesden, London, N.W.10.
67 **English Electric Co.**, Queens House, Kingsway London, W.C.2.
68 **E.M.I. Sales & Service**, Hayes, Middx.
69 **McMichael Radio**, 190, Strand, London, W.C.2.
70 **Ultra Electric**, Western Avenue, Acton, London, W.3.
71 **Invicta Radio**, Parkhurst Rd., Holloway, London, N.7.
72 **Telegraph Condenser Co.**, Wales Farm Rd., North Acton, London, W.3.
73 **Rola Celestion**, Ferry Works, Summer Rd., Thames Ditton, Surrey.
74 **Odhams Press**, 96, Long Acre, London, W.C.2.
75 **Iliffe & Sons**, Dorset House, Stamford St., London, S.E.1.
76 **Wolsey Television**, 75, Gresham Rd., Brixton, London, S.W.9.
77 **Lee Products**, 90, Gt. Eastern St., London, E.C.2.
78 **General Electric Co.**, Magnet House, Kingsway, London, W.C.2.
79 **Dubilier Condenser Co.**, Ducon Works, Victoria Rd., North Acton, London, W.3.
80 **Plessey Co.**, Vicarage Lane, Ilford, Essex.
81 **Lloyds Bank**, 71, Lombard St., London, E.C.3.
82 **National Provincial Bank**, 15, Bishopsgate, London, E.C.2.
83 **Telequipment Electronic Instruments**, 73a, Beresford Rd., Hornsey, London, N.8.
85 **Pamphonic Reproducers**, Westmoreland Rd., Queensbury, London, N.W.9.
86 **Association of Radio Battery Manufacturers**, 41, Gordon Square, London, W.C.1.
87 **Marconiphone Co.**, Hayes, Middx.
88 **Ferguson Radio Corporation**, 105, Judd St., London, W.C.1.
89 **Gramophone Co.**, Hayes, Middx.
90 **Vidor**, West St., Erith, Kent.
91 **Collaro**, Ripple Works, Bye-Pass Rd., Barking, Essex.
92 **Garrard Engineering & Manufacturing Co.**, Newcastle St., Swindon, Wilts.
93 **Livingston Laboratories**, Retcar St., Dartmouth Park Hill, London, N.19.
94 **Chloride Batteries**, 6/10, Whitfield St., London, W.1.
95 **Whiteley Electrical Radio Co.**, Radio Works, Victoria St., Mansfield, Notts.
96 **Linguaphone Institute**, 207/209, Regent St., London, W.1.
97T **Brown Brothers**, Browns Buildings, Gt. Eastern St., London, E.C.2.
98T **Kerry's**, Warton Rd., Stratford, London, E.15.
99T **Hobday Bros.**, 21, Gt. Eastern St., London, E.C.2.
100T **Petter Radio & Electrical Supplies**, 201/7, Forest Rd., Walthamstow, London, E.17.
101T **L.E.S. Distributors**, 15, Alfred Place, London, W.C.1.
102T **J. J. Eastick & Sons**, 12, Errol St., London, E.C.1.
103 **Waveforms**, Radar Works, Truro Rd., London, N.22.
104 **Keith Prowse & Co.**, 159, New Bond St., London, W.1.
109 **Gramophone Co.**, Hayes, Middx.
121 **Sali**, 79a, St. Leonard's Rd., Windsor, Berks.
122 **Valradio**, New Chapel Rd., Feltham, Middx.
123 **W. G. Turnidge**, St. Andrews Walk, Bethnal Green, London, E.2.
124 **Stratton & Co.**, Eddystone Works, Alvechurch Rd., West Heath, Birmingham, 31.
125 **Electrical Trades Union**, Hayes Court, West Common Rd., Bromley, Kent.
126 **Television Society**, 164, Shaftesbury Avenue, London, W.C.2.
127 **Bernards (Publishers)**, The Grampians, Western Gate, London, W.6.
128 **White-Ibbotson**, 205, Station Rd., Harrow, Middx.
129 **British Broadcasting Corporation**, Broadcasting House, London, W.1.
130 **Admiralty**, Whitehall, London, S.W.1.
131 **Air Ministry**, Parliament Square House, Parliament St., London, S.W.1.
132 **War Office**, Whitehall, London, S.W.1.
133 **Champion Electric Corporation**, Champion Works, Newhaven, Sussex.

Army Communications

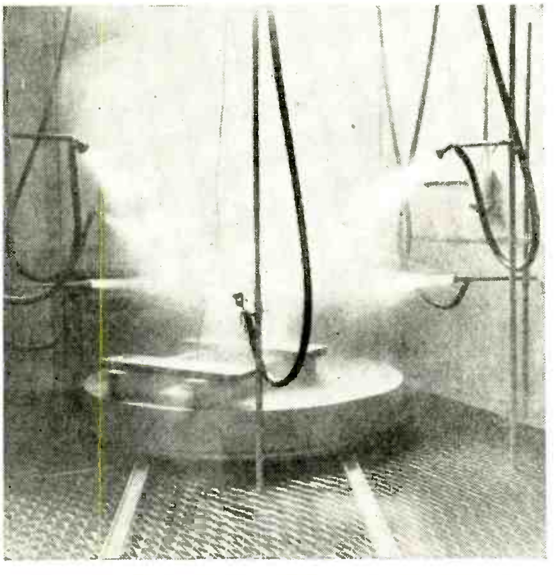
The Rôle of the Signals Research and Development Establishment

OF the many establishments concerned with the development of communications in the fighting services, those providing for the needs of the Army and the R.A.F. are co-ordinated under the Ministry of Supply which is responsible for seeing that duplication of effort is avoided and that standardization, where possible, is not precluded.

The Signals Research and Development Establishment at Highcliffe, near Christchurch (formerly the Signals Experimental Establishment, Woolwich), is concerned primarily with the needs of the Army, and its functions, both active and passive, play an essential part in translating operational requirements into realizable designs, which can be made in quantities by the resources of industry.

Many of its most intriguing activities are at the moment subject to security regulations, but during a recent visit sufficient was seen to enable an appreciation of the value of the Establishment's routine work to be made.

The main divisions are broadly: Research, Development, Technical Services and Engineering. Lines of demarcation between the divisions are not rigid, and all are well versed in the kind of misuse—perhaps it would be kinder to say, the normal stresses—to which apparatus is subjected by the Army in the field.



"Driving rain" test for splash-proof components (in this case a re-entrant horn loudspeaker). More searching tests are arranged for equipment classified as waterproof.

Some indication of the severity of these stresses is gained when one sees the refined instruments of torture which have been devised by the Technical Services Department merely to simulate, and not necessarily to exceed, known conditions of transport and use. Methods of packing, which are devised by the Engineering Division, are tested by vibration and drop tests and equipment which is amenable to air transport is tested at the low temperatures and pressures associated with high altitudes. Materials for colour codes and printed scales are subjected to ultra-violet radiation equivalent to intense sunlight, and desert sandstorms are simulated in yet another test chamber. Meters and valves are given impact tests which in some cases are the equivalent accelerations 100 times that due to gravity. Equipment subjected to sustained vibration from the engines of transport or armoured fighting vehicles is examined stroboscopically over a wide frequency range on a vibration table. Under these conditions an ordinary broadcast receiver presents a nightmarish spectacle of weaving surfaces and rocking components with first one section then another losing stability as the frequency is raised.

Much thought has recently been given to the waterproofing of radio equipment for operations involving beach landings and the wading of rivers, and a demonstration was given of the use of resealable protective covers for handcart, trailer and truck wireless transmitting and receiving stations.

Another interesting demonstration showed the method of handling aerial masts from 30 to 100 ft in height and designed, by the Mechanical Design Group of the Engineering Division, for vertical erection. Not only are these masts capable of carrying comparatively heavy top loads in the form of special aerial arrays, but they do not require the open space formerly needed for derrick erection and can be pushed up through tree cover without disturbing the terrain.

An important section of the Technical Services Division is the Components Development Group whose responsibility it is to investigate new principles and materials which may show promise of improving reliability, stability of performance or reduction in size of communications components. Demonstrations were given of sensitive test equipment for indicating the temperature coefficient of capacitance or inductance. Examples were shown of new d.c./a.c. vibrators with increased output, and electromagnetic relays designed to be immune from false operation due to external shocks. Among new materials being investigated were noted glass and enamel glaze dielectrics for small fixed capacitors, and inter-granular barrier layer dielectrics for larger capacitors. The latter consist of partially reduced titanium oxide powder, sintered in an oxidizing atmosphere, and have greater stability at high temperatures than electrolytic capacitors. They are suitable for frequencies below 10 kc/s and have a minimum "Q" in the region of 100 c/s which points to the possibility of use in tuned smoothing circuits.

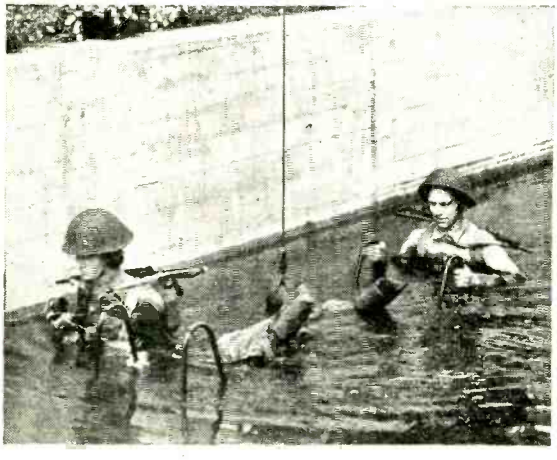
The Radio Group of the Development Division is responsible for the design of communications equipment for use by the Royal Corps of Signals and for infantry, vehicular and tank sets, which are frequency-

Operating a transmitter-receiver at a temperature of — 40 degrees Fahrenheit.

modulated at v.h.f. By comparison with the infantry pack sets used during the last war, the latest designs show an appreciable, though not spectacular, reduction in weight. Where they do score is in the reduction in size and the silhouette presented to the enemy; it is now a matter of some difficulty to spot the signaller in a platoon. Intensive miniaturization, with whole i.f. stages now occupying the space formerly taken by a "miniature" coil can, is largely responsible, but much ingenuity has been exercised in the layout of sub-assemblies, which leave no wasted space and which are colour-coded to facilitate replacement by semi-skilled men.

The new tank sets chassis, when withdrawn from their cast-metal containers, open out like a book to give access to valves and components. When closed the only wiring to be seen is the power supply and interconnecting leads between sub-assemblies. Three transmitter-receiver channels are provided for communication between tank and infantry, between tanks in a troop and between troops in a squadron. "Netting," in which receivers are tuned to the arbitrary frequency of a master transmitter, has given place to independent frequency selection by reference to built-in crystal calibrators.

Testing waterproofed equipment by operating a v.h.f. hand-cart set "on the wade."



Although radio developments are apt to steal the picture on occasions like this, it is salutary to be reminded that the bulk of the Army's communications are still carried by wire, and a large and active Lines Group at S.R.D.E. concerns itself with telephone and telegraph equipment. Of course, there is inevitably some overlapping of line and radio methods, and in the latest multi-channel carrier telephone equipment which is of compact unit construction, soldered-in miniature valves were noted. In a two-wire audio repeater, which gives the equivalent of four-wire working over distances up to 25 miles, carrier methods are also used for one direction.

The speed of laying of field cables has been increased by the development of twin-twisted non-kinking copper-steel conductors, polythene insulated and nylon-sheathed, which can be laid from a dispenser drum at speeds up to 100 m.p.h.

A new teleprinter having a quarter the weight of the present Army teleprinter was shown. The use of a travelling-type basket instead of a travelling drum has decreased the overall width to that of a man, so that bench space is saved in mobile units. Speeds up to 100 w.p.m. are available.

To find what are the essential elements in speech intelligibility and if possible to effect a reduction in the required transmission bandwidth, the Lines Group are undertaking research involving the synthesis of speech from elements of known characteristics. These take the form of hand-drawn sound tracks which are converted to audio currents through a photocell. Some astonishingly life-like effects have been produced.

The problems of speech intelligibility through the high ambient noise (90 to 110 phons) in a tank are being tackled by the Electro-acoustics Group which is engaged on a statistical analysis of special "immediate appreciation" articulation tests carried out in a soundproof room in which the acoustic environment, simulating battle conditions, is provided by banks of loudspeakers covering the whole of one wall and fed from a 1-kW audio amplifier. Other work of this department includes routine measurements on microphones, headphones and loudspeakers, the development of a limited number of standard transducers to reduce the range of types in service, and the design in conjunction with industry of blast-proof loudspeakers.

In addition to its function as a prime mover in research and development, S.R.D.E. constitutes a buffer state between Army and Industry and ensures continuity in the execution of long-term plans for re-equipment, irrespective of changes in Army Staff or industrial management. These aspects are admirably summed up in the words of Dr. G. W. Sutton, the Chief Superintendent: "The function of the Establishment, therefore, emerges quite clearly, though a written specification of this function is not quite so easy to formulate. It is partly an inductive element, since it must maintain continuity of philosophy and consequent action. It is partly capacitive, since it must absorb transient forces arising at either end of the circuit. Perhaps it is not inappropriate to regard it also as a resistive element, since it is a convenient place in which to allow inevitable surges of technical opinion to become dissipated."

LETTERS TO THE EDITOR

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

Too Many Recording Characteristics?

I AM afraid that Ruth Jackson's suggestion in the August issue with regard to the recording characteristics difficulty would be no solution of the problem, even if recording companies did agree on a standard characteristic. As things are, the companies do not appear to adhere any too strictly to their various characteristics, and indeed it is hardly practicable to apply the same measure of top pre-emphasis to, for example, a recording of a female choir as is sometimes now applied to band or orchestral recordings, unless the recording level is very considerably reduced. In any case, widely variable equalization would still be required at the reproducing end to cope with the peculiarities of loudspeakers, listening room characteristics, and microphone placing at the actual recording, to say nothing of the individual listener's preferences with regard to balance. I consider the only solution lies in the provision of four independent controls, two each for bass and treble, giving a wide variation of both slope and point of origin to the equalization curves. The present tendency to provide switched equalization for the four major recording characteristics is in my experience quite inadequate.

Honiton, Devon. R. MARKER.

THE entry of a member of the opposite sex into the arena of audio controversy is a welcome event, but I am sorry that Ruth Jackson should have abandoned the realism and practical commonsense usually attributed to her sex in joining those starry-eyed males who think that there is some virtue in devising correction circuits which are the exact complement of published recording characteristics. Do these give more than compensation for the performance of the cutter head and its associated amplifier? What of the studio acoustics and the microphone characteristics, the "recording technique" of the performers and the opinion of the recording company's musical director if he is not satisfied with the first playback; are all these included in the characteristic? If not, then I say that there are not enough "recording characteristics," and that ultimately there should be one for each disc in the catalogue. And what will the amplifier makers do then, poor things? What the wise ones already do; give the customer the widest possible variable controls and let *him* get on with it. HENRY MORGAN.

Hindhead, Surrey.

The Nanofarad

FROM time to time, in various journals, correspondents call attention to the virtues of the nanofarad, with its abbreviation nF; but there seems to be no general move in Great Britain to adopt it. This seems a pity, for its advantages are manifest. The average capacitance used in radio engineering is of the order of 10^{-9} F, and one never quite knows whether to write it 0.001 μF or 1,000 pF. That 1nF is preferable to either seems too obvious to need emphasis. The less one has to use μ the better, for it is not provided on typewriters; and when it comes to 0.01 μF and 0.1 μF the alternatives in pF are clumsy.

Another strong point in favour of using the nF is that fewer people would have an excuse for the irritating and time-wasting practice of writing component values as a separate list instead of on the circuit diagram. Almost all capacitances could be stated in reasonably small whole numbers, followed by p, n, or nothing, for F and μ are redundant when written alongside a capacitor symbol.

The only conceivable explanation for not having joined our European and other friends on this seems to me the characteristic British reluctance to be unconventional. I remember when anybody who ventured to talk pF excited either mystification or hilarity, but now no radio engineer would be without his puffs. "Resistor" was once considered pedantic, but has completely won through; and "capacitance" and "capacitor" are well on the way. I do not accept the defeatism of those who say it's no use trying to alter illogical terminology and conventions because they are too firmly rooted. From now on I intend to join the nF minority, and I urge this course on all who are not afraid to do now what everyone will be doing in ten years' time.

Bromley, Kent. M. G. SCROGGIE.

Colour Coding

I NOTE with pleasure in the June *Wireless World* that R. V. Goode expresses the opinion that the "spot" colour should always be a band.

At the first Radio Exhibition at which colour-coded resistors were displayed, I pointed out to the assistant that trouble would be caused when the resistor was fixed so that the spot became invisible. However, it takes more than a single suggestion at an exhibition followed by a letter to bear fruit. That the spot is becoming rarer is at least satisfying, and I trust that soon it may become a radio crime.

I now have another suggestion to make. It derives directly from the fact that the "spot" colour is the one which determines the position of the decimal point, and is therefore vastly more important than either of the others. The decimal point colour to be found on a cathode bias resistor is not found on the third band of an anode resistance or a grid leak. My suggestion is, therefore, that in accord with its predominating importance, this third band be emphasized.

I therefore ask those resistor manufacturers who *must* follow a detailed specification, to make that important third band as wide relative to the other two as the tolerance permits. To those who make for the public and the set builder, I ask, please make that band as wide as you dare. Two, three or even four times as wide as the others. Approximately 40 per cent to 50 per cent of the resistor length might be a suitable width. To those who draft specifications, I ask that you call for wide third colour bands as suggested above.

Then, perhaps, one day electronic equipment will contain "easy-find" resistors which by their predominating colour literally radiate information as to whether they have high, low or medium values. The service technician, when checking a particular cathode resistor or grid leak will be able to pick it out instantly, instead of having to make a detailed search as at present, when 1.5 MΩ and 550 ohms actually have identical colours, though theoretically running in opposite directions.

Toronto, Canada. P. G. A. H. VOIGT.

Frequency Response Measurements

THE letter from Henry Morgan in your July issue seems to imply that response curves, as normally used in audio measurements, are either misleading or worthless.

Mr. Kelly, who is referred to in the letter, is a fellow Yorkshireman and happened to be on a visit when the above letter appeared. He spent some of his holiday helping me with loudspeaker response curve oscillograms, which seem to show that although in theory Mr. Morgan may be correct, in practice there is nothing to his arguments.

If a trace covering 20 to 500 c/s in 7 seconds is repeated, but the frequency is allowed to remain constant for about ¾ sec. at 50, 100 and 500 c/s the steady frequency simply forms a natural part of the continuous trace. The reason is, of course, that sound frequencies are extremely rapid vibrations, and if the audio range is covered in 15 to 20 seconds there is ample time to get a picture of the true performance.

