Wireless World

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Domestic Radio on Show

THE British radio industry is nothing if not resilient. Early in the year it suffered the shock of doubled purchase tax on domestic sound and vision receivers and valves. Besides, it has been labouring for some time under a feeling of uncertainty as to its commitments for the national defence programme. Then there have been threatened or actual shortages of essential materials. Taking all these things into account, it might well have been expected that manufacturing programmes, as made evident at the recent Radio Exhibition in London, would have shown distinct signs of austerity and a marked tendency towards the cautious *status quo*.

As is shown in our review of the exhibition, printed elsewhere in this issue, the contrary is the case, and a distinctly healthy state of affairs is revealed, at any rate in regard to television. In this branch of the art and in domestic sound receivers the exhibition may fairly be said to have been representative, though no other branches are fully covered.

In television the absence of austerity was particularly noticeable, and a rather unexpected trend towards bigger pictures was clearly evident. Last year we recorded the tendency towards standardizing the 12-in tube for direct-viewing sets: that practice is now well established, but, surprisingly, we have many sets with still larger tubes of 15in and 16in, while the 9-in type has almost disappeared. There was even a 21-in model, though this is by way of being a novelty at present.

So far, the question of metal *versus* glass for cathode-ray tube cones has not developed into an open battle, and, broadly speaking, the use of metal has been restricted to the larger tubes. No doubt the scarcity of the particular type of steel alloy used for this purpose has imposed rather artificial and perhaps temporary restrictions.

Although dogmatism would be unjustified, it is fair enough to say that the amount of effort put into the development of larger and still larger tubes suggests great confidence in direct viewing as opposed to projection systems, for which there seems to be, among the majority of designers, rather less enthusiasm than last year.

In sound receivers there is a much greater tendency towards standardization in technical features, and much less to record in the way of trend of design. The comparatively few novelties introduced are in the nature of the single swallow that proverbially does not make a summer. Perhaps, however, the "valveless" crystal-triode set shown as a non-commercial novelty this year may point the way to future trends. Though crystal-triodes are not yet ordinary articles of commerce, it is a fact that crystal diodes and contact rectifiers generally are coming into wider use in conjunction with thermionic valves, both in sound and television receivers.

Unkind things are often said about the mechanical design of radio equipment, but these reproaches are becoming rather out-dated. The principal advance noted this year in the way of mechanical design is the provision of better accessibility, particularly for maintenance, and this subject is treated at length on another page.

It is pleasing to record a tendency to group valves for domestic receivers into something approaching "preferred" ranges. These, while meeting the needs of most designers (and simplifying their tasks) help to restrict the number of different types in use.

Although, as we have already said, the exhibition was fully representative only in the field of domestic equipment, there was at least enough in some other spheres to attract the visitor with other interests. In this connection we must not forget the highly successful Convention on Audio Engineering, organized by the British Institution of Radio Engineers. The convention was held in the exhibition building, and proved to be a valued extra attraction to many visitors with specialized interests. A selection of some of the topics discussed is dealt with elsewhere in this issue. *Wireless World* believes that the holding of conventions, meetings, lectures and demonstrations in conjunction with the annual exhibition would do much to enhance its prestige and value.

Radio Exhibition Review

Trends in Domestic Receiver Design—and Some Highlights

In the following pages the technical Staff of *Wireless World* report on tendencies in design as exemplified at the 18th National Radio Exhibition

TELEVISION

AN obvious trend in television receivers, which even the least observant visitors to the Exhibition cannot have failed to notice, is towards larger pictures. Last year 12-in tubes were in the majority, but with the 9-in still very well represented. This year 15-in and 16-in tubes are roughly as common as the 12-in and the 9-in is plainly disappearing; there was even one set with a 21-in tube! This trend is perhaps most plainly shown by the fact that a 15-in tube no longer looks large, while a 9-in definitely seems very small.

In the cabinet work the favourite material is wood, for both table and console models. Plastic cases are still used by some firms and Sobell have even a console model of this type, but they are comparatively rare. The "safety glass" is commonly a plastic, moulded to the tube contour and very frequently it is tinted. Such tinted screens permit better contrast to be secured for daylight viewing, provided always that the picture itself is bright enough to stand the transmission loss of the screen. At least three different densities of screen are used. Of some 29 firms exhibiting direct-viewing receivers, some 13 had models with tinted screens and the rest had clear screens. There is, therefore, no general trend one way or the other and the choice is a matter of personal preference; some makers have models of both types.

The picture shape is still usually rectangular, but a few models are designed with the so-called "double-D" picture. In this the sides of the picture are curved and the top and bottom straight; the picture width is made equal to the diameter of the tube. An effectively bigger picture is thus secured, but the corners are lost. As there is commonly little of interest in the corners, this loss is not very important.