Mr. Kelly's explanation is in the following words: "The velocity of frequency variation can be neglected providing the rate of change of frequency with respect to time is sufficiently small compared with the rate of change of amplitude with respect to frequency of the circuit under test. To bring a sordid note of reality into this discussion I would hesitate to guarantee any measurements made on electro-mechanical or electro-acoustic apparatus to better than ±1 db, using commercially available test equipment such as valve voltmeters, gramophone records, etc., under normal uncontrolled conditions. Under these circumstances whilst the argument 'When is a cycle not a cycle?' is an interesting hypothetical discussion, I think it bears no relation to actual practice, always providing the engineer knows what he is doing."

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

Jargon

YOU give a monthly display, to our delight, of strength in physics, but I venture to express regret that chemistry appears to be a weaker subject. (Your second leader, July, 1952.)

"Jargon" is a rare gas (though perhaps not rare enough) exhaled by civil servants, motor car salesmen and estate agents. That given off by the B.B.C.—the collection of which involves no exceptional bandwidth acceptance—is (*pace* Ramsay et Rayleigh) "Skrypton."

Ringwood, Hants. ROBERT BRIGGS-BURY.

Towards International Broadcasting

THE medium-wave band is overcrowded, and sooner or later we in Western Europe will have to change over to metre waves for our internal services. But, as metre waves have a restricted range, we must then take steps to ensure that we can listen to each others' programmes.

The existing medium-wave (and also long-wave) channels could still be used for international exchanges, but, in these days of post-war financial stringency, cost may be a problem, especially for the smaller countries.

By sharing the cost, this difficulty could be overcome. I suggest one high-power station each for the smaller countries and perhaps two or three each for Great Britain and France. The stations would radiate first-rate programmes, predominantly musical to overcome the language difficulty. Short announcements might be multi-lingual. The radio or cable interconnections necessary might also be used for exchanges of television programmes.

Expenses of the international service could be covered by a union of the "ENFRABENELUX"* countries, each country contributing according to her number of listeners.

Rotterdam, Holland. C. L. ZAALBERG.

* Presumably England-France-Belgium-Netherlands-Luxembourg.—ED.

What is a Thermostat?

SOME confusion seems to exist over the use of the word "thermostat," which is generally, but apparently not always, used to describe a device that operates by breaking the circuit.

For automatically heat-regulated devices where the electrical circuit is not broken (which have the incidental advantage of not producing radio interference) I feel a new word is needed.

Bexley Heath, Kent. A. E. DURRINGTON.

[We agree. "Thermostat" is defined in B.S.205 as "an automatic device responsive to changes in temperature. In electrical work it usually opens or closes a circuit."—ED.]

"Pre-recorded"

THE words of your correspondent R. P. Truman (July issue), who protested against the B.B.C.'s use of the meaningless term "pre-recorded," seem to have sunk in. I have not heard it used since.

All the same, the B.B.C. still fail consistently to say what they probably mean when referring to recording. Early the other morning (6.55 a.m.) the announcer said "'Bright and Early' was recorded this morning by the . . . Band." Cruelty to musicians, I call it! Why not have allowed the poor fellows to record their performance at a reasonable hour the day before, or, if bandsmen are in fact early risers, have given us the benefit of a "live" performance!

Then we have the seemingly straightforward announcement "The programme was recorded." But the seeds of doubt are sown in our minds by an occasional statement that "The programme was recorded, and will be heard on the Light Programme at . . ." Can we be quite sure that we have been actually listening to a recording in both cases? "The programme was broadcast from a recording" would at least be unambiguous.

The suspicion arises in my mind that in this matter the B.B.C. suffers from an inferiority complex; they know in their hearts that they are failing to make the best use of the outstanding advantage of our medium and strive subconsciously to conceal the fact that they use so many recordings. Broadcasting can present living actualities in a manner unrivalled by the printed word or the gramophone record.

London, S.W.7. CHARLES P. SLOAN.

Amplifiers and Superlatives

An Examination of American Claims for Improving Linearity and Efficiency

By D. T. N. WILLIAMSON* and P. J. WALKER†

Recent articles, particularly in the United States, have shown that some confusion of thought exists about the "goodness" of an amplifier for reproducing sound. This has been accompanied by a debasement of the terms used to describe the properties of an amplifier; words that have a precise meaning when standing alone become meaningless when qualified by superlatives. This article, which starts with a discussion of what constitutes a good amplifier, attempts to clear up some misconceptions and generally to clarify the position.

THE most commonly specified parameter of an amplifier is its harmonic distortion or intermodulation content, and this has tended to be regarded as the primary standard of "goodness." In 1944, one of the writers suggested[1] that a standard of 0.1 per cent total harmonic distortion at maximum output was a good level of performance to aim at. Such a low distortion content is readily achievable by modern design methods, and is, in fact, undetectable by listening tests, however refined. This arbitrary figure was chosen, not because it was the maximum permissible, but because, being rather lower than was absolutely necessary, a good margin is left for any deterioration of the equipment when in service.

The requirements for a good amplifier were listed in the article already mentioned, but are worth repeating and extending. These are:—

(1) Negligible non-linearity distortion up to the maximum rated output. (The term "non-linearity distortion" includes the production of undesired harmonic frequencies and the intermodulation of component frequencies of the sound wave.) This requires that the dynamic output/input characteristic be linear within close limits up to the maximum excursion of any waveform, with frequency components inside and outside the working range, which is likely to be fed to the amplifier. This should hold good under conditions of varying load impedance such as are likely to be encountered in practice.

(2) Linear frequency response within the audible frequency spectrum of 10-20,000c/s.

(3) Negligible phase shift within the audible range. Although the phase relationship between the component frequencies of a complex steady-state sound does not appear to affect the audible quality of the sound, the same is not true of sounds of a transient nature.

(4) Good transient response. In addition to low phase and frequency distortion, other factors which are essential for the accurate reproduction of transient waveforms are the elimination of changes in effective gain due to current and voltage cut-off in any stages, the utmost care in the design of iron-cored components, and the reduction of the number of such components to a minimum. Changes in effective gain during "low-frequency" transients occur in amplifiers with output stages of the self-biased Class AB type, causing serious distortion which is not revealed by steady-state measurements. The transient causes the current in the output stage to rise, and this is followed, at a rate determined by the time-constant of the biasing network, by a rise in bias voltage which alters the effective gain of the amplifier.

(5) Low output resistance. This requirement is concerned with the attainment of good frequency and transient response from the loudspeaker system by ensuring that it has adequate electrical damping. The cone movement of a moving-coil loudspeaker is restricted by air loading, suspension stiffness and resistance, and electromagnetic damping. The efficiency of a baffle-loaded speaker is rarely higher than 5-10 per cent, and the air loading, which determines the radiation, is not high. Electromagnetic damping is therefore important in controlling the motion of the cone. This effect is proportional to the current which can be generated in the coil circuit, and is therefore proportional to the total resistance of the circuit. The output resistance of the amplifier therefore should, in general, be much lower than the coil impedance.

(6) Adequate power reserve. The realistic reproduction of orchestral music in an average room requires peak power capabilities of the order of 15-20 watts when the electro-acoustic transducer is a baffle-loaded moving-coil loudspeaker system of normal efficiency. The use of horn-loaded or other efficient loudspeakers may reduce the power requirement to the region of 10 watts. In an amplifier for the best possible quality it is, of course, assumed that output peaks required in practice will be comfortably below the maximum available. Even so, good design should ensure that the overload characteristic will not suffer temporary paralysis or "blocking" on momentary overload.

(7) The level of hum and noise should be at least 80db below maximum output.

This is a formidable specification, and by no means every amplifier styled as "high quality" will meet it. However, provided that these requirements are met *in every respect* and that extraneous components occurring within the audio range (produced either by components inside or outside that range) do not

* Ferranti Research Laboratories.
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[1] M.O. Valve Co., Ltd. Internal Report No. Q253, later published as "Design for a High-Quality Amplifier," by D. T. N. Williamson, *Wireless World*, April-May, 1947.

exceed a small fraction of 1 per cent, any amplifier will sound as good as any other amplifier and it becomes impossible to "improve" a power amplifier in the sense of producing better sound.

Efficiency.—On the other hand it is, of course, absurd to say that amplifiers cannot be improved in any sense. Efficiency, compactness, and reliability are important and it is with regard to these factors that improvements are possible and in many cases desirable. The size and purpose of an amplifier will determine how much weight should be given to each of these factors.

In small amplifiers with power outputs below twenty watts, power efficiency is not usually of prime importance, and other considerations such as ease of construction and certainty of results may easily outweigh it. With large amplifiers, efficiency becomes a very important factor. Sometimes it is not possible to produce a high output *unless* the efficiency is high, because of valve dissipation limits.

Controlled and Uncontrolled Production.—The designer's aim is (or should be) to produce the best possible sound for those who will ultimately make use of his efforts. If he designs for construction not under his control, he must, as far as possible, ensure that every amplifier made will meet his performance figures without undue difficulty and with the employment of limited measuring equipment. In such a case, the avoidance of circuitry which is not straightforward, or in which deviations from specification in the values and construction of components is liable to produce poor results, is paramount.

The designer who has control over the production of the complete equipment has a different set of problems. He has much greater freedom of choice, and it is likely that he will arrive at different circuitry.

The amplifier which was described in *Wireless World*, April-May, 1947, is an example of the first kind of circuitry. The success it has achieved since then, in the hands of people with widely varying degrees of skill, is indicative that trouble-free performance is readily obtainable with only simple adjustments. This amplifier was based upon a triode output stage with a good output transformer, the performance of which was improved by overall negative feedback.

The only valid criticism which can be made about its performance is on the score of efficiency. The output of about 15 W is produced for an h.t. consumption of 56 W, an efficiency of only 27 per cent. By the use of tetrodes as output valves this could be raised to the order of 35-40 per cent, which means that, for the same power consumption, the output could be increased to 22 W, or, alternatively, that the power consumption could be reduced by about 20 W.

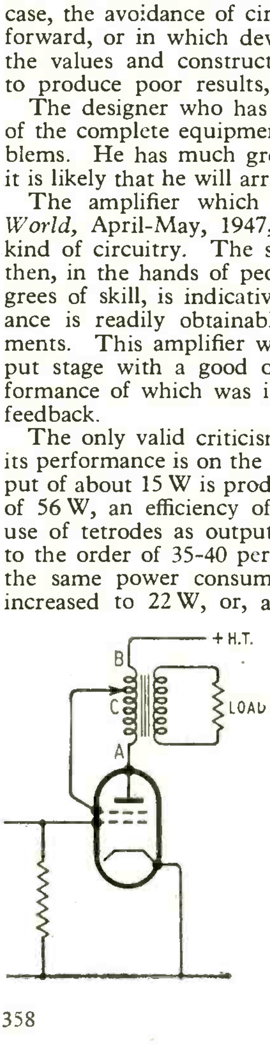
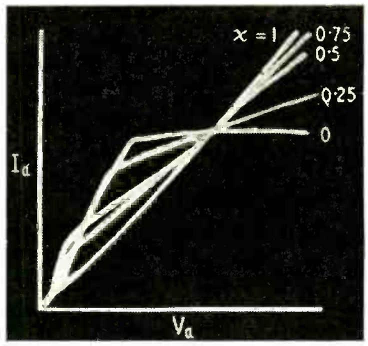


Fig. 1. Basic circuit used by Hafler and Keroes.

Whether this is worth doing or not is problematical. In the designer's opinion, the additional risk of trouble in unskilled hands outweighs the advantage of higher maximum power output, as in the vast majority of cases even the present level of output cannot be fully utilized. The reduction in power consumption and h.t. voltage would not greatly affect the cost, although it would give a higher factor of safety for the capacitors in the circuit. There is, however, no evidence that this is at present inadequate.



Oscillogram showing transition of I_a-V_a curves from tetrode to triode form as the tapping point in Fig. 1 is moved from B to A.

Circuits with Distributed Loads.—Articles[2, 3] have recently been published in the United States claiming the superiority of a so-called "ultra-linear" output circuit in which the output valves are used as tetrodes, with negative feedback applied non-linearly by connecting the screens to a tap on the primary of the output transformer. It is stated that the performance is audibly improved over that of triodes with similar degrees of negative feedback.

The present writers do not believe this claim. The circuitry which forms the basis of these American claims for "ultra-linearity" and higher efficiency has, in fact, been familiar in this country for several years, and the technique has been further developed and used in a commercially produced high-quality amplifier.[4, 5] It consists of the distribution of the load impedance between the electrodes of each output valve in order to obtain the optimum performance from that valve.

In its simplest form, and as used by Hafler and Keroes, the circuit arrangement is as shown in Fig. 1. The circuit is normal, except that the screen of the tetrode can be tapped on the output transformer primary winding, thus coupling it to the anode in any ratio, and rendering a section of the load impedance common to both electrodes. If the tap is affixed at point A, giving a coupling factor of unity, the stage behaves as a triode, its performance being determined by the dynamic characteristic of the screen and control grid, and if the tap is shifted to point B, the coupling factor is zero, and the stage behaves as a simple tetrode. If now the screen is tapped at intervals between point B and point A, there will be a progressive inclusion of the load impedance in the screen circuit and a progressive change from tetrode characteristics at B, to triode characteristics at A.

It is convenient to consider the stage as being a tetrode with negative feedback applied to the screen. It differs from a tetrode stage with feedback applied to the control grid, first in that the screen introduces a non-linear element in the feedback loop, and secondly, because as the degree of feedback is in-

[2] Hafler and Keroes: "An Ultra-linear Amplifier," *Audio Engineering*, November, 1951, pp. 15-17.
[3] Hafler and Keroes: "Ultra-linear Operation of the Williamson Amplifier." *Audio Engineering*, June, 1952, pp. 26-27.
[4] First introduced in 1945; see advertisement of the Acoustical Manufacturing Company in *Wireless World*, July, 1945, p. 10.
[5] Moir: "Review of British Amplifiers," *FM-TV*, October, 1951, pp. 30-32

creased, the permissible anode swing is decreased, due to anode current cut-off on the negative excursions of screen voltage, until finally the I_a-V_a curves become those of a triode. A more complete account of the behaviour of the circuit is given in the Appendix.

The curves of Fig. 2, which apply to a single valve, show the effect of changing the tapping point. The output at the point of overload, the relative gain and the output resistance decrease as the degree of feedback is increased, the output resistance decreasing very rapidly because it is dependent, not on the gain reduction, but on the amplification factor, which undergoes a large change.

The distortion at constant output, which is predominantly second harmonic, rises slowly at first until the point of overload is reached. Since the maximum power output is progressively reducing, the distortion curves for maximum output or a percentage of maximum output will show a progressive reduction from tetrode to triode operation.

In view of the increase in distortion, as shown in Fig. 2, it would appear that there is little to be gained by the use of this circuitry, since a simple tetrode, with feedback to the control grid, would give a similar reduction of output resistance, and this would be accompanied by a progressive reduction in distortion. This is indeed true in the case of a single valve.

When push-pull connection is considered we obtain a different state of affairs, because of the cancellation of second harmonic components, and we arrive at the curves shown in Fig. 3. The general shape of the curves is maintained under varying loads. With up to 30 per cent of the winding common to screen and anode the reduction in distortion is greater than the reduction in gain. This "something for nothing" is small, however, and can be lost or even reversed if there are appreciable departures from precise balance at any frequency.

It is, of course, not essential to have the screen tapped directly on the primary winding, and an auxiliary winding tightly coupled to the primary (ideally in the form of a bifilar winding) may be used. This has the advantage that the screen supply voltage may differ from that of the anode to give optimum operating conditions.

The "Acoustical" Circuit.—A further development of this circuit ("super-ultra-linear," perhaps?) used in the Acoustical "Q.U.A.D." amplifier and its predecessor, takes the common portion of the winding and inserts it in the cathode, giving the circuit of Fig. 4. As far as the anode and screen circuits are concerned, this arrangement is identical to that of Fig. 1 (neglecting winding resistance and leakage reactance). The only difference lies in the grid circuit, since that portion of the voltage appearing across the common winding is now applied in the grid circuit as overall negative feedback. It is, of course, feedback of the most desirable kind, since it is the most practical method of applying voltage feedback over a single stage without either throwing gain away wastefully or increasing the load on the previous valve.

Since the screen is now connected to a decoupled point, it follows that the designer is free to use different voltages for screen and anode if required, without the necessity of additional windings, with their attendant disadvantages. Further, the arrangement makes it possible to provide the optimum degree of smoothing for the anode and screen supplies. The grid resistor may be taken to the cathode end of the common winding if desired, with the result that the input resistance is increased, thus facilitating the design of the previous stage and reducing the value of the coupling capacitance necessary.

The use of all the electrodes in this way gives additional flexibility in design, so that the parameters of the output stage may be varied to suit the penultimate stage—a technique giving greater scope in arriving at a well-balanced ratio of stage distortions and hence an optimum final design. In the output stage of the Acoustical "Q.U.A.D." amplifier, using two KT66 valves, the values are so chosen that an output of 12

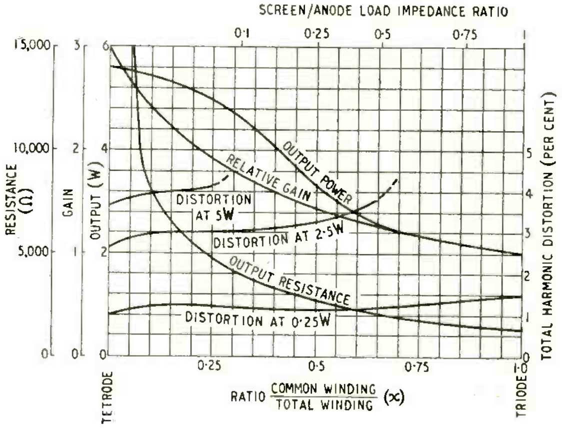
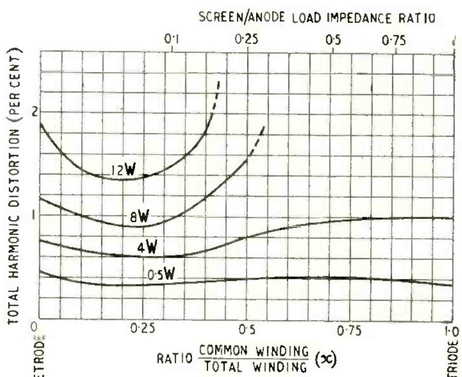
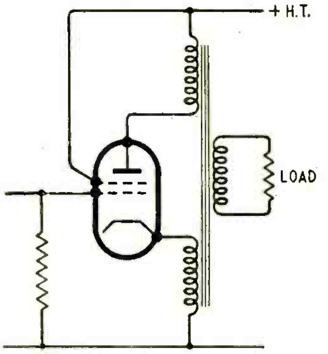


Fig. 2. Curves of output power, relative gain, output resistance and distortion for the circuit of Fig. 1. The distortion components are predominantly second and even harmonics.