The transformerless technique which has been developed in the last few years is obviously here to stay. A very common practice is to use an auto-transformer which is tapped for the mains-voltage adjustment and which enables a supply of 250V to be obtained from all mains. The h.t. supply is taken directly from this through a half-wave rectifier and the valve heaters are series-connected in groups and fed from a tapping. The ratios involved in the auto-transformer thus do not depart very widely from unity and so the component is much smaller, lighter and cheaper than a double-wound transformer. Its stray field is also much smaller. The disadvantage that there is no isolation from the mains is not an important one in commercial practice, because the cabinet provides the necessary insulation.

Some sets do not have the auto-transformer and these are suitable for d.c. operation as well as a.c. Since no step-up of voltage can be obtained on d.c. supplies, they must obviously be designed for the lowest voltage supplies and a dropping resistor used for higher voltages. This increases the heat dissipation and makes the design more difficult.

The e.h.t. supply for the tube is nearly always derived from the line fly-back[1] and the voltage used is

[1] "Flyback E.H.T.," by W. T. Cocking, *Wireless World*, August and September 1950.

considerably greater than a few years ago. The use of 7-10 kV is now common in 9-in and 12-in models and up to 14 kV in the 16-in. This has resulted in a marked increase of picture brightness; in fact, in many cases the picture can be made too bright. Above a certain level flicker becomes evident and this point can be reached in many of the new sets—even in the 16-in tube ones. In order to improve the regulation of the fly-back e.h.t. supplies, some makers fit a Metrosil resistor across their output. This has a resistance which depends markedly on the applied voltage and so a rise of voltage results in a lowering of resistance and an increase in the current drawn from the supply, with the result that the rise of voltage is less than it would be without the stabilizer. One example of this method is the Ekco T164—a table model with a 16-in tube.

Economy scanning circuits are widely used. Their use is essential with some of the new "short" tubes, which are better named "wide-angle" types. In these the pentode used for the line scan is arranged to be operative for about two-thirds of the scan only and the initial third is provided by a diode controlling the release of the energy stored in the deflector coil at the end of the fly-back. This energy is utilized to charge a capacitor which is connected in series with the h.t. supply—the system being commonly known as h.t. boost. Without it, the transformerless set would be almost impossible. The system depends on the use of low-loss materials for the scanning components and for this reason Ferroxcube has largely displaced laminations for the line-scan transformer.

One of the greatest practical difficulties with such circuits is in securing a linear scan and there are two different methods in use. The first is usually attributed to Schade[2] and in one form is exemplified by the circuit of Fig. 1 which is the scanning circuit of the Bush TUG26—a 16-in model. In this, V_1 is the line-scan output pentode which feeds the e.h.t. rectifier V_2 through the usual auto-transformer. The economy diode is V_3 and, since its cathode is connected to a point of high peak pulse voltage, the heater-cathode potential is kept low by feeding its heater through a bifilar winding on the auto-transformer. Picture width is controlled by varying the tapping point of the deflector coils on the auto-transformer by the switch S and the choke L_1 enables the effective inductance loading to be kept roughly constant. The main linearity circuit is LC; the pentode current flows through a part of it and develops a voltage to control the diode. For a more detailed description of the characteristics of circuits of this type the reader is referred to recent article in *Wireless World*.[3]

An alternative method of linearity control is to insert a saturated reactor in series with the deflector coil. The scheme used by Ekco is shown in Fig. 2. Here L_1 is the saturated reactor. In this case the coil is wound on an open Ferroxcube core which is saturated to the requisite degree by a permanent magnet. An adjustment is provided as a linearity control. The back-e.m.f. developed across it falls as the current increases and so acts to control the current in the

[2] "Magnetic Deflection Circuits," by Otto H. Schade, *R.C.A. Review*, September 1947.

[3] "Efficiency Line-Scan Circuits," by W. T. Cocking, *Wireless World*, August, September and October 1951.

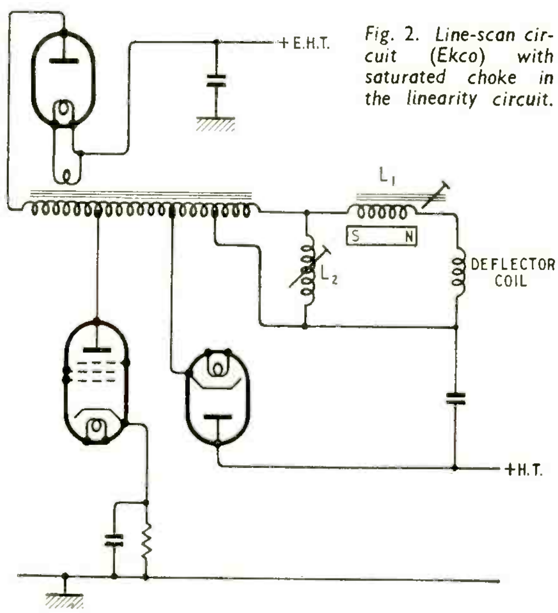


Fig. 2. Line-scan circuit (Ekco) with saturated choke in the linearity circuit.