Above: Fig. 3. Curves of distortion for a push-pull arrangement (predominantly third and odd harmonics).



Right: Fig. 4. Basic circuit used in the Acoustical Manufacturing Company's "Q.U.A.D." amplifier and its predecessor.

watts is obtained from a 320-V supply with a grid-to-grid input of 72 volts peak, the input resistance being 1 mehogm. The total harmonic distortion of the output stage alone is not more than 0.7 per cent, and the output resistance is approximately half the load resistance.

By comparison with the same valves used as triodes to obtain the same output, the following advantages are apparent:

(1) Distortion is less than half that of triode connection, due to the cathode and screen feedback.

(2) Efficiency is increased from 27 per cent to 36 per cent, resulting in the h.t. voltage being lower by about 100 V, thus simplifying reliability problems both in the amplifier itself and throughout the range of pre-amplifiers, tuners, etc., which may take their supply from it.

(3) Less smoothing is necessary for equivalent hum-levels.

Additional overall negative feedback can be applied to the complete amplifier, and with the ratios used in the above example, 8 db less feedback is required for a given level of distortion than with triodes. This assists in maintaining a good margin of stability and reduces the effect of overloading due to the presence of frequencies in the input which are outside the effective feedback range.

There remains the question of output resistance to be considered, about which there appears to be some confusion. This is probably due to the general use, as a measure of the efficacy of damping, of the load resistance/output resistance ratio, sometimes called the damping factor, the scale of which becomes virtually meaningless at high values. It appears to be common practice to aim at as high a value as possible, with presumably infinity (zero output resistance) as the ideal. An output resistance of zero is, of course, only an arbitrary figure, which has ultimately to be added to the speech coil resistance.

Independently of the output-stage circuitry, zero—or any reasonable value positive or negative—can be obtained by a mixture of negative voltage and positive current feedback. It should be pointed out, however, that the optimum value is dependent upon the loudspeaker and particularly the intended performance of its enclosure, so that the doctrine "the more damping the better," is not always sound.

Comparison of Output Circuits.—To summarize, Table I gives a comparison of the relative merits and demerits of various output circuits. It will be seen that there is little to choose between the performance of triodes and distributed-load tetrodes (especially the cathode-coupled variety), with the exception of efficiency, in which respect the tetrode circuits are superior to the triode.

In order to avoid misapprehension, it should be stated that a similar order of performance is obtainable from a conventional tetrode circuit, by the application of the appropriate degree of negative feedback, preferably in the form of multiple loops to ease the stability problems. The advantage of the distributed-load circuits is that, as a considerable amount of negative feedback is included in the output stage itself, the design of the remainder of the amplifier is simplified and the problems of stability and restriction of scope in design usually associated with large amounts of overall negative feedback are avoided.

Practical Difficulties.—So far we have only been considering the ideal case. In a practical transformer, however, the windings are not perfectly coupled, but are more loosely coupled by a complex network of leakage reactances formed by the distribution of leakage inductance and self-capacitance throughout the windings. This departure from the ideal may mean that, at high frequencies, the circuit is not at all as it would appear on paper, and the effective sense of the coupling may even be reversed, producing oscillation. In a less severe case, peaks and troughs in the frequency response characteristic may occur, accompanied by "ringing" and instability when the amplifier is excited by a transient.

These defects are serious, and can only be avoided by designing the output transformer carefully and by maintaining close control over its production, as even with transformers of the same nominal specification, wide variations in performance at high frequencies may occur due to minor variations in the quality and thickness of insulants, and in the positioning of windings.

The designer who has complete control over production can arrange that the materials and construction of the transformer do not depart from specification, and even if they should do so he has facilities to detect and correct the deviation at an early stage. He is therefore able to make use of circuitry of the type discussed, without the dangers which would attend its use in unskilled hands or where measurement facilities are absent. The advantages obtained have already been discussed.

The constructor with limited facilities cannot be too strongly advised to keep to proven circuits which are inherently trouble-free. In particular, he should

TABLE I

Parameter	Triode-connected tetrodes (Class A)	Tetrodes (Class A)	Tetrodes with load distributed between anode and screen (optimum value)	Tetrodes with load distributed between anode, screen and cathode (Q.U.A.D. arrangement)
Efficiency (per cent)	27	38	36	36
Relative power output	1	1.4	1.35	1.35
Relative distortion just below onset of grid current	1	2	1.5	0.5
Load resistance / Output resistance	2–4	0.05–0.1	0.5–1	2

keep to designs requiring the minimum number of coupled circuits in the output transformer, since the possibility of pitfalls is greatest in this component and increases rapidly with the number of windings when all these must be closely coupled.

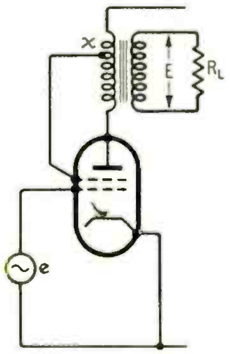
It will be appreciated from the foregoing that there are a large number of solutions to the problem of designing a first-class amplifier, and no one of these solutions can be called the best solution. Each has its advantages and disadvantages, and the individual designer must choose that which most nearly meets his needs. The "goodness" of an amplifier is not shown by its circuit diagram. Circuits have no inherent magic properties, but are merely the tools with which the designer seeks to achieve a certain result, and different designers—provided always that they have the same high standards in view—may achieve the same result by different means.

APPENDIX

Let

$$\mu = \frac{E_a}{E_g} = g_m R_a,\ m = \frac{E_s}{E_g}$$

$$\therefore \frac{E_a}{E_s} = \frac{\mu}{m}$$



x = fraction of output fed to screen.

E = output voltage in load R_L, produced by grid voltage e.

Neglecting the effect of screen current in the load, which is normally less than 10 per cent,

Current in load due to e

$$= e\,\frac{\mu}{R_a + R_L}$$

Current in load due to xE $= -\,x\mathrm{E}\,\dfrac{\mu}{m\,(R_a + R_L)}$

$$\therefore \text{Voltage in load} = E = \left\{ e\,\frac{\mu}{R_a + R_L} - xE\,\frac{\mu}{m(R_a + R_L)} \right\} R_L$$

$$\therefore e\,\frac{\mu R_L}{R_a} = E\left(1 + x\,\frac{\mu R_L}{m R_a}\right)$$

$$\therefore \quad \boxed{\text{Gain} = \frac{E}{e} = \frac{\dfrac{\mu R_L}{R_a + R_L}}{1 + x\,\dfrac{\mu}{m}\,\dfrac{R_L}{R_a + R_L}}}$$

When $x = 0$,

$$\frac{E}{e} = \frac{\mu R_L}{R_a + R_L}$$

when $x = 1$,

$$\frac{E}{e} = \frac{\dfrac{\mu R_L}{R_a + R_L}}{1 + \dfrac{\mu}{m}\left(\dfrac{R_L}{R_a + R_L}\right)}$$

Output resistance.

Let $R_L \to \infty$, then $\dfrac{R_L}{R_a + R_L} \to 1$

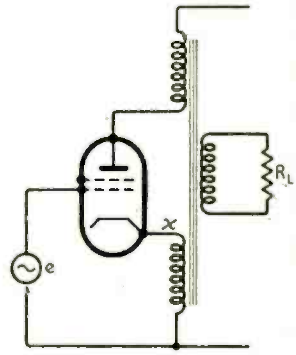
Then gain $(x = 0) = \mu$

$$\text{Gain } (x) = \frac{\mu}{1 + x\,\dfrac{\mu}{m}} = \mu'$$

$$\text{Output resistance } (x = 0) = \frac{\mu}{g_m}$$

$$\boxed{\text{Output resistance} = \frac{\mu'}{g_m} = \frac{\mu}{g_m\left(1 + x\,\dfrac{\mu}{m}\right)}}$$

"Q.U.A.D." case



Gain is given by

$$\frac{\mu\,\dfrac{R_L}{R_a + R_L}}{1 + x\,\dfrac{\mu}{m}\,\dfrac{R_L}{R_a + R_L}} = A$$

$$\text{Gain with feedback} = \frac{A}{1 + xA}$$

$$\boxed{\text{Gain} = \frac{\dfrac{\mu\,\dfrac{R_L}{R_a + R_L}}{1 + x\,\dfrac{\mu}{m}\,\dfrac{R_L}{R_a + R_L}}}{1 + x\,\dfrac{\mu\,\dfrac{R_L}{R_a + R_L}}{1 + x\,\dfrac{\mu}{m}\,\dfrac{R_L}{R_a + R_L}}}}$$

$$\begin{matrix}\text{Output resistance} \\ \text{with feedback}\end{matrix} = \frac{\begin{matrix}\text{Output resistance} \\ \text{without feedback}\end{matrix}}{1 + x\mu}$$

$$\boxed{\text{Output resistance} = \frac{\dfrac{\mu}{g_m\left(1 + x\,\dfrac{\mu}{m}\right)}}{1 + x\,\dfrac{\mu}{1 + x\,\dfrac{\mu}{m}}}}$$

RADIO PROPAGATION WARNINGS

New WWV Forecasts.—In addition to giving announcements of *prevailing* radio propagation conditions over the North Atlantic, the service broadcast by WWV—the N.B.S. standard frequency station, Washington—now gives a *forecast* of communication conditions for the next 12 hours.

These radio disturbance forecasts, prepared four times a day, are transmitted in morse twice each hour—19½ and 49½ minutes past the hour—on 2.5, 5, 10, 15, 20 and 25 Mc/s. The letters "N," "U" and "W" continue to be used signifying normal, unsettled and disturbed prevailing conditions, respectively. The letter is now followed by a digit indicating the expected propagation conditions for the next twelve hours. The significance of these numbers is shown in the table. If, for example, propagation conditions are normal but are expected to be only "fair to poor" within the next twelve hours, the forecast would be broadcast as N4 in morse code, repeated five times, i.e. "N4, N4, N4, N4, N4."

Digit	Propagation condition
1	Impossible
2	Very poor
3	Poor
4	Fair to poor
5	Fair
6	Fair to good
7	Good
8	Very good
9	Excellent

WORLD OF WIRELESS

Training Technicians ✦ V.H.F. Broadcasting Plans ✦ More Purchase Tax ✦ Radio Exports

Technical Training Scheme

MEANS of providing more technically trained men in the industry have been constantly before the R.I.C.'s Technical Training Committee and the Radar Sub-Committee of Lord Hankey's Technical Personnel Committee. As a result full-time three-year technical training courses have now been organized by the Ministry of Education and will start in September at five centres in London, the Midlands and the North.

The objective is to provide students so well trained in the theory and practice of electronics that they will be able, on completion of the course, to take their places at once as assistants to qualified research and development engineers. The entry age will be between 16 and 17.

While the appropriate examinations of the City and Guilds and Brit.I.R.E. will be taken during the course, the syllabus, it is understood, will be wider in scope than is required by those bodies and will reflect to some extent the needs of the region. Special attention is to be paid to industrial electronic applications. In most cases successful completion of the course will carry a college diploma.

Details of the courses are obtainable from the principals of the following colleges participating in the scheme:—Northern Polytechnic, Holloway Road, London, N.7; Norwood Technical College, Knight's Hill, West Norwood, London, S.E.27; E.M.I. Institutes, Ltd., Pembridge Square, London, W.2; Coventry Technical College, The Butts, Coventry; and Bolton Technical College, Manchester Road, Bolton.

European V.H.F. Broadcasting

PLANS for the assignment of frequencies in the v.h.f. band to European broadcasting stations—both sound and television—were approved by twenty-one countries at the recent meeting in Stockholm. Nine eastern European countries and Portugal were not signatories although they attended the Conference, which was convened in Sweden at the suggestion of the Swedish Telegraph Administration.

At Atlantic City (1947) three bands between 30 and 300 Mc/s were allocated to broadcasting (41-68, 87.5-100 and 174-216) and plans were produced at Stockholm for each of these. Bands 1 and 3 were allotted to television and Band 2 to sound broadcasting. So far as the first band is concerned, the same five channels, each 5 Mc/s wide, as used by the B.B.C., have been decided upon. Provision is made in the plan for some 700 European television stations in these two bands.

Plans providing for both a.m. and f.m. stations have been drawn up for the second band, which allows for some 2,000 stations in Europe.

P.T. on Speakers

UNDER an Order* which came into operation on 4th August, loudspeakers and domestic sound and television relay apparatus are now chargeable with purchase tax at the same rate ($66\frac{2}{3}$ per cent) as radio broadcast receivers.

Although the Order does not differentiate between chassis and cabinet-fitted loudspeakers, it is understood that *any* loudspeaker which can be used with a domestic, car or portable receiver is chargeable.

As this change has been introduced since some of the advertisements in this issue were prepared, we are asked to state that the prices quoted in them may, therefore, be incorrect.

* Purchase Tax (No. 2) Order, 1952.

Televising the Ionosphere

SIR EDWARD APPLETON, and particularly his work on the ionosphere, forms the subject of a 40-minute film which has been produced especially for television and will be seen by viewers on 30th August. Sir Edward, who is now vice-chancellor of Edinburgh University and was for some years secretary (administrative head) of the D.S.I.R., started his research into the existence of the ionosphere whilst in the Cavendish Laboratory, Cambridge, where, from 1919 to 1924, he taught physics under Sir J. J. Thomson. The film includes sequences taken at the radio astronomy experimental station at Jodrell Bank, Cheshire, and at the D.S.I.R. Radio Research Station, Slough, Bucks.

Exporting Flight Simulators

AN order from the Canadian Government for flight simulators for Sabre jet aircraft, amounting to nearly $3,000,000, has been received by Redifon. These flight simulators, which have already been supplied to train crews of the B.O.A.C. Stratocruisers (see *W.W.*, April 1951) produce by electronic means in a grounded replica of a flight deck the various conditions—both normal and abnormal—experienced in the air. The use of flight simulators results in a more thorough training, as with this equipment crews can undertake more hazardous operations.

British Exports

THE total value of the British radio industry's exports for the first six months of the year was £12,169,000—nearly 20 per cent higher than in 1951 despite the fact that June's exports were the lowest since February, 1951. Owing to the introduction of import restrictions in some markets, there was a fall during the second quarter in the exports of domestic receivers, but this was partly made up by the export of components and associated products and capital equipment.

R.I.C. Premiums

PRIZES awarded under the Radio Industry Council's scheme for encouraging technical writing (see *Wireless World*, January issue, p.3) are to be known as R.I.C. Premiums. Up to six of these, of twenty-five guineas each, are to be awarded annually to non-professional authors of articles. A leaflet explaining the scheme has now been issued by the R.I.C., and copies are available at the National Radio Exhibition. To coincide with the Exhibition, an interim award of one 1952 premium is to be made; it is to J. R. Acton for his article "The Single-pulse Dekatron" published in *Electronic Engineering* for February.

Club Directory

Secretaries of many Radio Societies in the United Kingdom keep us informed of Club activities, and therefore changes of addresses, etc., but it would reduce the possibility of error and help us considerably in the compilation of a new Directory of Clubs, which we propose publishing shortly, if secretaries would kindly send us, by the 20th September, the following details:—full name of Society, call sign, whether affiliated to the R.S.G.B., place and frequency of meetings, and name and address of secretary.

Amateur Courses

READERS in metropolitan Essex may like to know that amateur radio evening courses have again been organized by the East London R.S.G.B. group in collaboration with the Essex County Council. They are to be held in the Ilford Literary Institute (High School for Girls), Cranbrook Road, Ilford, from September. The eight-month course of lectures in preparation for taking the Radio Amateurs' Examination will be given on Wednesdays; there is a six-month refresher course for amateurs on Tuesdays, while on Mondays there is a course covering morse and codes of practice. The fee for each course is 10s. Enrolment is from 8th to 12th September.

PERSONALITIES

E. D. Hart, M.A., A.Inst.P., A.M.I.E.E., who recently joined the Equipment Division of Mullards as head of the Technical Department, was for many years with Marconi Instruments and was Technical Editor of *Marconi Instrumentation*. In his new post he will be responsible for technical publications and other technical commercial activities. He is chairman of the Joint Advisory Committee on Radio Communication and Radar Measuring Instruments recently formed by R.C.E.E.A., R.E.C.M.F. and S.I.M.A.

R. R. C. Rankin, O.B.E., A.M.I.E.E., the new technical manager of both Mullard and Mullard Equipment, is responsible for co-ordinating engineering on all types of electronic equipment (both telecommunication and industrial) produced by the companies. He was on the staff of the S.H.A.E.F. Chief Signal Officer at the end of the war, after which he was with Standard Telephones & Cables.

T. E. Goldup, one of the new vice-presidents of the I.E.E., has been a member of the Institution since 1922 and was chairman of the Radio Section for 1943/44. He was appointed to the Radio Research Board of the N.P.L. in 1950, is a Governor of the Ministry of Supply's School of Electronics, Malvern, and a member of a number of advisory bodies. He joined the Mullard organization, of which he is now a director, in 1923.

T. E. GOLDUP, M.I.E.E.

Dr. E. C. S. Megaw, M.B.E., the new chairman of the Radio Section of the I.E.E., has been in the Royal Naval Scientific Service since 1946, prior to which he was for sixteen years in the G.E.C. Research Laboratories. Dr. Megaw, who received his D.Sc. from Queen's University, Belfast, is director of physical research at the Admiralty.

Dr. E. C. S. MEGAW, M.B.E.

W. E. Miller, M.A. (Cantab.), the president-elect of the British Institution of Radio Engineers for 1952/53, was one of the founder members of the Institute of Wireless Technology (1932)—now the Brit. I.R.E. On leaving Cambridge University in 1924, he went to the Cambridge Instrument Co. for a short while before joining the editorial staff of *Wireless & Electrical Trader*, of which he was technical editor (1926-40) and is now editor. He is the author of a number of radio books, including "Radio Circuits" and "Television Explained."

H. J. Finden, M.I.E.E., who is responsible for the development and design of electronic instruments in the Plessey Co, is to read a paper on "Developments in Frequency Synthesis" at the conference on instruments and measurements to be held in Stockholm from 22nd to 25th September.

D. Thomson, whose lectures and demonstrations of L.P. recording are well known to London B.S.R.A. members, has now taken an appointment with Duwe (Wholesale), Ltd., in Manchester, where he will continue to keep in touch with the Association through the newly formed North West Centre.

P. V. Hunter, C.B.E., Hon. M.I.E.E., has resigned the deputy-chairmanship of B.I. Callender's Cables but will continue on the boards of several of the subsidiary companies in the group, which includes British Telecommunications Research, T.C.C. and United Insulator Co.

OUR AUTHORS

S. W. Amos, co-author of the article "F.M. Feeder Unit" in this issue, graduated from Birmingham University with a B.Sc. (Hons.) degree in physics in 1936 and, after four years as a teacher, joined the B.B.C. as a maintenance engineer. In 1943 he was appointed lecturer at the B.B.C. Engineering Training School and then transferred to the technical instruction section dealing first with a.f. subjects and latterly with television. He is, of course, a frequent contributor to *Wireless World* and co-author of the book "Radio Receivers and Transmitters" and the B.B.C. Engineering Training Manual "Sound Recording and Reproduction" which we recently published.

G. G. Johnstone, who, with S. W. Amos, contributes the article on page 334, graduated from King's College, London University, as B.Sc. in 1945. He was in the Technical Publications Section of the Ministry of Aircraft Production, dealing mainly with telegraphic equipment, prior to joining the B.B.C. in 1948 as an engineer in the Outside Broadcasting section. He recently entered the Engineering Training Department as instruction writer and has been engaged on automatic monitors, unattended transmitters and television transmitters.

R. T. Lovelock, contributor of the article on noise limiters for television sound in this issue, transferred from the G.E.C. Telephone Works to the company's radio laboratories in 1932 and assumed responsibility for the design and maintenance of measuring equipment. Since 1936 he has been responsible for both measuring gear and the reliability testing of components and materials. Mr. Lovelock is also concerned with the development of valve application circuits. He has represented the G.E.C. on several R.I. Council technical committees and B.S.I. committees.

W. E. MILLER, M.A. (Cantab.).
(See centre column.)

A. H. B. Walker, who contributes the article "Variable H.T. Power Pack" in this issue, joined the Rectifier Engineering Dept., of Westinghouse, after graduating B.Sc. in 1934. Four years later he transferred to the company's research laboratory and was associated with the development of the "Westat" constant potential rectifier and the "Stabilistor" a.c. voltage stabilizer which he described, respectively, in our April 1940 and November 1944 issues. He has also been concerned with the development of copper oxide, selenium and germanium rectifiers. Since 1949 he has been deputy-chief of the Westinghouse Research Laboratory.

P. J. Walker, who, with D. T. N. Williamson, contributes the article "Amplifiers and Superlatives" in this issue, has been responsible for most of the design and development of audio equipment made by the Acoustical Manufacturing Co. (Huntingdon), which he founded in 1936. He is well known as a lecturer on loudspeakers and high-quality reproduction in the home.

IN BRIEF

Television licences in the United Kingdom increased during the first six months of this year by 357,350, bringing the total at the end of June to 1,538,550. The total number of receiving licences at 30th June—including television and 145,000 for receivers fitted in cars—was 12,748,000.

I.E.E. Council.—Among the new members of the Council of the I.E.E. who take office on 30th September are Dr. C. Dannatt (director of research and education, Metropolitan-Vickers), O. W. Humphreys (director, G.E.C. Research Laboratories), A. H. Mumford (asst. engineer-in-chief G.P.O.), Prof. M. G. Say (professor of electrical engineering, Heriot-Watt College, Edinburgh) and H. R. L. Lamont (senior lecturer in electronics, Dept. of Electrical Engineering, Royal Technical College, Glasgow).

I.E.E. Radio Section.—The following have been elected to fill the vacancies which occur on the Radio Section Committee of the I.E.E. on 30th September: Dr. E. C. S. Megaw (director of physical research, Admiralty) chairman; C. W. Oatley (Engineering Laboratory, Cambridge University) vice-chairman; N. R. Bligh (G.E.C. Research Laboratories), J. H. H. Merriman (G.P.O. Radio Planning Branch), Brig. E. J. H. Moppett (Pye Telecommunications), Dr. A. R. A. Rendall (B.B.C. Designs Dept.), and Dr. J. A. Saxton (Radio Division, N.P.L.) ordinary members. To fill the vacancy caused by the election of C. W. Oatley as vice-chairman before the completion of his term of office as an ordinary member of the Committee, G. G. Macfarlane (T.R.E. Malvern), has been co-opted.

German Patents.—We have been advised by the City Librarian, Leeds, that German patent specifications are again being received in the Library of Commerce and Technology, and the first consignment, Nos. 800,001-815,938, arrived in June. Although those issued during the war (678,144-800,000) are not available, there is an arrangement with the Patent Office, London, whereby photostat copies of individual patents can be obtained. The practice of lending specifications to libraries and industrial organizations outside the City is being continued.

Prospectuses covering the full-time and part-time courses at the Norwood Technical College, Knight's Hill, London, S.E.27, and the S.E. London Technical College, Lewisham Way, London, S.E.4, include details of courses in telecommunication engineering, radio and television servicing, radar and u.h.f. techniques.

Guided Missiles.—All the main information now available on the development of guided weapons in Britain, the United States, Germany, the U.S.S.R. and elsewhere, is presented factually in "Development of the Guided Missile," by Kenneth W. Gatland, recently published for *Flight* by Iliffe & Sons (price 10s 6d).

"Television Oscilloscope."—An error occurred in the circuit diagram of this instrument (Fig. 5, p. 280 of the July issue). The screen feed resistor R_{16} was shown as 150 kΩ instead of 40 kΩ.

R.I.C. SYMBOL—A winged lion rampant surmounts the globe on the six-colour poster advertising the Earls Court Exhibition.

High Power from Kirk o'Shotts.—The high-power television transmitter at Kirk o'Shotts, which was supplied by Emitron Television and is capable of delivering a peak power of 75 kW into the aerial, was brought into service on 17th August. It replaces the low-power standby transmitter which has been in use temporarily since the Scottish station was opened in May.

Electro-physiologists and others concerned with the recording of low-frequency phenomena are invited to the meeting of the Electro-Physiological Technologists' Association at Hurstwood Park Hospital, Haywards Heath, Sussex, on 20th September at 10.30 a.m. when a number of papers and demonstrations of special interest will be given. Readers are asked to write to the Secretary, G. Johnson, at the above address, intimating their intention of attending.

B.S.R.A. Manchester.—A lecture-demonstration on tape recorders will be given by Salford Electrical Instruments to members of the Manchester Centre of the B.S.R.A. at the Engineers' Club, Albert Square, Manchester, on 22nd September at 7.30.

B.S.R.A. Portsmouth.—At the meeting of the Portsmouth Centre of the B.S.R.A. at 7.30 on September 11th in the Guildhall Central Library, G. H. Hornsby and P. O. Sharpe will speak on "The Marriage of L.P. with *ffrr*."

Amateur Exhibition.—The sixth annual amateur radio exhibition, organized by the R.S.G.B., will be opened at the Royal Hotel, Woburn Place, London, W.C.1, by Sir Ian Fraser, C.B.E., M.P.—a past-president of the Society—at 12 noon on 26th November. The show will remain open until 29th November.

Glasgow Show.—Scottish retailers are staging a radio and television exhibition in the St. Andrew's Hall, Glasgow, from 22nd to 27th September.

Amateur Television.—Six members of the Television Society have undertaken to design and construct the various units for the Society's 10-W television transmitter which will operate on B.B.C. standards on 427 Mc/s (vision) and 423.5 Mc/s (sound). It is expected to be completed in October.

Institute of Physics.—The 32nd annual report of the Institute for 1951 records an increase of 222 in the membership, making the total 4,080. At the annual general meeting O. W. Humphreys (director, G. E. C. Research Laboratories) was elected a vice-president and Dr. S. Whitehead (director, British Electrical and Allied Industries Research Assoc.) honorary treasurer.

Sponsored Television.—Associated Broadcasting Development Company is the title adopted for the new company recently formed to promote sponsored television in this country. The directors include Sir Alexander Aikman (chairman of E.M.I.), Norman Collins (chairman of High-Definition Films), Sir Robert Renwick (president, R.E.C.M.F.) and C. O. Stanley (chairman of Pye).

Pye's technical director, B. J. Edwards, and export director, P. M. Threlfall, recently flew to Bangkok, Siam, to supervise a demonstration of Pye television transmitting and receiving equipment which had been flown out a few days earlier. It was the first television demonstration in the country and aroused great enthusiasm.

R.F. Heating.—Parties of up to 30 senior engineering students from technical colleges and research establishments are invited by Wild-Barfield Electric Furnaces to tour the production shop, metallurgical and chemical laboratories and the furnace development section of their works at Watford. Particulars of the tours, which will be conducted on weekday afternoons from 1st September to 31st May, are obtainable from Elecfurn Works, Watford By-Pass, Watford, Herts.

Underwater Television.—Rees Mace Marine is contemplating offering a complete Pye underwater television installation, similar to that recently installed on H.M.S. *Reclaim*, for hire to ship owners, harbour boards, salvage and insurance companies and has circularized over sixty of these organizations in this country to ascertain their reactions.

NEW ADDRESSES

Decca.—The telephone numbers of the Decca Companies at 1-3, Brixton Road, London, S.W.9, have been changed from Reliance 3311 and 4211 to Reliance 8111.

Ediswan.—The Birmingham Office of Edison Swan Electric Co. is now at Swan House, 10, Hospital Street, Birmingham, 19. (Tel.: Central 6411/2.)

Addison Electric Co. has moved from 163, Holland Park Avenue, London, W.11, to Bosworth Road, London, W.10 (Tel.: Ladbroke 4280).

Pennine Amplifiers' new address is Page Street Works, Back Page Street, Huddersfield, Yorks. (Tel.: Huddersfield 5145).

Industrial Electronics, manufacturing and consulting engineers of 99, Gray's Inn Road, London, W.C.1 (Tel.: Holborn 9873/4), have opened a factory at Magnet Works, Derby Road, East Sheen, London, S.W.14. The London Office will remain at Gray's Inn Road.

INFORMATION THEORY

By "CATHODE RAY"

It is a very inconvenient habit of kittens (Alice had once made the remark) that, whatever you say to them, they *always* purr, 'If they would only purr for "yes" and mew for "no," or any rule of that sort,' she had said, 'so that one could keep up a conversation! But how *can* you talk with a person if they always say the same thing?' ("Through the Looking Glass")

FOR some years the higher-brow journals have been carrying learned papers on the Theory of Information. This month a Symposium on it is being held at the I.E.E., and it may possibly even be mentioned in newspapers. If so, I can hardly wait to see what they make of it; for it tends to bear one swiftly out of one's depth in profound philosophical waters. But of course all new ideas seem strange and difficult at first. The important thing is that information theory is stimulating progress on a great number of different fronts at the same time. One of them is our own subject of communications; in fact, information theory grew out of communication theory. Now it has got itself mixed up with electronic computors, mathematics, the theory of games, the workings of the brain and nerves, the psychology of the senses, the study of languages, codes and ciphers, thermodynamics, noise, time, the quantum theory, radar, prophecy, and goodness knows what. I even saw an article on the electrical control of dangerous machinery and processes which was based largely on it. Though we may not be interested in all of these things, scientifically inclined readers will no doubt agree that it is time to have at least a rough idea of what this ubiquitous theory of information is.

Measuring Information

In the first place, "theory" mustn't be taken to mean some isolated hypothesis, such as an attempt to explain why the sun doesn't cool down quicker or why the favourite came in last. It means the whole scientific study of "information." And what does "information" mean? In a broad sense it can be described as something which, when received, increases what one knows. To be able to study a thing scientifically, however, one has to be able to measure it. But how can "information" possibly be a subject for such precise treatment as mathematics? How, for instance, could one calculate the numerical ratio between two such pieces of information as "twice two is four" and "Queen Anne is dead"?

Non-scientific people have the same sort of reaction when they are told that energy is a mathematically calculable quantity. "How," they ask, "can you compare the quantities of energy expended in digging a trench and composing a symphony?" We remember[1] that energy, like information, is a thing that crops up in a variety of widely different forms, yet all of them can be precisely evaluated in joules. But to make this possible it was necessary to throw out some of the non-scientific associations of the word. So it is with information. The main thing to be thrown out is what most people find most interesting—its meaning. That may seem rather a drastic cut, but clearly it would be hopeless to measure information scientifically if its meaning were taken into account.

So "information," from now on, will exclude meaning. It is—or should be—a matter of no concern at all to the telegraphist in his official capacity if the telegram he is handling happens to be one arranging for his wife to run away with someone else. His job is not to pay attention to the meaning, but only to see that transmission is unaccompanied by any additions, deletions, or modifications.

Selections from a Code

A great many different systems have been evolved for expressing information. Sometimes each symbol is made to express a whole idea, as in the ancient Egyptian hieroglyphics, which were little pictures, rather like the graphical symbols used in circuit diagrams. That may be all very well within a restricted field such as radio circuit diagrams but a typewriter having a separate symbol for every word in the modern dictionary would be really too much. A logical method would be that attempted in shorthand—a symbol for each vocal sound. Most written languages—and English perhaps most of all—depart from this ideal. But the essential fact to note is that any sort of intelligible "signals," whether vocal, visual, written letters or numbers, code symbols, winks and nods, or what have you, *are selections from a known and agreed list of possibles.* In written English, for example, there is a list of 26 letters. Each letter written is a fresh choice. Seeing then that information is a selection or choice, the most suitable unit of measurement is the simplest possible choice—between two alternatives: yes and no, on and off, heads and tails, 1 and 0. This unit is called the binary digit, now commonly abbreviated to "bit."

I discussed the "bit" some time ago[2] with particular reference to numbers, explaining how the binary system of numbers, though not in general use, has advantages in telecommunication and computors because two opposite alternatives are so much easier to distinguish from one another than the ten symbols (0 to 9) in the

[1] "Energy," *Wireless World*, January, 1952.

[2] "Tens or Twos?" *Wireless World*, Sept., 1951.

common decimal scale, especially when there is severe noise or interference. We also saw how numbers in the decimal or any other scale can be "translated" into bits. The first bit in a series distinguishes between two alternatives, represented by the first parting of the ways starting from the left in Fig. 1. The second bit begins from the choice expressed by the first, so the total result of the two is a choice of 1 from among 2^2 or 4 possibles. The third bit narrows the selection to 1 in 2^3 or 8; the fourth, 2^4 or 16; the fifth, 2^5 or 32; and so on. Looked at the other way round, a choice of 1 from a list of 32 possibles is equal to 5 bits, because any one of 32 can be selected by a series of 5 yes-or-no choices. The mathematical way of saying this is that 5 is the logarithm of 32 to base 2. The principle holds good for all numbers, and can be written:

$$b = \log_2 n$$

where b is the number of bits equal to a choice of one from n alternatives. So a single digit in the decimal scale (it might well be called a dit !) is $\log_2 10$, or about $3\frac{1}{3}$ bits.

The same principle can be applied to letters, hieroglyphics, or in fact any "information." This is evidently what Alice had in mind when she pointed out that the two alternative signals in her kitten's repertoire were sufficient, if used according to an agreed code, for carrying on an intelligent conversation. That is indeed the foundation of information theory.

How Many Bits ?

An ordinary telegraph is limited to saying "yes" or "no," for at any given moment there are only two alternatives—signal or no signal. So to send information expressed in words it is first necessary to reduce it to these terms. Since information in English is drawn from a list of 26 alternatives, there must be on the average more than one binary digit per letter.

Fig. 1. *One binary digit (or "bit") is the amount of information given by the selection of one from among two. This is represented by the two alternatives branching away from A. The diagram carries the process as far as 5 bits, which is the amount of information given by a selection of one from among $2^5=32$. For example, item 14 out of the 32 could be selected by the following series of five up-or-down switching signals—up, down, down, up, down.*

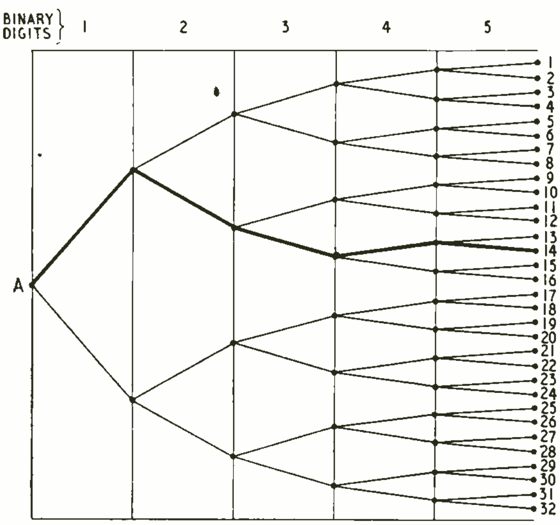


Fig. 1, or the formula just given, shows that 1 in 26 is between 4 and 5 bits. In practice, of course, more than 26 characters are needed, as there are the numerals and punctuation marks and a spacing signal between words, but the same code can be used for both letters and figures if there are two extra spacing signals for changing over from one list to the other. And since one can't have fractions of a bit, the smallest practical number of bits per letter or figure, if all are made the same length, is five, which allows 32 combinations. This is exactly what is done in the Baudot code, Fig. 2. A word of five letters, plus a space, is signalled by $(5+1)5=30$ currents or no-currents; i.e., bits. In the same way one can reckon the information content of any word, sentence, or message.

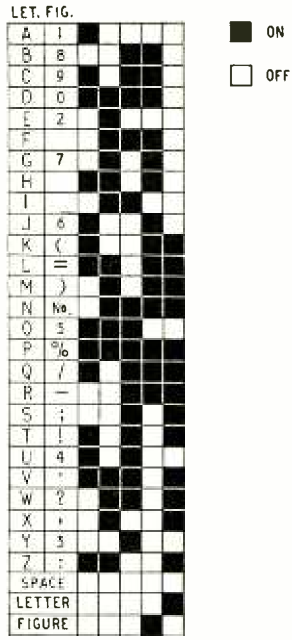


Fig. 2. *The Baudot telegraph code, shown here, is an example of how a series of 5 binary digits can indicate any one from up to 32 letters (or other signs).*

Communication engineers are interested in information theory because they want to make sure that the available channels—telegraph or telephone lines, radio links, etc.—are being used as efficiently as they could be; that is to say, are conveying information at the greatest practicable rate. As the bit is the unit of information, the logical unit for rate of communication, or capacity of a channel, is the bit per second, which I am going to abbreviate to b/s. As we have seen, it is really a measure of the rate at which choices are indicated. In simple line telegraphy a choice is indicated electrically by turning a current on or off; in telephony, by varying its strength in a complicated way; in radio, by varying the amplitude (a.m.) or frequency (f.m.) of a high-frequency a.c. In no case can a series of choices be indicated by an unvarying current, whether d.c. or a.c.