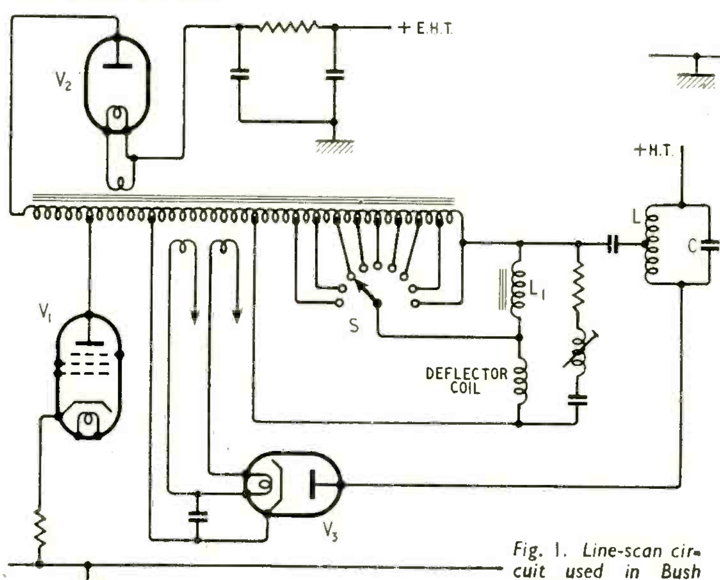
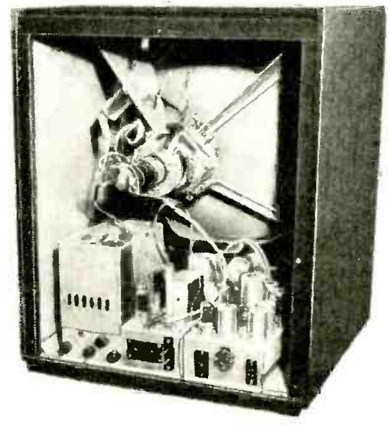


Fig. 1. Line-scan circuit used in Bush TUG26.



Ekco T164 receiver with 16-in tube.

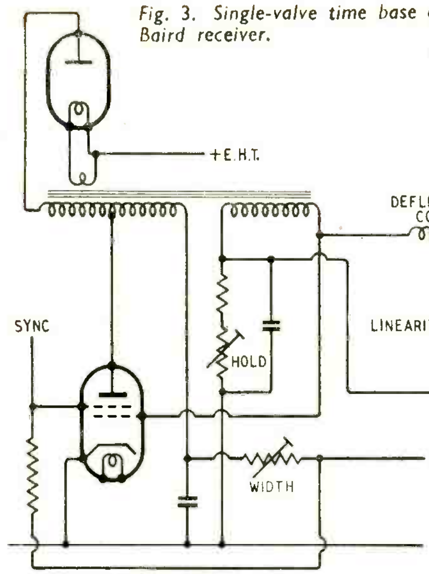


Fig. 3. Single-valve time base of Scophony-Baird receiver.

diode, tending to cut it off towards the end of the scan. Instead of the permanent magnet, a closed core is sometimes used with an extra winding through which a controllable direct current is passed to adjust the degree of saturation. The shunt inductance L_2, in Fig. 2, is adjustable as a control of picture width.

While most sets probably still use an output pentode driven by a separate saw-tooth voltage generator for the line-scan, there is an increase in the number in which a self-oscillating current generator is employed. There are several forms of this. Scophony-Baird use the arrangement of Fig. 3, in which the transformer is coupled back to the control grid. This electrode also acts as an "economy" diode, but it does not permit h.t. boost to be obtained.

In the case of the G.E.C. BT5145, however, the self-oscillating action is obtained between the control and screen grids (Fig. 4) and the anode circuit is similar to that of a driven output stage. A diode V_3 is used and gives h.t. boost.

With the larger tubes now used the line structure of the picture naturally becomes more prominent unless the viewing distance is proportionally increased. To counter this the Ekco TC165 is fitted with spot wobble.[4] A small extra pair of deflector coils is fitted between the focus magnet and the normal deflector coils and is fed from a 11.5-Mc/s oscillator to provide a small vertical deflection at high frequency. There is an amplitude adjustment at the rear and a switch is provided to cut out spot wobble. This is almost a necessity since the focus adjustment is much more difficult if the lines cannot be seen.

Frame time-base design is much more conventional and nearly always there is a saw-tooth voltage generator followed by a pentode transformer coupled to the deflector coils. An exception is English Electric, who use a high-inductance deflector coil resistance-capacitance fed. The voltage generator is quite often a blocking oscillator, but some makers prefer to use two valves working as a multivibrator. For example, Baird use a cathode-coupled multivibrator, whereas Philco employ earthed-cathode valves connected in the original Abrahams-Bloch form.

Compensation for the finite reactance of the output coupling circuit is always needed, and there are two main forms in general use. One, due to Blumlein,[5] depends on negative feedback through both differentiating and integrating forms of circuit. The other depends on pre-distorting the input to the output valve by passing it through an RC-network which has the effect of adding a more or less linear saw-tooth wave to its integral.[6] Neither circuit is new; both are well-known and have been used for years and one cannot say that there is any definite trend towards a preference for either.

Turning now to the signal side, there is a marked tendency towards the superheterodyne in preference to the straight set. This is unquestionably due to the

[4] "Television Spot Wobble," by R. W. Hallows, *Wireless World*, March 1950. "More About Spot Wobble," by T. C. Nuttall, *Wireless World*, May 1950.

[5] "Time Bases," by O. S. Puckle, p. 137 (2nd Edition). Chapman & Hall.

[6] Puckle, *loc. cit.*, pp. 117-123.

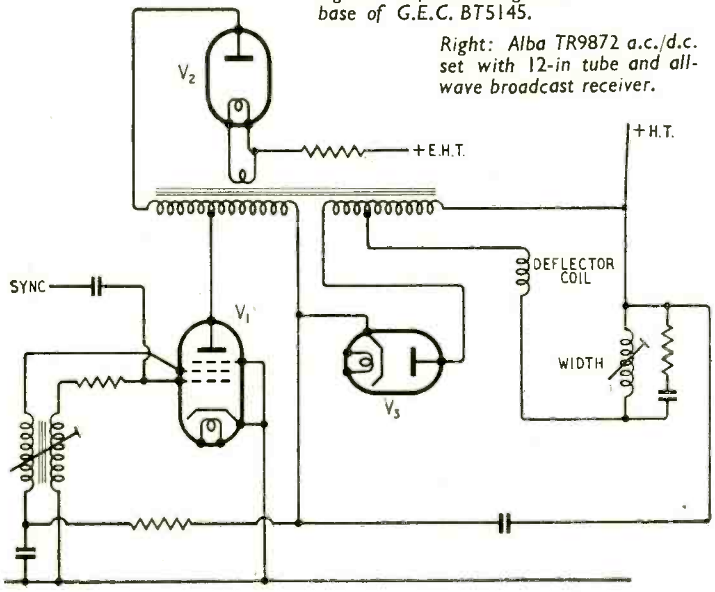
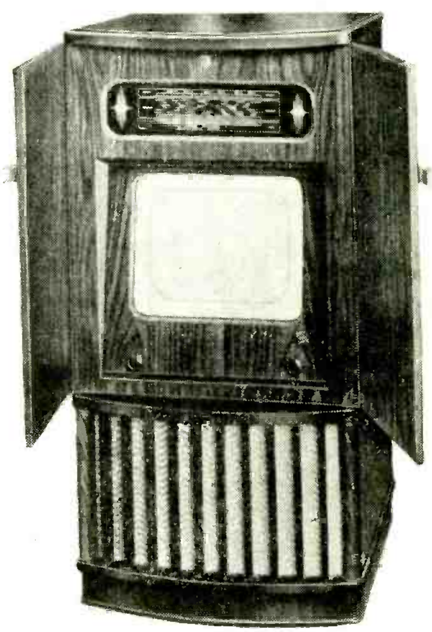


Fig. 4. Self-oscillating time base of G.E.C. BT5145.


Right: Alba TR9872 a.c./d.c. set with 12-in tube and all-wave broadcast receiver.

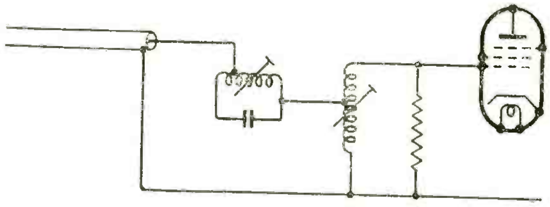
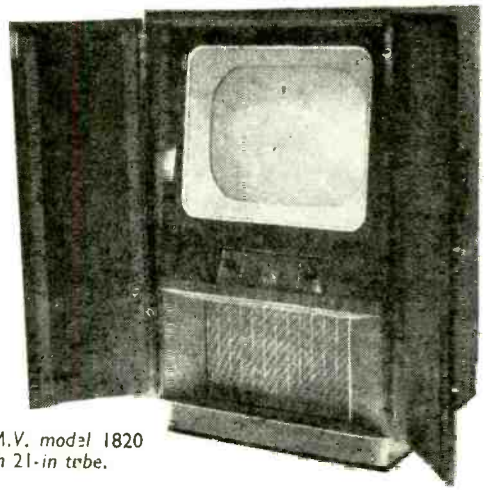
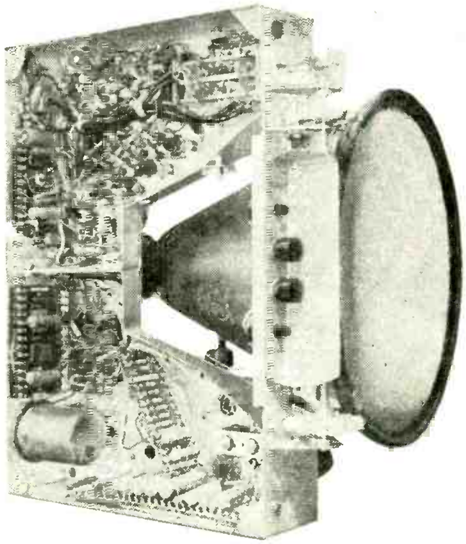


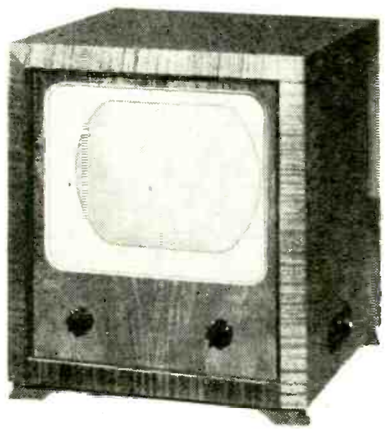
Fig. 5. I.F. input rejector used in Invicta T112.