The simplest case would be a system in which a pulse of current stood for one of the choices (1) in a binary scale, and no current for the other (0). On the average, assuming there were no special conditions making either of these two symbols more likely to occur than the other, half the bits would be signalled by current and half by no current, so there would be half as many pulses of current as bits. In other words, the signalling rate in b/s would be twice the average number of current pulses per second.

The pulse frequency would be greatest when the two binary signals occurred alternately, as in Fig. 3. But of course if this condition were permanent there would be no information—a continuous extension of Fig. 3 could be generated locally at the receiving end and the telegraph line wouldn't be needed ! With real signals, the pulse frequency might for a moment be as high as this maximum; at other times an unusually long succession of symbols of one kind might bring it down close to zero. The frequency would fluctuate randomly between these two limits—zero and half the bit frequency. In short, *a band of frequency is required*, and its width is proportional to the rate of information conveyed. This is roughly what is known as the Hartley Law, from an important paper by R. V. L. Hartley, of U.S.A., published in 1928. In our binary pulse telegraph, then, a bandwidth of *p* pulses per second is required for a signalling speed of 2*p* bits per second.

In radio (a.m.) it comes to the same thing—the only difference is that the starting point is shifted from zero to some high frequency—the carrier-wave frequency. That is, with the single sideband system. In the usual double sideband system used for broadcasting the frequency band is duplicated, but that is merely for convenience, to simplify the equipment. In f.m. radio, instead of the amplitude the frequency of the carrier wave is varied, and the extent of the variation does not depend on the frequency of signalling. So at first it looked as if the Hartley Law could be got around by making the frequency variation smaller than the modulation frequency. But the mathematicians completely punctured this idea by proving that the bandwidth in f.m. must actually be greater than in a.m., however small the frequency deviation.

If one were to use sharp-cornered pulses as in Fig. 3, the maximum frequency in sine-wave *cycles* per second would be many times greater than the pulse frequency, because of all the harmonics needed to build out the spiv shoulders. But this is a pure luxury; the signals can still be read after they have been considerably rounded off, say by passing them through a low-pass filter. There is a limit to this process, however. A simple way of looking at it is to say that the limit is reached when all the harmonics of the highest pulse frequency have been removed, leaving only the fundamental. Then *pulses* per second in our previous finding become *cycles* per second, and it reduces to the conclusion that a bandwidth of *f* c/s can pass signals at 2*f* b/s.

Although this result has been arrived at by reasoning that is far from what the mathematicians call rigorous, it is just about right according to the official findings until quite lately. It is in any case a good rough rule. To follow recent developments, however, we shall have to consider the meaning of information more closely.

It is very much bound up with codes. The Baudot illustrates the "bit" idea very nicely, but it was invented for a particular type of telegraph which provided accurate timing of the pulses, and is not convenient for general purposes. What about the Morse code? It can be signalled as a 3-symbol or ternary code—dot, dash, and space—but more often is a binary code in which a dot is regarded as a single "on" and a dash as a succession of three "ons" (Fig. 5). With one "off" between dots and dashes and three "offs" between letters, the number of on-or-off elements per letter varies from four (for E) to sixteen (for J and similar letters), the average being $11\frac{1}{4}$. The number per figure is considerably greater. Each element is potentially a bit, but would it therefore be fair to say that the information was greater by Morse than by Baudot? Surely one would say that Morse was occupying more channel capacity to send the same real information. You would not consider you had received a ton of timber just because 5 cwt had been loaded so badly that it filled a one-ton lorry.

So it is important to distinguish between channel capacity and actual rate of information. If information at 40 b/s is bulked out to occupy a channel with a capacity of 100 b/s, one could say that the efficiency of coding was 40 per cent. It looks as if the efficiency of the Morse code, relative to Baudot, is $5/11\frac{1}{4} = 44.5$ per cent. But this is hardly being fair to Morse, who, to do him justice, though he had probably never heard of information theory, allowed for a most important element in it which we must now consider.

Improbable Bomb Story

The basis of measuring information is really improbability. The more probable a signal, the less information it contains. This may not be particularly obvious at first, due perhaps to the difficulty of thinking of words or other signals apart from their meaning. If so, perhaps the following example will get round it. Suppose a signal were to be used to convey a certain piece of information: the whereabouts of an unexploded bomb on a map divided into squares. If the map were divided into two squares, say A and B, the probability of either being signalled would (in the absence of any other information) be exactly 1 in 2—a fairly high degree of probability. But the information conveyed would be small—it would do no more than direct attention to one half of the whole map. If the map were divided into 26 equal-sized squares lettered A to Z, the probability of any letter being called would be only 1 in 26—less than 4 per cent, compared with 50 per cent in the first case—and the information would be greater. The chance of any particular square in a 1,024-square map being called would be less than 0.1 per cent, and the information would be greater than in either of the previous cases. It would not, however, be 512 times greater than in the two-square signal. By using the Fig. 1 technique, successively halving each area of the map, any one out of 1,024 ($=2^{10}$) squares could be pointed out by a 10-bit signal.

Fig. 3. *The maximum current frequency of binary signals (i.e., current on or off) occurs when all the odd signals are of one kind and all the even signals of the other. An unending sequence of this kind has zero bandwidth and conveys no information.*

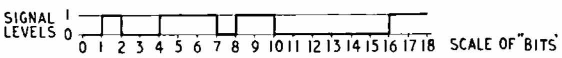


Fig. 4. *An actual signalling sequence is irregular and may contain any frequency from zero to maximum—it occupies a definite bandwidth.*

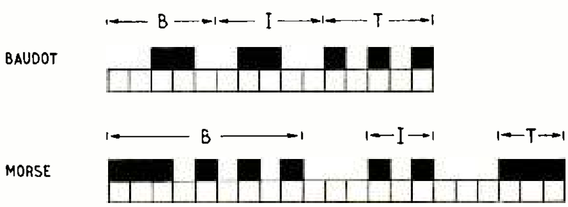


Fig. 5. *Comparative numbers of signal elements (potential "bits") needed in Baudot and Morse codes. To send at the same word speed by Morse would occupy more bandwidth.*

Imagine now that one of the 1,024 squares occupied half the map, the other half being divided equally into the remaining 1,023. A signal that indicated the big square would convey much less information than one disclosing the identity of one of the tiny squares. In fact it couldn't make any difference to the amount of information how many squares the other half was divided into; it would be the same as if there were only a simple choice between two halves, namely 1 bit. Our formula $b=\log_2 n$ is evidently untrue if n means the *number* of alternatives, unless they all happen to be equally probable. The probability of half the map was 1 in 2, or $\frac{1}{2}$, which can be regarded as an *im*probability of 2. If we simply make n mean the improbability, instead of the number of alternatives, the limitation of the formula is removed. The information content of 1 out of a list of 32 equally probable letters is, as we saw, 5 bits; and it would make no difference to this if the other 31 letters were all the same, so that the choice really lay between only two letters, one having an improbability of 32 and the other 32/31.

When the letters in a sufficiently large sample of typical English are counted, it is found that E turns up, on the average, once in every 8 letters. So its information is not 4.7 bits (as it would be if all the letters were equally unlikely to appear) but $\log_2 8=3$ bits. If it occurred every time, so that its probability was 1 in 1 (a complete certainty) one would know in advance what letter was coming, and its arrival would bring no information at all. Log 1=0. As Alice remarked, "How *can* you talk with a person if they always say the same thing?" J, on the other hand, averages 1 in 800, so its information rating is $\log_2 800 = 9.65$ bits.

Morse Had the Right Idea

Clearly it is not the best possible information packing system that gives as much time to low-information letters like E as to high-information letters like J, X, and Z. If E and other frequent letters are conveyed by a briefer-than-average symbol, the average length of a message in code is reduced, because the longer-than-average symbols occur so seldom. Ideally, information should be spread evenly over time. So Morse was on the right lines when he represented E, which has the smallest information content of any letter in the English language, by the smallest signal—a single dot. If the average length of a letter in Morse is calculated so as to allow for the relative frequency with which each occurs, it comes down from $11\frac{1}{4}$ bits to 9. That is still nearly twice Baudot, partly because it allows so much margin for inaccurate keying and partly because its basis is theoretically inferior, though practically more adaptable. Even Baudot is not theoretically perfect, except for coding 32 equally probable symbols.

So long as measurement of information was based on the assumption that all the n symbols in an agreed list were equally likely to be used, our $\log_2 n$ formula was something quite definite to build on. But now we have brought in this question of probability our foundations seem to have given place to the shifting sands of chance. The table showing that Z occurs less often in English than once per 1,000 letters would be quite unreliable if applied to an article on zebras or zinc.

So the relative probability of letters in English is more complicated than just making a table showing how many of each occur, on a wide average, per 1,000. To assess the information value of any particular occurrence of a letter it is necessary to take account of what has gone before it. While in general the odds are 40 to 1 against a U, if the previous letter happens to be a Q they become heavily on. So the theoretically ideal code would be continually reviewing the odds as the message went along, and adjusting the lengths of the symbols accordingly. This appears to be quite impracticable, but as we shall see presently it is an important idea.

Errors from Noise

So far we have been considering only binary signals. But of course one could work in decimals—which would be particularly convenient for numbers—or even in a scale of 26 or more for letters. The signals could be distinguished from one another by amplitude, or frequency, or in some other way. If dots were formed in 32 different amplitudes, then every dot could signal a whole letter or other symbol—5 bits per dot instead of only 1. In principle it might seem that there was no limit to the rate at which information could be signalled; it was only a matter of identifying sufficient different amplitudes. But that would be forgetting about noise and other interference, which introduces an element of uncertainty into reception by adding to some amplitudes and subtracting from others. With a binary code, noise has to compete with the full power of the transmitter every time, and if that came in much above the average noise level, the risk of failing to identify any digit in a message would be very small. There is always *some* risk, because "white" or random noise has occasional peaks many times its average level, but the risk falls off very rapidly indeed as the signal/noise ratio is increased (Fig. 6). With a signal 30 times mean noise amplitude (nearly 30 db) the risk would be utterly negligible. One could change over to a scale of 4, as in Fig. 7, and still have a tenfold amplitude margin (20 db) for distinguishing one from another. Since each digit now indicates a selection from 4 possibles, it is equal to 2 bits, and the rate of signalling is doubled. But if one were to use a 32-scale code, each

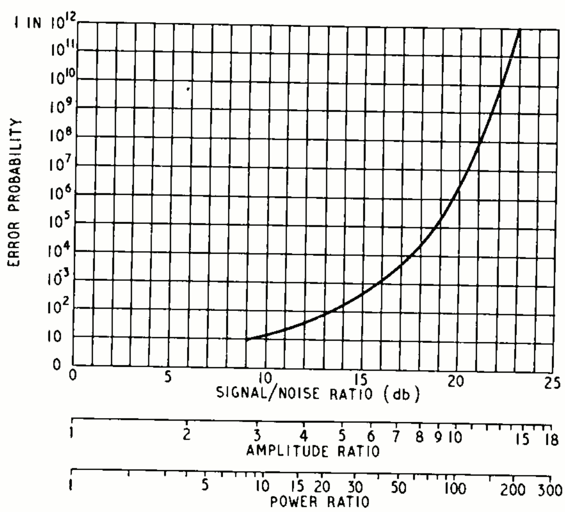


Fig. 6. Showing how risk of errors due to noise varies with signal/noise ratio, using p.c.m. signalling.

signal step would be no more than average noise amplitude, and the proportion of errors would be so large as to wipe out the advantage of higher speed.

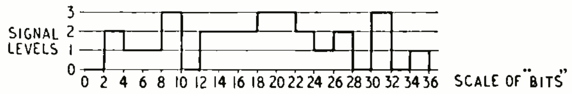
One fact that emerges from this is that the capacity of a channel to transmit information depends not only on its bandwidth, as in the Hartley Law, but also on signal/noise ratio. Since noise cannot be reduced below a certain minimum level,[3] this means transmitter power. One can send more information through a channel of given bandwidth by increasing the power, *provided that the code is suitably adapted.* But it works out that a very large power increase is needed to gain any worthwhile increase in signalling speed (or reduction in bandwidth for the same speed). Suppose it is agreed that a margin of 20 db (10 times amplitude) is necessary to ensure the desired standard of accuracy. Changing from binary to scale-of-4 coding doubles the speed but means increasing the minimum adequate signal amplitude threefold (Fig. 7), or 9 times the power. Doubling the speed again can be done by using a scale of 16, which requires 15 times the original amplitude and 225 times the power. So there are severe practical limits in this direction. The reason for the steep rise in power is our basic fact that the amount of information in a signal is (with equally improbable symbols) equal to the *logarithm* of the number of different symbols, which with the kind of coding we are considering is one plus the number of distinguishable signal levels. Numbers increase out of all proportion to their logs.

Can we find a formula for the maximum possible rate of signalling information? We can certainly do so if we continue to assume this particular sort of coding (which, incidentally, is called p.c.m.[4]) and a particular error risk, say 1 in 1,000 million—or 1 in a million million if you like; as Fig. 6 shows, it doesn't make much difference to the required signal/noise ratio. But the object of information theory is not to find a formula for what we know we can do already, but for the ultimate perfection with which to compare present and prospective systems. We have already seen that the proviso "with equally improbable symbols" limits what can be done, because symbols are not equally improbable, and this offers scope for abbreviating the code. Some have so little improbability that they can easily be guessed; U after Q, for example.

Redundancy

When we send a telegram, we usually cut out quite a lot of words that we would write in a letter to say the same thing. Even in such a laconic communication as "Coming home Saturday" there is a certain amount of padding. If it were mutilated in transit and arrived as "Comi hom Satday" the recipient (unless unusually dim) would receive just as much real information. The experts have a word for this characteristic that enables some of the signals to be lost without loss of information—redundancy. This word has a nasty sound, but it can be quite helpful in enabling one to make good the losses in transit. The G.P.O. ought to be particularly grateful to it, for without redundancy their telephone system would be worth very little. I once phoned a friend and asked him to write down what I said, which was "I faw your thotograth in the newftater ve uvver bay." I need hardly tell you what he wrote—you can guess the message of which I uttered a distortion. Many pairs of consonants cannot be distinguished over the phone, and if there weren't a good deal of redundancy in ordinary language it would be impossible to reconstruct the messages being spoken. The amount of redundancy varies with the type of message; if we were phoning a chemical formula, in which redundancy would approach zero, it would be necessary to create some, by saying "F as in Freddie," etc., in order to get it across without fear of error.

Fig. 7. *Where the peak signal strengh is sufficiently above noise level, it is possible to distinguish more than two different levels, as here. But the signalling capacity is not nearly proportional to the signal power required.*



Shannon's Formula

Now a very interesting result of information theory, due mainly to C. E. Shannon of U.S.A., is that the error risk can be made as small as one likes by using a sufficiently elaborate code, retaining only enough redundancy to offset noise; and that there is a definite theoretical limit to the information rate in b/s, beyond which no imaginable or even unimaginable code can go. The actual formula for it is surprisingly simple:

$$f \log_2(1+N)$$

where f is the frequency bandwidth and N the signal/noise power ratio. The $\log_2(1+N)$ takes the place of 2 in the Hartley-type formula, which is actually correct when $N=3$. Using any known practical code with such a small signal/noise ratio, there would be too many errors. In theory it is possible to make the error rate negligible, but only by using an extremely elaborate coding and decoding, which would use up at lot of time.

One of the conclusions is that p.c.m is perhaps nearer to the ideal than any other yet put into practice. And it has the great advantage that it can be used not only for telegraphy but for telephony or any other waveform—in fact that is its main purpose, as explained in Thomas Roddam's article just referred to, and in my "Tens or Twos?" Although speech currents look as if they have a continuously varying waveform, in practice the effect of noise is to prevent more than a limited number of different levels being distinguished at the receiver; that being so, the waveforms can be broken down into code formations like Fig. 7, and the same principles apply as for telegraphy, semaphore waving, or any other code signals.

But it is important to be clear about what is the information to be transmitted. In speech, is it the words spoken, or is it the sounds of the words? If just the words, then waveform telephony is an exceedingly inefficient method of signalling them. The vowel "ee," a very simple frequently occurring sound, and therefore having a low information rating, occupies the channel with hundreds of cycles of a.c.; whereas in telegraphy one or two would be enough. The consonant "th," also very common, necessitates a large bandwidth if it is to be clearly distinguished from "f." It is possible to use a channel of the same bandwidth to send the words by telegraphy many times faster than they could be spoken. But if the

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[3] "Noise," *Wireless World*, May and June, 1952.

[4] "P.C.M.," Thomas Roddam, *Wireless World*, March, 1949.

information to be transmitted includes tone of voice, giving recognition of the speaker, and emotional characteristics, and, in music, the sound of an actual performance rather than merely the score, that's different. Even so, it is possible to economize. The ingenious Vocoder[5] economizes very considerably by sending not the actual sound waveforms themselves but only signals needed to switch on generators of those sounds at the receiving end whenever they are uttered by the speaker. Although the result is admittedly not equal to telephony at its best it gives recognizability of speakers' voices, using only a fraction of the usual frequency band.

One hopes now that information theory is going to be a help in dealing with that most wildly extravagant of all telecommunications—television.

[5] "Channels of Communications," *Wireless World*, July, 1947.

New Electronic Organ

Methods of Tone Generations Used in the "Gregorian" Instrument

BUILT to meet the requirements of organists whose standards of tone equality and general performance are those of the traditional pipe organ, the new "Gregorian" instrument recently demonstrated in London is a joint production of Alfred E. Davies and Son, organ builders, of Northampton, and the Acoustical Manufacturing Company of Huntingdon.

The simulation of organ tone by electronic generators is an intriguing problem, involving as it does the control of build-up and decay times, as well as harmonic content —not to mention the introduction of prefatory wind noises in the case of some stops—which all help to make the organist feel really at home, and not at the keyboard of some strange new electro-mechanical instrument. Mr. P. J. Walker, whose interest in traditional organs is of as long standing as his interest in high-quality reproduction, has for many years been working on this problem, and privileged visitors to the works at Huntingdon have from time to time been invited to play or to criticize a succession of prototypes. It is now felt that the results can be offered for general criticism by organists, and that if there are criticisms that they can be met.

Among organists themselves there is no unanimity as to what constitutes, for example, diapason tone; judgment is inevitably a personal matter compounded of taste and experience. To meet this range of preference, interchangeable plug-in filter units are provided in the "Gregorian," so that an instantaneous change to other tone colours can be made until the customer is satisfied. In addition, each basic note in the 96-valve generator can be individually "voiced."