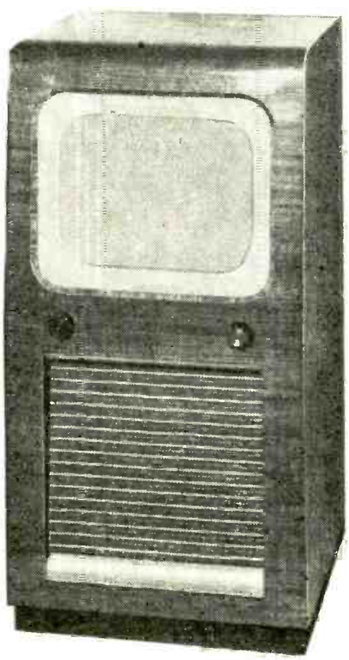
H.M.V. model 1820 with 21-in tube.



Underview of chassis of English Electric receiver.



Pilot TM54 table model receiver with switch channel selection.



Ferguson console with 16-in tube.

Plug-in coils for channel selection in Philips television receiver.

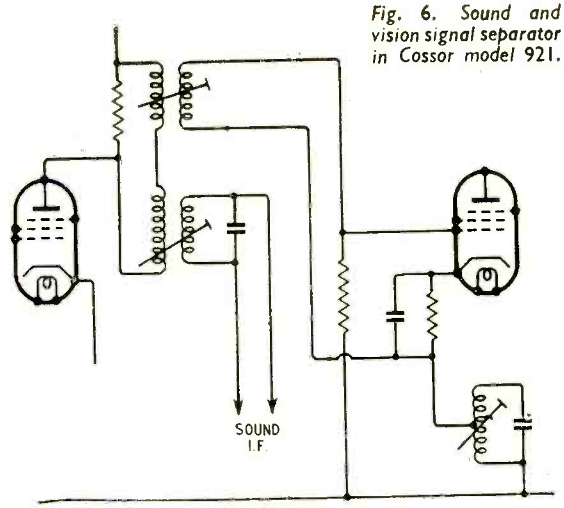


Fig. 6. Sound and vision signal separator in Cossor model 921.

need for catering for five television channels. There is also a definite trend towards the use of higher intermediate frequencies and a figure of some 34.5 Mc/s bids fair to become standard. This high frequency has been chosen largely because it permits much greater freedom from the special superheterodyne interference problems. It is probably the only frequency which gives such freedom on all five television channels. The factors involved were dealt with in *Wireless World* some time ago.[7]

Because the frequency is nearer the signal frequency, however, there is a greater risk of interference from signals on the intermediate frequency and, to counter this, sets with the 34.5-Mc/s frequency often include an input trap circuit. The Invicta T112 is an example and has an input wavetrap tuned to 36 Mc/s (Fig. 5).

The usual practice is to have one r.f. stage at signal frequency and a frequency changer which is quite often of the single-valve type. Some sets have three signal circuits, but two only is a common number. These early circuits are common to both sound and vision channels and the split takes place after the mixer. One method of doing this is shown in Fig. 6; this is used in the Cossor 921 and the sound-channel rejector takes the form of a cathode trap in the first vision-channel i.f. stage.

The method of catering for reception of any of the five television channels varies very much from one set to another. Quite a number provide continuous tuning by fitting the signal- and oscillator-frequency coils with dust-iron cores and designing them to give the requisite coverage. In some cases (Ekco), the adjustment is made in the factory; in others, (Bush), they are arranged as a user adjustment.

This continuous coverage is by no means universal, however, and several other schemes are in use. Pye and Invicta have tapped coils so that the dealer can make a change of channel by altering certain connections. Philips adopt plug-in coils; the coils are pre-set in the factory and one set can be plugged-in in the place of another without adjustment. Other firms make signal and oscillator circuits with their valves as a complete sub-unit which can be replaced if a different channel is needed. This scheme is used by Murphy and G.E.C. and is almost invariably the one adopted when the straight set is retained.

[7] "Television Station Selection," by W. T. Cocking. *Wireless World*, July 1949.

Diode noise limiters are now standard fittings on both sound and vision channels. On the sound side a series diode is usual, but on vision there is more variety. A biased diode across the tube input is common but a similar diode is sometimes fitted to the detector output instead. A third variety is the use of a biased diode to give negative feedback on the video stage on noise peaks.