The tone generators are L-C controlled oscillators from which the fundamental and harmonics are drawn separately from different parts of the circuit. Build-up and decay times are controlled by a third winding on the iron-cored coupled circuits which control the effective Q of the tuned winding. Wind noises are simulated by the deliberate introduction of random circuit hiss during the build-up period. Tremolo is effected by varying the h.t. supply to all generators above the F♯ below middle C.

Electronic methods are not relied upon exclusively for the generation of authentic organ tone. The associated loudspeakers are not "reproducers" in the accepted sense, but are mounted in pipe-like baffles constructed of woods chosen for their "resonant" qualities—using the term this time in its musical context.

The effect as a whole is most pleasing, and although professional organists may be expected to express the usual divergence of opinion, it is safe to say that their audiences will not be conscious that the organ tones are of electrical origin.

With two manuals, pedal, and choice of eight stops from a comprehensive list to suit the acoustics of the auditorium, the price is £1,460, ex works. A smaller specification with five stops is available.

50-WATT V.H.F. TRANSMITTER

PRELIMINARY information is now available of a new Pye 50-watt v.h.f. transmitter which is designed for telephony operation in the band 60-184 Mc/s. It is crystal-controlled with a frequency tolerance of ±0.003 per cent. Harmonic suppression is said to be better than 50 db. High-level amplitude modulation is used with a modulation capacity of 100 per cent. It operates from single-phase a.c. mains of standard voltages and frequency and on full modulation consumes 585 VA.

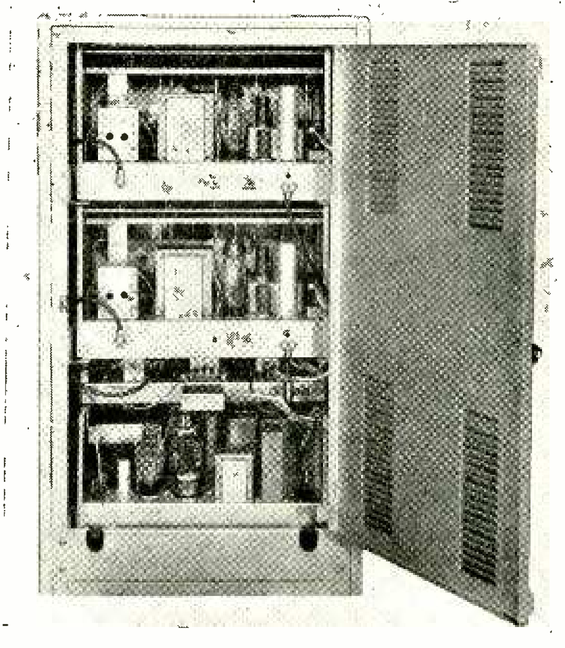
The standard equipment comprises two units, (a) r.f. and modulator and (b) power unit. These are mounted one above the other and interconnected by cable and a 12-way plug and socket. When assembled in a standard 19-in rack the overall height of the two units is 19¼ in and the maximum depth 10 in.

Various alternative assemblies are possible to meet special requirements and one such is shown in the illustration, where is seen the rear view of two transmitter units mounted in one of the latest Pye enclosed cabinets together with a power unit below.

Provision is made in the transmitter for switching to any one of six ordinary crystals or to four temperature-controlled units, and re-alignment of the circuits can be effected in under 30 seconds.

The equipment may be remotely controlled over a single pair of telephone lines up to a distance of 15 miles. The makers are Pye Telecommunications, Ltd., Newmarket Road, Cambridge.

Two Pye 50-watt v.h.f. transmitter units mounted in an enclosed-type cabinet with power unit below.



Progress in Amateur Television

Review of Current Activities and Techniques

By M. BARLOW* (G3CVO)

Camera built by K. A. J. Russell of Bournemouth. It uses an RCA 5527 iconoscope pick-up tube working on 250 lines (non-interlaced) and contains a pre-amplifier, a line amplifier and a viewfinder.

THE recent successful two-way television contact between the amateur television stations G5ZT/T and G3BLV/A/T at Plymouth was another milestone in the history of post-war amateur television transmission. Readers of *Wireless World* will remember various notes concerning the activities of G2DUS/T and other members of the British Amateur Television Club. During the four years of its life this Club has fostered considerable interest in the peculiar problems associated with amateur picture transmission, and it numbers amongst its members many of the leading names in amateur radio and television.

Before the war many people built various forms of disc scanners, but it was not until the influx of ex-Government radar equipment after the war that any progress was made with electronic systems. After spasmodic efforts to contact other experimenters working along the same lines, a small group of enthusiasts began to publicize the idea in the lay press and the amateur magazines. In the early days, G2DUS possessed the only camera tube, and the remainder of the amateurs were forced to use "telestill" and telecine equipment working on the flying-spot scanning system with "surplus" radar cathode ray tubes for scanning. Results were surprisingly good, and since then considerable improvements have been made. It is now quite possible to obtain resolution equivalent to a 3-Mc/s bandwidth, with good contrast range, on this type of transmission, using a minimum of components and for a total outlay of about £15.

With the emphasis on economy in money and materials rather than long-term reliability, several short cuts have been made, and several truly amateur —rather Heath Robinson—forms of construction have been tried out. Naturally, shortage of suitable components has been a hold-up. The once plentiful RCA 931A photocell is now scarce, and expensive (by amateur standards) at 30s. There is no substitute available. Scanning tubes should be blue, short-persistence types; some of the ex-Government double layer types have to be used instead. There are no really suitable scanning tubes available, either "surplus" or as manufacturers' rejects. Some of the newer types of counter tubes, for instance, would be ideal for divider chains, but are unobtainable or too expensive. On the r.f. side, suitable valves for transmitters are very scarce, and indeed have only just come into use at all. The main trouble, however, is the shortage of camera tubes. Until the latest currency restrictions, RCA 5527 iconoscopes could be readily imported at a cost of about £30, a price comparing favourably with the average amateur communications receiver. These tubes are insensitive and have their faults, but for amateur use they are ideal, being electrostatically deflected and linear in construction, so doing away at once with most of the complicated camera scanning circuits. Pending the arrival of a similar British tube, camera progress has been rather erratic, although some twenty-five assorted tubes are now in use by B.A.T.C. members. Amongst these is a 5527 acquired for 30s in Lisle Street and apparently in perfect condition!

Live reproduction without the use of a camera tube has received much attention, and it has been found that by using a true flying-spot system, and scanning

Television picture obtained with Mr. Russell's camera (see above). The subject, an advertisement photo, was illuminated by two 500-watt photoflood bulbs and this picture was taken from the screen of a 9-in monitor tube.

* Hon. Secretary, British Amateur Television Club.

with a 5FP7 or some projection tube, fair results can be obtained. The method is recommended to the amateur who wishes to televise himself at little expense and without occupying too much space. The "studio" is in darkness or faint red light, the blue sensitivity of the photocell providing sufficient discrimination. Using ex-R.A.F. camera lenses, a 5FP7 running at 6 kV will scan an area of some four feet square with about 4-in depth of focus, which is quite sufficient for elementary experiments.

For transmitting cine film (usually 16-mm of great antiquity!) the favoured method is to run the film through the scanner continuously at 25 pictures per second and to scan it with two 50-c/s rasters one above the other, the direction of scan being opposite to the film motion. Extremely good results have been obtained by G. Short and F. Rose (G3BLV), but the system is not too popular in the amateur world owing to the shortage of suitable film material.

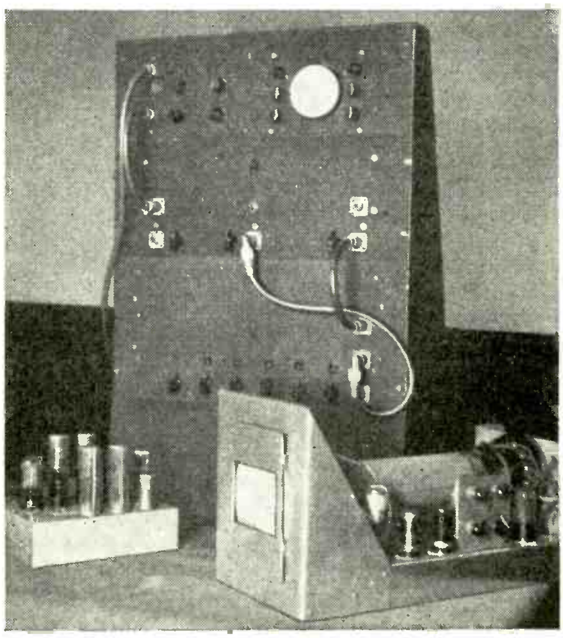
The real stand-by of all amateur television enthusiasts is the telestill unit, capable of transmitting small transparent pictures. Quite good results can be obtained with very simple equipment; for instance, by using a "surplus" ACR1 5-in electrostatic scanning tube and strapping it in parallel with a VCR97 monitor, two EF50s will provide a common time base and also flyback suppression pulses. One photocell and a three-stage video amplifier, with a phase inverter stage for transmitting either positive or negative transparencies, completes the outfit, and at a cost that is distinctly encouraging to those of us who count the money available in shillings and pence rather than pounds. With this unit as a basis, improvements can quickly be made: the addition of a lens system permits the use of 35-mm film strips or 2in × 2in slides; the use of the family television set as a monitor requires the building of a sync pulse generator, but to begin with the original transitron time bases will provide quite sufficient synchronization from their screen grids; a scanning tube with magnetic deflection (such as the 5FP7) will reduce the noise generated because of its finer face-grain. Altogether some 65 telestill units are in operation in this country at the moment.

It is in the more advanced realms of television that the limitations of "surplus" equipment begin to be felt. There are two members carrying out research into colour television, and one trying stereoscopic television. When one remembers that the only suitable photocell is very blue-sensitive and almost totally insensitive to red, and that the only available short-persistence scanning tubes have either a blue trace or a coarse-grained screen, the elementary snags appear at once. Nevertheless, results have been encouraging with the revolving colour-wheel system that is being used. Converted magslips do the driving, while the actual colour filters are cut from cellulose acetate sheet designed for stage lights. Polaroid inserts are used in the stereoscopic units, the viewer having to wear spectacles.

On the radio side, progress has been much slower. Although Dutch amateurs have been transmitting television pictures since 1948 and there are now four amateur stations in the Netherlands, besides some 16 stations in 11 other countries, it was not until 1951 that the Post Office announced the release of vision transmission licences in this country. Unfortunately, initial permission only covered the 3-, 6-, 13- and 25-centimetre bands, all virtually unbroken ground even for amateur *sound* transmission; later the 70-cm band was also released for use. Furthermore, a charge of £3 per annum is asked for the vision permit, in addition to the £2 10s of the normal sound transmitting fee. As a result, the great majority of the television experimenters in this country are forced to carry out their experiments over a closed circuit, and it is noticeable that this branch of amateur radio

Camera built by B. Cederqvist of Helsinki. It contains an RCA 5527 pick-up tube and an amplifier using miniature valves. The deflection circuits for the pick-up tube are housed in a separate unit.

Flying-spot scanner and control equipment used by F. Rose in the recent two-way television contact at Plymouth. On the left is the photocell and its amplifier and on the right is the scanning unit.



appeals particularly to those non-transmitting constructors of an inventive turn of mind. Considerable work is being done with the aim of putting several television stations on the 70-cm band, but these will be for purely experimental communication purposes only. Again, lack of suitable valves is delaying matters.

Circuits.—Video amplifiers tend to ignore peaking coils because of the difficulty of adjusting them correctly without proper test gear. R-C correcting networks are popular instead. A band-pass of 3 Mc/s is usually aimed for. Pulse generators vary enormously, from the simple two-valve arrangement already mentioned to much more complex interlace circuits. Normal standards employed for closed-circuit use are 200-300 lines, 50 pictures per second sequential scan, or 405-625 lines, double interlace. For the sequential scans of a more complex variety, crystal control is common, followed by a simple frequency divider and pulse generator. A normal B.B.C.-type waveform is aimed at, although the precise values vary owing to the lack of accurate test gear. Both blanking and sync pulses are used in more complex equipment, although these are the same thing in simpler apparatus. Where interlacing is used the divider chain has been a source of much bother. Stabilized multivibrators are preferred to phantastron or step counter circuits, a discriminator being used to beat the locally generated 50 c/s against the mains to provide a correction voltage for the master oscillator. Pulse mixing and vision-sync mixing are done either by injecting on different electrodes of the same valve, or by common-load mixing with two valves. Modulators are very experimental, owing to the peculiar difficulties associated with the 70-cm band. Power supplies are regulated for all units. Radio-frequency and ringing-choke e.h.t. systems, not to mention the sound and vision transmitters, are apt to generate annoying patterns, and B.B.C. programmes on medium waves can appear on the camera channel!

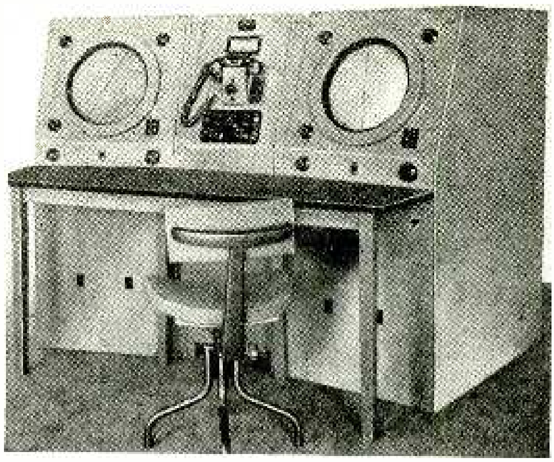
It is hoped that this brief account of the work being done in this country will be of interest. To those readers who are professionally engaged in television work and perhaps a little inclined to scoff, we suggest that they see what *they* can do using only "surplus" goods and very little test gear!

Comprehensive Airfield Radar

RADAR equipment operating in the 3-cm band has been developed by Cossor Radar to meet the needs of airfields requiring a comprehensive control-of-approach aid at a reasonable price. It is claimed that the equipment provides for complete supervision of all aircraft within a radius of 20 miles, and all movement of aircraft on the runways. It also enables aircraft to be brought down through cloud to make a safe landing when visibility is limited to about half a mile. It can be used as static or as mobile equipment.

The control console, shown in the illustration, has, normally, two 15-in cathode ray tubes for the P.P.I. display. One can be used to cover a range of four to five miles and the other to extend the coverage up to the maximum of about 20 miles.

Good range discrimination is obtained by using pulses of 0.1 μsec duration, while undesirable ground echoes are kept down to a minimum by using an aerial system giving a beam of 0.7 deg in the horizontal plane and 3.5 deg in the vertical. The aerial can be tilted to direct the beam



Console of Cossor airfield radar equipment showing twin 15-in display tubes and radio telephone panel between them.

at elevations between 0 and 12 deg, the angle of tilt being controlled from the display console.

Large aircraft can be detected at 20 miles or more and smaller ones at 10 miles, and it is possible to follow an aircraft to within half a mile of the airfield.

The aerial system, or scanner, is a paraboloidal reflector measuring 12ft × 3ft and normally rotates at 20 r.p.m. It is fed by a waveguide which can be up to 30ft in length. The transmitter peak power is about 40 kW and it is operated from a 180-V, 500-c/s supply generated by a motor alternator which can be operated from standard mains supplies.

Radio telephone facilities can be provided at the control console when required.

New All-wave Aerial

BY employing wide-band transformers wound on Ferroxcube cores a new interference reducing aerial system has been introduced by Antiference for which a number of interesting features is claimed. Over a range of 100 kc/s to 30 Mc/s, and using a screened twin-feeder between aerial and receiver transformers, the insertion loss is said not to exceed 6 db at any part of the band. Another is the entire absence of resonances, which ensures that the tuning of the receiver's input circuit is not disturbed by changes in aerial reactance so that the ganging holds over the whole range of frequencies covered.

The balanced feeder, used in conjunction with transformers having a high coefficient of coupling between the halves of the low-impedance windings, is said to ensure maximum rejection of longitudinal or "parallel" noise currents.

The versatility of this new aerial is exemplified by the fact that it has been found possible to provide adequate inductance in the transformers to ensure a satisfactory performance with receivers having high-impedance input circuits, as found in certain Continental receivers.

Despite the comparatively high primary inductance provided, leakage inductance in the transformers is surprisingly low, an insertion loss figure of 2.5 db at 30 Mc/s being claimed for a single transformer.

Transformer windings are impregnated to ensure stability of performance in all conditions of weather and in all climates. They are housed in watertight containers.

The new "Exstat" aerial is available in several different forms allowing for the use of horizontal or vertical wires or rods and there is also a composite system in which the mast supporting an H- or X-type television aerial is used as an anti-interference aerial for broadcast reception, in addition to its normal function. Specially designed insulating brackets are used for the mast in this case.

VARIABLE H.T. POWER PACK

By A. H. B. WALKER*
B.Sc. (Hons.), A.M.I.E.E.

Cathode-follower Rectifiers Giving Wide-range Voltage Control

ALTHOUGH stabilized h.t. power packs are widely used in electronic work, their stabilization ability is not always required and they are often used simply because they allow the h.t. voltage to be "turned up and down" in a most convenient way. This facility is useful, for example, in developing circuits which must in themselves be made independent of h.t. changes, as it enables the effects to be easily studied. Again, stabilized power packs often come to be used in laboratories because they form a convenient source of h.t. for a particular test, and the complication and expense of the stabilization system is frequently only justified for a small proportion of the time of use. Further, for various reasons such "luxury" power units do not normally provide the desirable facility of continuous control of the voltage from maximum down to substantially zero in one range. In practice, in experimental work it is very convenient to be able to turn on the h.t. supply gradually, as anyone who has had much experience of working with bench hook-ups will agree.

Drawbacks of Other Methods

A variable voltage h.t. supply can, of course, be obtained cheaply by using a potentiometer or a series resistor in conjunction with an existing power pack, but the series resistor method is undesirable as it produces very bad voltage regulation, and the potentiometer method is only satisfactory in this respect if the potentiometer current, and hence the power unit supplying it, is made very large in relation to the experimental load. Other methods are, of course, available (e.g., multi-ratio or variable transformers feeding the h.t. rectifier), but these involve additional equipment and offer no attractive features to offset the additional complication and expense, particularly in small light-weight power packs.

About two years ago the writer felt that, for these reasons, there was a need in his laboratory for a number of small non-stabilized h.t. and l.t. supply units which should be capable of delivering an output voltage continuously and smoothly adjustable from substantially zero up to the maximum, without introducing a higher output impedance than that of a normal fixed-voltage h.t. rectifier and smoothing filter. To conserve bench space the units were to be small and light and provided with self-contained voltmeter and milliammeter and with a low voltage supply for external valve heaters, while to justify themselves they had to be inexpensive. A simple design was evolved, and the power packs built to it have proved very satisfactory over two years' continuous laboratory use.