In most sets, the v.f. signal is fed directly to the cathode of the c.r. tube but in the English Electric model an a.c. coupling is used with a black-level clamp. This is not the same as the usual d.c. restorer circuit, which works on the sync-pulse amplitude, for it operates on the black level of the back porch. A diode is used and is switched by a sine wave derived from the ringing choke e.h.t. circuit.

Projection television sets based on the Mullard tube operating at 25 kV and using the Schmidt optical system were well in evidence last year. This year they take substantially the same form. The different models are all similar so far as the projection part is concerned but differ in their circuitry, cabinet styles and viewing screens. Models were shown by Philips, Decca, Dynatron, Peto-Scott, R.G.D., Etronic and Valradio. This last firm had a model designed for a power supply as low as 50-V direct current.

As an example of television technique Mullard exhibited a system which could reproduce on a television screen anything written on a glass screen. A sheet of glass was scanned by a projection tube operating at 25 kV and using the Schmidt optical system. Anything placed on the screen,—writing, a photograph, etc.,—reflects light according to its character and this reflected light is picked-up by a photo-cell. The resulting video signal is amplified. It is, in effect, a television transmission system using a flying-spot scanner. Although shown in the form of a novelty it has obvious application to radar, where it can be used to superpose a map or written information on a plan-position indicator.

BROADCAST RECEIVERS

ALTHOUGH television may be said to have "stolen the Show" the sound broadcast receiver is still the focal point in the majority of homes, and the industry offers a sufficient variety of four-valve superheterodynes in polished veneer cabinets to sustain the pre-war atmosphere of the stands. For the most part these follow strict economy in circuit design and provide a performance which is adequate under present medium-wave conditions, but here and there a welcome break from convention is to be noted. In the Ace Radio "Selector" chassis, for instance, the usual 532-pF tuning condenser is replaced by one of 187 pF maximum in each section, giving a more favourable L/C ratio in the tuned circuits and some measure of bandspread tuning. There are two medium-wave ranges, 130-275 metres and 270-570 metres; the long waves cover 1,000-2,000 metres and there is a short-wave range of 16-33 metres.

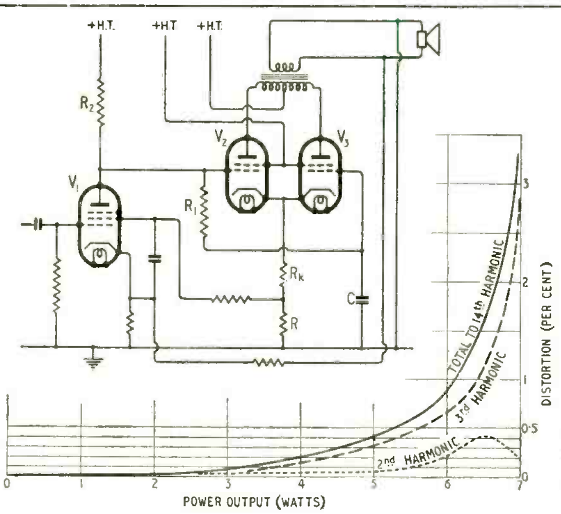
Quite a few table models now incorporate frame aerials for flat dwellers and others who may find it inconvenient to take advantage of an outdoor aerial. The Ekco "Festival" set is of this type and is also notable for the fact that switched tuning of four fixed stations takes the place of the normal continuous tuning scale. In the Ferranti Model 215 the frame aerials are switched out of circuit and separate input tuning coils used with an external aerial.

In general the export versions of most manufacturers' sets contained the refinements, which, before the days of purchase tax, would have been available at a price attractive to the home market. The 9-valve circuit of the Murphy 160, for instance, has been designed primarily for optimum short-wave efficiency and incorporates 10 wavebands selected by push-button, eight with bandspread tuning. Maximum gain is derived from the push-pull output stage on short waves, but negative feedback is introduced on the medium-wave range. Several H.M.V. export models (e.g., Models 5312 and 5411) employ an earthed-grid triode as r.f. amplifier on the short-wave ranges. The Marconiphone T28 series also adopts this form of r.f. amplification and the T28BT is designed for operation from a 6-volt accumulator; press-button illumination of the tuning scale is provided in the interest of battery economy. Six-volt operation is also a feature of some Bush export receivers and of the Invicta Model 94 export model.

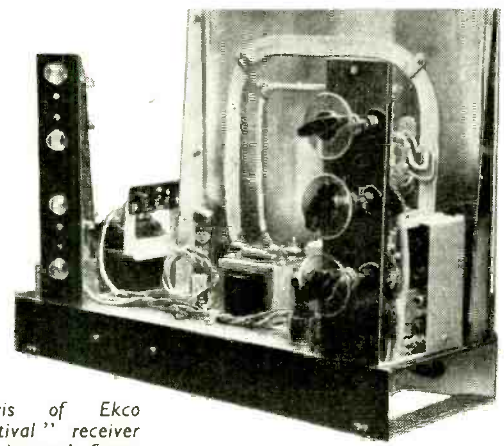
Increasing public interest in the possibility of higher quality of reproduction is reflected in the return to push-pull output stages in moderately priced consoles and radio-gramophones as well as in the luxury class. Typical of this trend are the Bush SUG26 and the McMichael 551AC.