The circuit, which is perhaps a little unconventional, employs cathode-followers as the two rectifiers in a centre-tap rectifier circuit, but the action is more clearly followed if it is first considered in the simple diagrams of Fig. 1.

In the familiar circuit of Fig. 1(a), the cathode potential follows the d.c. potential applied to the grid, the anode current adjusting itself to the value necessary to develop the required voltage across the load resistor R. In Fig. 1(b) the steady d.c. grid potential is retained, but the anode supply has been changed to a.c. Assuming capacitor C to be disconnected, it is evident that the cathode potential will now follow the grid potential only during those portions of the positive half-cycle of the supply when the anode voltage is sufficiently high, and will fall to zero during intermediate periods. If a steady positive d.c. voltage of, say, 200 volts is applied to the grid, the waveform at the cathode will consist of a series of roughly flat-topped pulses 200 volts high. If the capacitor C is now connected across the load R, and the time constant CR is made sufficiently long, the cathode potential will tend to remain steady at a value somewhat

* Research Laboratory, Westinghouse Brake & Signal Co.

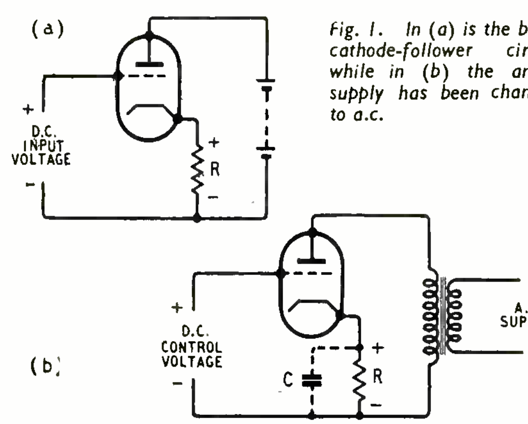


Fig. 1. In (a) is the basic cathode-follower circuit while in (b) the anode supply has been changed to a.c.

lower than the original peak potential, and both the peak value and the conduction angle of the anode current will increase as a result of a reduction in the net bias in order to sustain the increased power now being delivered to the load R. If the load current is now increased (R reduced) the output voltage will again fall slightly due to the anode resistance of the valve, but it will at all times remain under the control of the grid potential, and the additional power will be supplied by a lengthening of the valve conduction angle. Since the grid potential can be easily varied, this circuit provides a convenient way of setting the level of the d.c. voltage developed by the rectifier to any desired value with the minimum of components and complication. Clearly the best voltage regulation will be provided by a valve having a high slope and a low anode resistance, as in a normal d.c. operated cathode-follower circuit.

The complete power pack circuit is shown in Fig. 2. It is basically that of Fig. 1(b), but a conventional centre-tap rectifier circuit has been used, followed by a normal smoothing filter. For reasons apparent from the above discussion, the smoothing filter cannot be of the choke input type, and a reservoir capacitor of moderate size is used in order to extend the conduction angle and reduce the peak valve current. The d.c. control voltage which is applied to the grids is obtained from one half of the centre-tapped transformer secondary winding by means of a miniature metal rectifier, a reservoir capacitor and a potentiometer (which forms the panel-mounted voltage control).

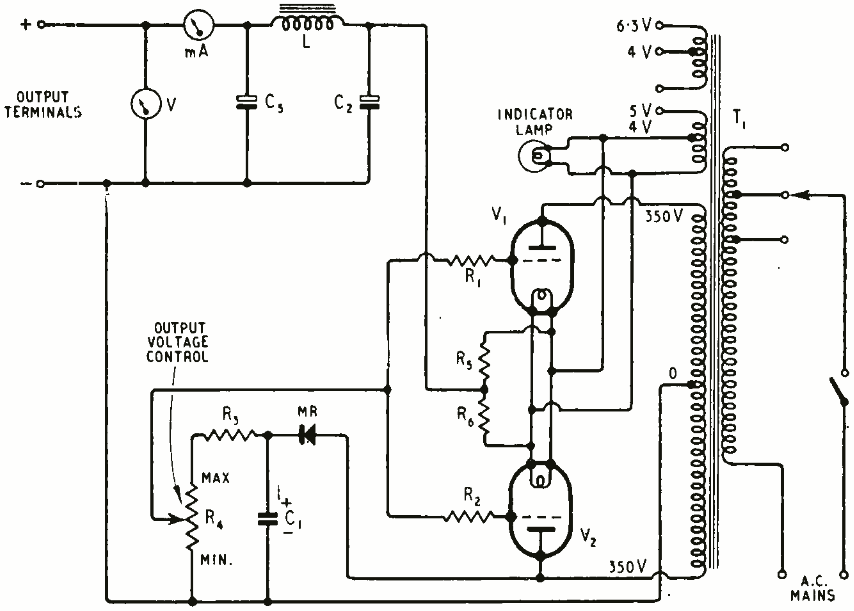


Fig. 2. Complete circuit diagram of the cathode-follower power pack.

The Components

None of the components is in any way critical, and the power unit may be constructed almost completely of "surplus" parts if desired with a considerable saving in cost. The PX25 valves and the EP53 transformer were used as these were already available, although in order to reserve a free heater winding for external use (4 V and 6.3 V at 4 A), this meant that the other heater winding was necessarily loaded above its nominal rating. The transformer, however, appears to have an adequate safety margin, and no overheating results with the suggested layout. If a transformer having a centre-tapped winding for the rectifier filaments is available, or if indirectly heated valves are used, the artificial centre-tap potentiometer R_5R_6 will not of course be required. (In the original design a "humdinger" was used here, although there is, of course, no need for adjustment of the tapping point and two ¼-watt resistors are simpler.) Other valves have not been tested in this circuit owing to the continued satisfactory performance of the PX25s, but any high-slope power triode or triode-connected tetrode or pentode should give very similar results.

LIST OF COMPONENTS

Resistors	
R_1 and R_2	10kΩ, ¼W
R_3 ..	100kΩ, ½W
R_4 ..	500kΩ potentiometer
R_5 and R_6	10Ω, ¼W (or humdinger)
Capacitors	
C_1 ..	4μF, 500V working. (Two 8μF, 350V working, T.C.C. type CE11L in series.)
C_2 and C_3	16μF, 450V working (T.C.C. type CE29P).
Choke	
L ..	10H, 100mA (approx.)
Valves	
V_1 and V_2	PX25 (or similar triodes or triode-connected tetrodes)
Metal Rectifier	
MR ..	1,000V peak inverse, 1mA (Westinghouse 36K12)
Voltmeter	
V ..	Miniature moving-coil, 500V f.s.d. (Ernest Turner model 225)
Milliammeter	
mA ..	Miniature moving-coil, 100mA f.s.d. (Ernest Turner model 225)
Mains Transformer	
T_1 ..	Primary: 200/250V Secondaries: 350-0-350V at 130mA 4V at 4A (see text) 4V and 6.3V at 4A (optional) (Varley type EP53)
Case ..	Imhof type 1050 with handles type 10A (modified as in text)

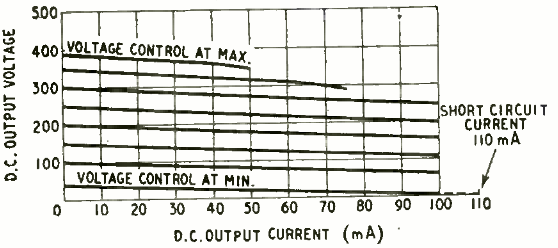


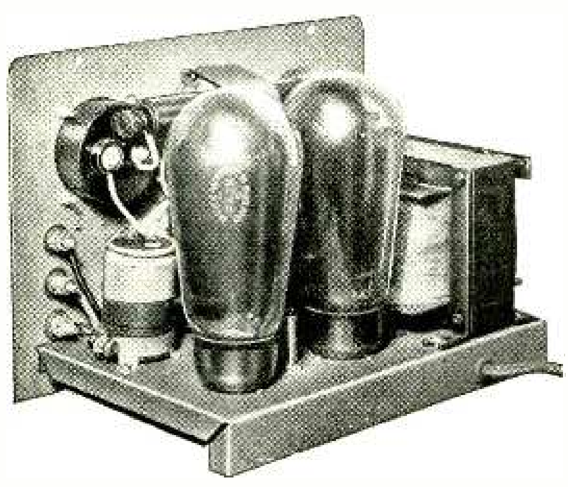
Fig. 3. Output regulation curves at different settings of the voltage control.

The output circuit is isolated from the chassis in order to allow the use of the power pack as a negative supply when necessary in experimental work, and similarly the auxiliary heater winding is left isolated and is brought out to terminals on the panel.

For convenience in use, and to save bench space, the components were assembled in a small commercially-made case measuring only 10in × 7in × 6in. The existing ventilation of such a small case was inadequate and so was increased by cutting two $1\frac{3}{4}$in diameter holes in the top and protecting these by an oval-shaped plate supported clear of the top by four small pillars. Two flat-topped "U" handles taller than the ventilator are fixed to the top of the case, and these form a convenient support for other equipment (or a further power unit) which may be stood on the top of the case without restricting the ventilation or becoming overheated. The ventilator also forms a conveniently shaped cleat round which the mains lead may be coiled for storage.

Details of Construction

Construction is simple, and the layout is non-critical except that there is not a great deal of space available, and if alternative components are used they should preferably not be much larger than those specified. If a different type of case is used it is important to see that adequate air-inlets are provided at the sides to cool the transformer and the electrolytic capacitors, since the heat to be dissipated is considerable. No fuses were included in the original models, but there is space for a fuseholder beneath the chassis if desired. Note that the cases of the electrolytic capacitors must be insulated from the chassis by strips of insulating cloth inside the mounting clips if it is desired to retain the flexibility of using the power unit as a negative supply.



Rear view of the power pack when taken out of its case.

Output voltage regulation curves with the control set to a number of different positions are shown in Fig. 3. The slope of these curves (which include the smoothing choke drop) corresponds to a d.c. output resistance of approximately 400 ohms, which is very similar to the output impedance of a conventional rectifier and smoothing filter. The performance of equipment fed from this variable voltage supply will therefore be similar to that which it would have when fed from a normal power unit.

In practical use, the small variations in voltage which result from mean load current changes are easily corrected by adjustment of the control knob, and the slight voltage regulation has not in practice proved troublesome. The attractive features of wide-range adjustable voltage, small size and weight and built-in metering have resulted in noticeable popularity of these power packs over the past two years in the writer's laboratory, and have enabled stabilized power units to be reserved for work which really requires very high stability or low output impedance supplies. This has justified their design and construction, and it is hoped that the suggestion will be of use to others engaged on electronic development work.

MANUFACTURERS' LITERATURE

Metal Rectifier Stacks by Sentercel; a technical bulletin giving dimensions and weights and explaining the coding system. From Standard Telephones & Cables, Ltd., Warwick Road, Boreham Wood, Herts.

Heat-resisting Glass used in r.f. insulators; an informative booklet "Physical Properties of Phoenix Glass," giving electrical, mechanical and other properties, from The British Heat Resisting Glass Co., Ltd., Phœnix Works, Loxdale Street, Bilston, Staffs.

Oscilloscope Camera Drive Unit with nine-speed gear box described in a leaflet from A.C. Cossor, Ltd., Cossor House, Highbury Grove, London, N.5.

Electronic Instruments for Nuclear Physics; a catalogue of equipment from Labgear (Cambridge), Ltd., Willow Place, Cambridge.

Valves for Industry and Communications; a revised and enlarged edition of a previous booklet, giving abridged data and general operational recommendations, from Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2. Also a similar booklet on **Industrial Photocells.**

Signal Lamps; a supplement to their Catalogue No. 126 from Arcolectric Switches, Ltd., Central Avenue, West Molesey, Surrey, England.

Front-projection Television Receiver; a descriptive leaflet and servicing information from the Rainbow Radio Manufacturing Co., Ltd., Mincing Lane, Blackburn, Lancs.

Television Waveform Generators for 405-line, 525-line and 625-line systems described generally in a leaflet from Telequipment Electronic Instruments, 73a, Beresford Road, London, N.8.

Loudspeakers; a leaflet giving brief specifications of a new range of Rola and Celestion types from Truvox, Ltd., Truvox House, Exhibition Grounds, Wembley, Middlesex.

Mains Switches and other electrical accessories listed in a catalogue from J. A. Crabtree and Co., Ltd., Lincoln Works, Walsall, Staffs.

Reliable Valves and the User

How Circuit Designers and Operators Can Help the Manufacturer

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

WHILE valve engineers can design a reliable valve entirely by calculation and special testing, the achievement of satisfactory performance is not a matter of engineering design only, for the valve must be mass produced and then be capable of operating under a variety of conditions. As a result there are two other factors apart from design which affect the performance: control of manufacturing limits (which, of course, is the responsibility of the maker), and the attitude of the user towards the application of reliable valves. It is the second one with which we are now concerned.

An examination of the distribution of electrical characteristics of any valve in production shows that it is always wider for the first period of production, and the effect shows up even when well-established existing designs are reintroduced. Also, it has been proved that high valve reliability can be secured only if there is a high yield on manufacture (known as a low production "shrinkage"). Such a state is achieved by uninterrupted production over a considerable period of time, when the familiarity of the individual operator with the job secures maximum skill and consistency. Consequently, the philosophy of making reliable valves is that it is essential to keep the number of individual types to an absolute minimum and the quantity of each of these types as large as possible, so that long and continuous manufacturing runs can be carried out (see graph). An appeal must therefore be made to the circuit designer to do his best to confine himself to a short list of types, and to be prepared to use more valves of these types, if necessary, rather than use yet another type that may be more elegant technically.

When reliable valves have been used for reasonable periods in equipments, the valve maker will want to know how well the product is behaving in all of the special applications for which it has been designed and manufactured. No matter what the difficulties, this information must be obtained so that an accurate correlation can be maintained between field conditions and the many valve-testing machines used in the factory. It is appreciated that with equipments distributed all over the world, often in the hands of semi-trained operators, this requirement is not easy to meet, but it has been solved by the air lines in both Canada and the U.S.A., and determined attempts are now being made in this country to see that the valve manufacturer is not hamstrung for lack of information.

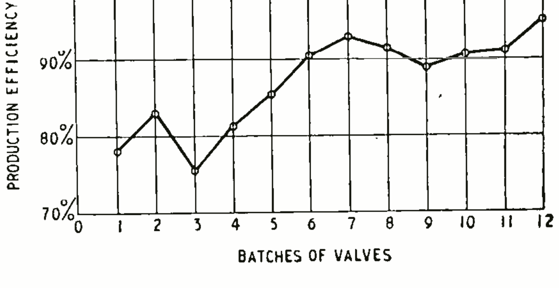
This policy of user-manufacturer liaison has benefits for the user as well. Each batch of valves that is manufactured is carefully tested for the main mechanical and electrical requirements, and samples of the valves are always exhaustively checked to the point of destruction for certain of the special characteristics. While this is going on careful records are kept of the performance, and these are retained so that individual valves may be traced and their performance assessed. Criticisms or complaints from users can then be investigated with a very real probability of satisfaction for both parties.

Perhaps the most important thing of all is the user's attitude towards the application of reliable valves. Past experience in the commercial manufacture of valves has shown over and over again that conservative operation leads to longer life and less frequent catastrophic failure from such causes as low emission or gas. This is especially true of unusual applications where the valve is often required to do a job for which it is unsuited by reason of design or method of manufacture. It would be illogical to assume that the reliable valve will be better in this respect simply because it is designed to give less trouble under severe mechanical conditions. It cannot be emphasized too strongly that the valve is a willing little chap too ready to give his life in the service of his master—and is very often required to do so!

Whilst the main effort of both valve maker and user is directed at present towards the immediate problem of making existing equipments more reliable by using valves that are replacements of existing types, it is very important that the policy for the future is well defined.

The biggest stumbling block to the ultimate reliability of glass-based valves is the valve holder. The valve manufacturer has recognized the problems of incompatibility between valves and valve holders and has compromised by specifying the use of a wiring jig to centralize the socket contacts during circuit assembly and a pin-straightening jig for the valve pins

Graph showing the increase in production efficiency with the number of batches of valves made in continuous manufacture.



* Brimar Valve Division, Standard Telephones and Cables Ltd.

before insertion into the valve holder. Despite all this, considerable evidence has been obtained that semi-skilled personnel can cause a "mechanical insertion" loss of 3 per cent or greater, and whilst this can be reduced by careful training, the requirement of 1 per cent failure in 1,000 hours (agreed as an objective definition of reliability) is easily swamped by this single possibility.

Because of the inevitability of some loss due to this, it is clear that for requirements demanding absolute reliability the valves will have flying leads and will be soldered into the circuit. The size of the envelope will be dependent on the dissipation requirement, the sub-miniature being used for low-dissipation valves with the miniature and noval types for better characteristics and higher dissipations.

Results of the present programme of work on reliable valves are likely to show that the valve is no longer the prime limiting factor to trouble-free performance of electronic equipment, and it is anticipated that the user will be turning to manufacturers of other circuit components for assurance of equal standards of reliability. This situation is already occurring with miniature potted circuits—the self-contained units including sub-miniature valves and components designed for ease of mass production and assembly.

In conclusion, it must be acknowledged that the user's attitude has up to the present been of real assistance in the design and early manufacture of the reliable valve. Considerable evidence has already been obtained from the Armed Services regarding the applications of the valves, and it is hoped that this trend will be continued when industrial equipment manufacturers begin to use them in quantity.

BOOK REVIEW

Amplifiers: The Why and How of Good Amplification, by G. A. Briggs and H. H. Garner, Pp. 202 + XIII and 178 illustrations. Wharfedale Wireless Works, Bradford Road, Idle, Bradford. Price 15s 6d.

ONE criticism that cannot be levelled at this book is that the authors have been parsimonious in the amount of material presented. In this respect, and in the method of presentation, "Amplifiers" follows the precedents of the previous "Loudspeakers" and "Sound Reproduction," between which it forms a link.

Having, with the skill of Autolycus, collected a bumper harvest—not excluding some notes on the care and maintenance of electrical machinery—the authors have sat down to sift and bag the crop, and here one feels their touch has been less deft. We all know that the best way to learn about a subject is to write about it, but having by devious paths arrived within grasp of the truth, it is not a bad plan to tear up the first draft and start again. Too often the authors have left in their rough working for all to see, and, as this is sometimes self-contradicting, it must be difficult for the beginner, for whom this book was written, to know where he is.