One of the most interesting push-pull circuits technically is that used in the new Ferguson "300" radio-gramophone. Phase reversal is effected in the output stage itself which is cathode coupled*. The grid of V_3 in the accompanying diagram is tied down to earth so far as a.f. voltages are concerned by the capacitor C, but the grid potential relative to the cathode varies in accordance with the fluctuations of current in R and R_k, and is 180 degrees out of phase with the input applied to the grid of V_2. The amplitudes of the a.c. components of the cathode currents in each valve, which are in opposition, are not quite equal and the difference provides the drive for V_3. The resistance R_1 is necessary only for bias purposes. One disadvantage of the cathode-coupled circuit is that it is not self-compensating as far as fluctuations of h.t. supply are concerned, but this has been overcome in the Ferguson amplifier by deriving the screen voltage of V_1 from the common cathode circuit of V_2 and V_3. As far as d.c. is concerned these valves are in parallel, and with this arrangement

* See, for example, S. W. Amos, *Wireless Engineer*, February 1946, p. 43.

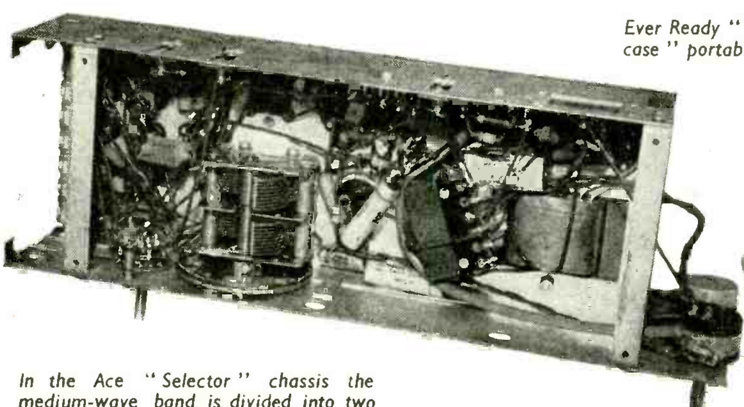


A cathode-coupled push-pull output stage in the Ferguson "300" gives low distortion with economy of components.



Chassis of Ekco "Festival" receiver with internal frame aerial.

Ever Ready "Brief-case" portable.



In the Ace "Selector" chassis the medium-wave band is divided into two ranges using 187pF tuning capacitors.

there is effectively negative d.c. feedback. The anode load R_2 of V_1 is of high value and gives the high internal gain desirable with overall negative feedback; it also gives a steady anode potential which differs from the cathode potential of the following stage by the amount required to bias the output valves. Direct connection to the grid of V_2 is then possible, and with the elimination of the usual RC coupling, much more feedback (actually 30db) can be applied from the output transformer secondary to the cathode of V_1 without low-frequency instability.

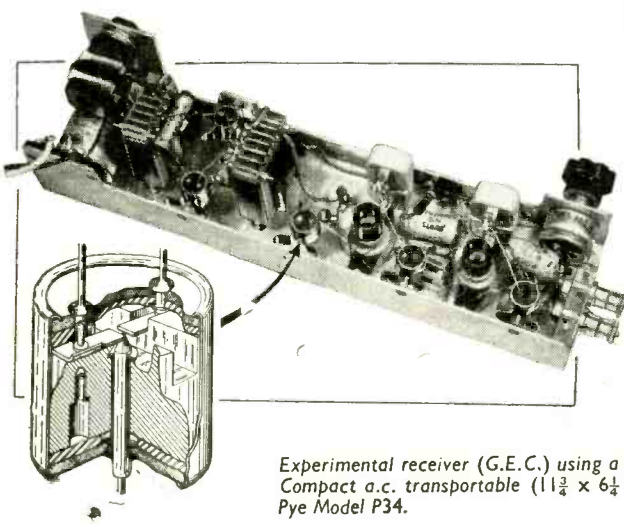
No fundamentally new acoustic methods for obtaining better quality were observed, though the many known alternatives all had their devotees. Murphy showed several modifications of their "baffle" type sets which are designed to present a large surface with the minimum of enclosed air. Avoiding the difficult intermediate types of cabinet, Dynatron go to the other extreme by totally enclosing the back of the loudspeaker to suppress out-of-phase radiation—the so-called "infinite baffle." They use a 4-cu ft chamber to reduce the stiffness due to the enclosed body of air and give it an irregular shape to prevent internal standing waves. A special loudspeaker unit with a fundamental resonance as low as 29 c/s has been developed to offset the rise in frequency on enclosure. Elliptical diaphragms are much in evidence in H.M.V. sets and are also used in some K.B. models. It is claimed that they confer greater freedom in cabinet design than circular types and give a better distribution of high-frequency response.