For instance, we are told (p. 54) that the function of a grid stopper resistance is to introduce damping into any fortuitous oscillatory circuits associated with the valve and that this resistance "will not reduce the input voltage to the grid." Five lines further on we find that the grid stopper in conjunction with the grid-cathode capacitance forms a low-pass filter and attenuates the high frequencies.

Other topics which the authors seem to have found rather indigestible include the rôle of transformers in coupling loads to valves, and the reasons why the optimum load for maximum power output is sometimes equal to and sometimes twice the valve a.c. resistance. The significance of the valve cathode as an equipotential surface is not sufficiently stressed, and hum in directly-heated filaments is ascribed (p. 21) to lack of thermal capacity. The virtues of barretters as mains voltage dropping resistances are rightly attributed (p. 56) to the fact that the resistance of the filament increases with temperature, but on the previous page "bargain" type wire-wound resistors with a high temperature coefficient are condemned. But the dyspeptic biscuit should be reserved for the treatment of loudspeaker damping, pp. 45-47, where it is stated that the coil when falling to rest will generate an e.m.f. "which will cause a current to flow in the coil and the field produced will interact with the flux of the field and tend to cause a movement in the opposite direction to the original one, taking the system past its dead centre position instead of coming to rest immediately." While this may not secure for the authors a patent for perpetual motion, it might form the basis of a new magnetic gun!

One final quotation in support of what must be the main criticism of this book: that the "Why" is less to be relied upon than the "How." On p. 172 in the chapter on hum we are told "The chassis can influence the spread of electro-magnetic hum. Magnetic materials are commonly employed and strong eddy currents exist throughout such substances. These can be virtually eliminated by using a dia-magnetic material such as aluminium, duralumin, or best of all copper which is even silver-plated in the highest grades of professional apparatus." We will overlook the error of including aluminium among diamagnetic materials, and, following the Euclidean technique, pursue the authors' thought to its logical conclusion, which is that we may well soon be asked to consider the virtues of yet higher grades of apparatus in which the copper chassis are coated with bismuth (seven times more diamagnetic than silver). Home constructors will no doubt content themselves by wiping their chassis over with a paraffiny rag (diamagnetism × 3 Ag). It may smell, but it will deter eddy currents, for as well as being diamagnetic it is an insulator, and cases have been brought to our notice in which eddy currents have been known to flow even in diamagnetic conductors!

The authors' belief that touches of humour enliven the text of technical books is commendable (and it is to be hoped they do not deny book critics a similar licence), but to be effective the jokes must flower in the right place and ungerminated seeds of humour must not be left lurking in seriously-intended passages.

If the Factual is not carefully sifted and becomes merely the Memorable, there is a risk that some readers, starting with the knowledge that the book will at times be intentionally funny, may think that the authors are trying to do for Good Amplification what Sellar and Yeatman once did for History.

F. L. D.

RESISTOR COLOUR CODES

AFTER being in almost general use for some time, the well-known colour coding of resistance values has now reached the status of a British Standard and is the subject of a new specification, B.S. 1852:1952. It defines the colours to be used, their significance and the methods of marking. Both coloured bands and the coloured body, tip and spot (or band) systems are approved, but the bands located at one end is the preferred arrangement.

A maximum of five bands is approved, the first three giving the resistance value, the fourth the percentage tolerance and the fifth the grade. In the alternative form of marking (coloured body, tip and spot) the tolerance is indicated by the appropriate colouring of the second tip of the resistor. Thus both ends may have colours differing from the body.

As the colours and corresponding numerical values are the same as those in general use now, they will not be repeated here. The coding is defined as applying to fixed resistors for telecommunication purposes.

Copies of the specification are obtainable from British Standards Institution, 24, Victoria Street, London, S.W.1, and cost 1s, including postage.

Bankers' Television

Remote Inspection of Documents

MOST banks manage to keep a watchful eye on their customers' overdrafts without a great deal of trouble, but the London firm of private bankers, Glyn Mills and Company, are somewhat unconventional in this respect—they do it by television. The reason is that one of their branches is divided into two, the main office being in Whitehall while the pay and ledger departments are at Osterley Park, some ten miles away. When this arrangement became necessary a few years ago it naturally created quite a problem in communications, particularly when staff in Whitehall had to get detailed information from documents kept at Osterley. It was clear that telephoning or teleprinting would be too slow and would introduce the possibility of human error—and, of course, they would be no use for verifying signatures on cheques. Phototelegraphy would be better, but still too slow. Obviously the only real answer to the problem was television, so in due course an experimental one-way television system was installed, using a radio channel for transmission of pictures from Osterley to Whitehall. Whether it will now become permanent or not depends partly on the question of cost and partly on the willingness of the Post Office to grant a permanent licence for the stations.

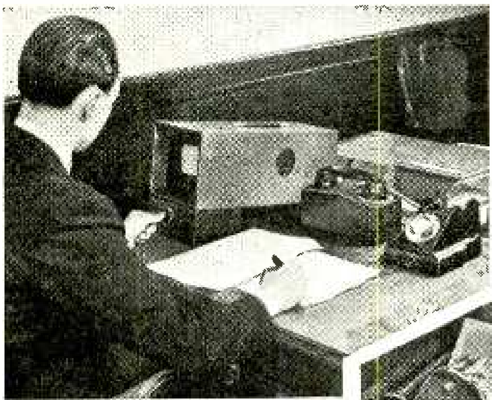
On Decimetre Waves

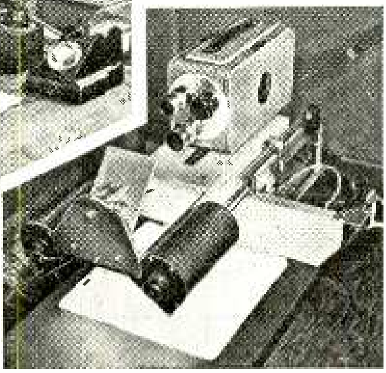
The equipment has been provided by Pye Ltd. of Cambridge. It consists of a small camera and control unit at Osterley, a 15-cm radio link beaming about half a watt of r.f. energy between paraboloidal aerials, and a small-screen desk receiver at Whitehall. There is also a remote control system which enables the viewer in Whitehall to move the camera about so that he can look at any particular part of a document. This works by sending different levels of two a.f. tones over a telephone line, which is also used for verbal communication. The picture obtained is very clear and is generally arranged to be larger than life size.

Miniature Camera

While television may seem a rather expensive luxury for private organizations to indulge in (the estimated cost of the installation is £10,000), the camera and its associated gear at Osterley actually come from a small transportable "industrial television" outfit which Pye have designed especially with an eye to simplicity and low cost. The miniature "Staticon" camera, which has a three-lens turret, measures only $11\text{in} \times 6\frac{1}{2}\text{in} \times 4\frac{3}{4}\text{in}$, and weighs under 13lb, and apart from the tiny pick-up tube (length 7in, diameter 1in), with its focus and deflector coils, it contains no more than a video amplifier and a tube blanking amplifier. Everything else—waveform generators, controls, power supplies, and so on—is housed in a separate unit, which also contains a 9-in cathode ray tube for monitoring. The definition used for the Glyn Mills television link is 525 lines, but the equipment can also be arranged to work on 405 and 625 lines.

As an interesting sidelight on the economics of the system, Glyn Mills and Company point out that the use of television in this way could actually reduce the overhead costs of city offices by making it possible for bulky records to be kept in the suburbs, where the rents and rates for office accommodation are very much lower. Moreover, the staffs of the suburban offices could live nearby and so save on travelling expenses.





(Above) Pictures are viewed at the main office in Whitehall on this small desk receiver. (Right) The miniature "Staticon" camera and its mounting at the transmitting end.

RANDOM RADIATIONS

By "DIALLIST"

Franco-British Television

AS A TECHNICAL ACHIEVEMENT, the relaying of French 819-line television by the British 405-line network was an undoubted success. It showed beyond a doubt that, thunderstorms apart, the conversion of one 50-frame scanning standard to another and the relaying of television transmissions over great distances are things which can now be done at will. Apart from their novelty, the entertainment value of the programmes that I saw was not very great; but there is every reason for expecting rapid improvements here. The definition was, on the whole, surprisingly good—I was particularly struck by its excellence in the military tournament relay.

T'other Way Round

Actually two separate and distinct conversions were made during these transmissions. The French engineers had rigged up a convertor on the lines of that developed by the B.B.C. and by means of this they successfully relayed the 819-line transmission over their 441-line system. Notice, though, that in both instances the conversion was from a larger number of scanning lines to a smaller. It remains to be seen what will happen when we relay our programmes to France and they are converted t'other way round from 405 to 441 and 819 lines. The 405-line image will, of course, be spot-wobbled to remove all lininess, and I feel pretty sure that French viewers with 819-line receivers will be agreeably surprised by the high quality of the images on their screens.

The Viewer's Bugbear

TUCKED AWAY amongst a dozen paragraphs in "World of Wireless" on page 225 of the June, 1951 issue, was one which stated that regular test transmissions of 819-line television were being made from a transmitter in the Eiffel Tower with a pass-band of only 4 Mc/s. To balance vertical and horizontal definition with an 819-line, 50-frames-a-second scan the modulation bandwidth required is about 14 Mc/s: the horizontal definition of a transmission made with a 4 Mc/s pass-band must be extraordinarily poor. Yet, *La Télévision Française* predicted at the time that it would prove acceptable to viewers so long as there was good contrast and good vertical definition, unbroken by line structure. Ever since that paragraph appeared, more than a year ago, I have kept a watch on French technical and lay publications for any adverse criticism of the quality of those transmissions. Not one word have I seen of any such comment. And that goes to prove the truth of the contention that I have so often advanced: *the* most offensive quality to the average viewer in a television image is lininess. You can prove to him by higher, lower or medium mathematics that what he really wants is balanced definition. "I'm sure you're right, old boy," he says; "but what I can't stick is those lines across the picture." Eliminate the lininess, as can so easily be done by means of spot-wobble or some equivalent trick, and your average viewer will begin to appreciate the value of balance in definition. But leave the image liny and he'll go on clamouring for what he misguidedly calls higher definition in the shape of more scanning lines—quite irrespective of the pass-band of either transmitter or receiver. Myself, I'm firmly convinced that the real answer to the viewer's prayer is either spot-wobble or spot-elongation.

Hard Labour

ONE OF MY RECEIVERS recently became intermittently noisy, although there was clearly nothing wrong with the receiver itself, for when taken into another room it behaved perfectly—even when its cabinet was shaken or rapped with the knuckles. But, in its own particular corner it emitted every now and then a volley of crackles and bangs, accompanied by variations in the volume of sound from the loudspeaker. It could be made, I found eventually, to do these things if one walked across one part of the floor. As there were two skirting-board 5-amp sockets in the neighbourhood, I knew that there must be a junction box below the largish area of floor-boards, the crossing of which produced a devastating response from the set. Despite the prevailing heat-wave, the furniture was shifted, the carpet rolled back and the necessary tools were collected.

Electricians, Please Note

Well, it shouldn't be hard to locate that junction box and to deal with the loose contact which it obviously contained. There would certainly be, immediately above it, a short piece of floor-board, between two adjacent joists. I found nothing of the kind. Every plank was from 8 to 15 feet in length. Carefully observed results of deliberately heavy tramping over the bare boards pointed to one 8ft plank as the probable concealer of the defective junction box. They were sound, thick boards and they were well and truly nailed down. When, after some hard work with hammer and the tool known as an "electrician's chisel," I had raised that plank, I found beneath it nothing more than an innocent lead-covered cable. After an interval for cooling off, I made careful measurements and decided that the box must be under a certain 12ft board. Having got that one up, I found I could see the box—but it was out of reach, for it was covered by the next floor-board but one—also a 12-footer. Further interval for cooling off; then at last up came the right plank. Sure enough, one of the connections in the junction box had become loose. This was put right in a jiffy. In fact, the job which actually took the best (or worst!) part of three perspiring hours, could have been done in ten minutes if only some thoughtless electrician had had the sense to saw through the floor-board and to leave an obvious short length above the box. Will electricians please note? My own practice—which may be a counsel of perfection—when rewiring, is to mark the short plank with a carpenter's pencil: "Junction box 5A," or "Junction box 15A," and to leave under it or on the joist a sheet of paper showing the connections of the various leads.

Gas Fitters, Too

THERE APPEARS to be a lamentable gap in the training of the skilled men who come, at our behest, to install gas connections in our homes. From conversations with not a few of them I gather that their training includes no instruction about the lighting and power cables that they are likely to encounter in the average house and that they are told nothing about the I.E.E.'s eminently sound regulation that the lead sheathing or the steel conduits of cables must not come into contact with gas pipes. A particular point in a gas pipe may be pretty well insulated from earth and, therefore, there may be a considerable potential difference between it and a properly earthed lead sheathing or conduit. Quite apart from the danger if an escape of gas occurs, intermittent contact between sheathing or conduit and a dirty gas pipe can lead to noisiness in the radio set. The electrically uninstructed gas man may (and too often does, if you're not there to keep an eye on him) nullify all the precautions you take to make your electric wiring safe and unproductive of noise in the wireless set.

UNBIASED

By FREE GRID

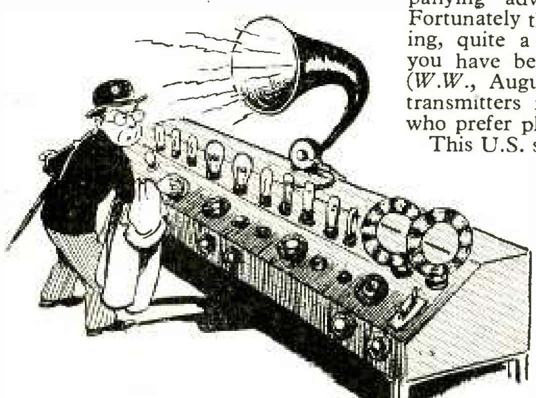
Comparisons are Odious

IN the far-off days of the knob-twiddling twenties, when each of our valves had a variable filament control and every circuit had its individual tuning knob, we pioneers were content with very simple Anglo-Saxon names for the bricks and mortar with which we built our sets. We talked vulgarly of condensers instead of capacitors; as for the variable ones, our unit of capacity, or capacitance, as I should say, was not the microfarad but the "plate," just as our unit of inductance was the "turn" and not the microhenry. We were content also to speak of the filament, grid and plate of our simple valves although some of us who thought we were more learned than others talked arrogantly of "anodes."

All this has, of course, long since changed and our vocabulary of technical terms has been ruthlessly hellenicized. But here and there we come across reminders of the vulgar Anglo-Saxon past, such as in the continuous use of the expression "magic-eye" instead of "cathode-ray tuning indicator" or "thermionic indicator." Perhaps, however, this is not a very fitting example as it has never been used in the innermost circles of radio engineering but, like the name magic lantern, only survives among women and technically ignorant but financially important people to whom set manufacturers must perforce pander if they are to keep out of Carey Street.

A far better instance of what I am getting at is provided by the word "grid" which, despite all the technical terminological changes that have taken place, still preserves its original name given because it looked like a grid just as the "plate" was so called because in its pre-cylindrical days, at any rate, it looked like one. Comparisons are always odious, but they are so in more senses than one in this particular case, where the various grids of the valve preserve their plebeian names while the two original workers in the thermionic vineyard have long ago joined the patrician "ode" family which flourished long before the day when Fleming first pressed cathode rays into the service of "wireless" (16.11.'04).

There would be no difficulty in finding suitable names equal in euphony, dignity and functional description as the cathode and anode. The control grid, for instance, could obviously become an "archode" and all the auxiliary grids could have names of equal aptitude; and while we are about it we mustn't forget the humble heater which would sound so much more imposing as a "thermode."



The knob-twiddling twenties

The Telesmellies

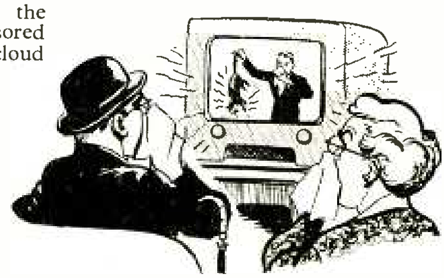
ALTHOUGH, the threat to the B.B.C.'s monopoly of sponsored television is at present "like a cloud no bigger than a man's hand," if I may follow the popular example in misquoting the words of Elijah's servant, we may find that the broadcasting heavens may eventually be black with clouds. If that happens it will be of little use girding up our loins and running like Elijah for there won't be anywhere to run to in order to get out of the storm. Sponsored television would only be the precursor of "sponsored-everything-else."

We can, of course, to some extent defend ourselves from this new menace by forcing the Government to introduce a bill to compel any sponsoring company to which it granted a licence to fit all its transmitters with the necessary apparatus so that listeners who want to hear the programmes without the accompanying advertising could do so. Fortunately this is, technically speaking, quite a simple matter and, as you have been quite correctly told (*W.W.*, August, 1951), certain U.S. transmitters now cater for listeners who prefer plug-free programmes.

This U.S. system of vocal evisceration or cackle-cutting ought to be adopted here. It would first be necessary to provide everybody with a special television receiver or adaptor unit at the expense of the sponsoring company which would give a tremendous fillip to the business of all sections of the radio industry. These receivers would be fitted with a blurb-bludgeoning relay which would be actuated by special signals sent out from the transmitter whenever the sponsorer's tall-tale teller came on the air to talk about the goods or services provided by his company. Should some viewers with perverted American tastes really want to hear all about "Buggins' Bed-bug Banisher" a turn of a switch would cut out the relay.

There is nothing in the least fanciful about this and I would suggest that the system be extended and the B.B.C. be compelled to send out these special cackle-cutting signals so that we can muffle the mouthings with which certain of the disc jockeys mar the music they provide for us.

This system of causing the transmitter to operate relays in the receiver has its dangers, of course, since the advertising moguls might easily fit the receivers with bottled perfumes and a relay-operated release valve on each cylinder. The addition of the smell of fragrant coffee and crisp gammon rashers to a televised breakfast scene would undoubtedly lower the sales resistance of viewers to these comestibles, and the realistic effect of a whiff of sulphuretted hydrogen added to a documentary on drains would have to be smelt to be believed. The result of this would be that the commercial broadcasting interests would unjustly get the credit of having invented the telesmellies.



Realistic effect

History Repeats Itself

IT did not surprise me to read that a County Medical Officer had drawn attention to the bad effect on children's health produced by long hours in a stuffy room gazing at television. I well recollect hearing from my mother of the stern denunciation by her father of similar evil effects produced by over-addiction to the musical box and zoetrope. In my young days the phonograph and the bioscope were the scapegoats, while, of course, tickling cats' whiskers brought my own children to the verge of physical and moral ruin. Interplanetary travel during homework hours will, I feel sure, undermine the health of my great-grandchildren.