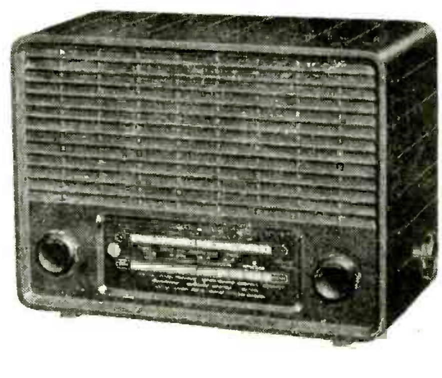
Recent advances in the quality of commercial disc recordings both at 78 and 33⅓ r.p.m. have resulted in complementary changes in the specifications of current high-grade record reproducers and radiogramophones. The H.M.V. Model 1614, for instance, which uses the latest gimbal-mounted lightweight pickup has an input filter circuit which can be switched at will to give a 20 per cent extension of the high-frequency range on the latest (and new) records, above what can be tolerated on early or well-worn records. Both Decca and Dynatron are fitting transcription-type playback turntables in their more expensive models to ensure the very best results from 33⅓-r.p.m. microgroove records.

What of the growing proportion of listeners for whom the sound programmes are a secondary though very necessary interest to television? Neatness and portability are predominant features of the sets which are encouraging them to replace the old table models ousted from pride of place by the television receiver. The demand at the moment seems fairly equally divided between mains/battery receivers, which are suitable for long periods of use in the home as well as for occasional use further afield, and "all-dry" battery portables, which achieve the acme of lightness and compactness in the so-called "personal" sets. The price paid for extreme compactness is limited battery endurance, and the tendency now is towards the slim attaché case form, which, although bigger, is in many ways more convenient to handle. The new Ever Ready "Briefcase" portable is typical of this trend and has a duration of 300 hours with a B107 "Batrymax" layer type h.t. battery and 110-120 hours from the No. 14 l.t. cell.

The decision of G.E.C. to show their experimental crystal triode receiver at the Show serves as an indication of possible future trends. Successful reception of B.B.C. programmes was demonstrated in London just prior to the Show on a receiver consisting of four r.f. stages, the equivalent of an anode bend detector and a push-pull output stage delivering 100 mW to a loudspeaker. Current consumption was 10 mA from a 70-V battery. G.E.C. Research Laboratories have succeeded in solving the chemical problem of extracting germanium in the required degree of purity and

A record changer for 78 r.p.m. and a separate transcription-type turntable for 33⅓ r.p.m. records are provided in the Decca Model 96 radio-gramophone.





Experimental receiver (G.E.C.) using a new type of germanium crystal triode throughout, and right: Compact a.c. transportable (11¾ x 6¼ x 9in) with frame aerials built into a plastic cabinet—the Pye Model P34.

have developed a slotted spring form of contact which, in conjunction with a conical crystal, gives the necessary precision of spacing under manufacturing conditions. It is emphasized that it will be some time before germanium *triodes* are available on the same basis as the diodes and that even then they will probably replace valves in electronic computors, and possibly hearing aids, before they invade the field of radio receivers.

VALVES and CATHODE RAY TUBES

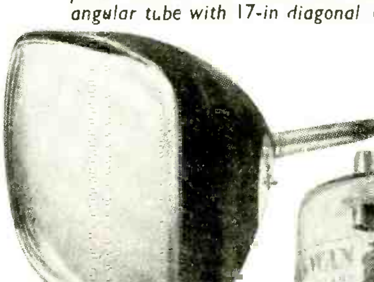
MINIATURIZATION of the receiving valve is now practically complete and the new size is becoming accepted as standard (once again!). Soon, the term "miniature" may be no more than an interesting archaism, unless of course it is kept on to describe what is now sub-miniature. Most of the new types are made in all-glass form, with the electrode support wires projecting straight through the base to form the connecting pins. Battery miniatures are almost exclusively on the B7G base, while mains types are divided between B7G, B8A and B9A (noval)—probably B9A will become standard in the end. The octal valve, standard a few years back, is beginning to look distinctly old-fashioned by comparison, although it is still in current use for the larger rectifiers and power output valves.

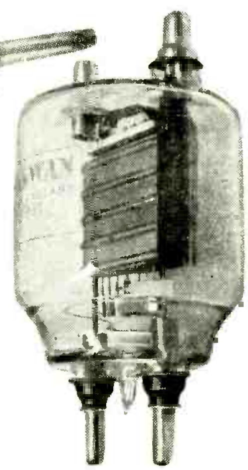
One can tell that the miniature situation has settled down, for a while anyway, by the existence of complete ranges of valves for specific equipments. For broadcast receivers, three firms are producing a 1.4-V battery range, a 6.3-V a.c. mains range and an 0.1A a.c./d.c. range for series-heater operation, all of which are recognizable by characteristic type numbers. Usually the same set of valves forms the basis of both the a.c. and the a.c./d.c ranges, the only difference being in the heaters. In addition, several makers are producing miniature ranges for television; these are mainly on the B9A base and have 0.3-A heaters designed for series operation in a.c./d.c. "transformerless" receivers. Mullard, for instance, were showing a preferred range known as the "World Series" which is designed to be acceptable for receiver design in any part of the world on any television standards.

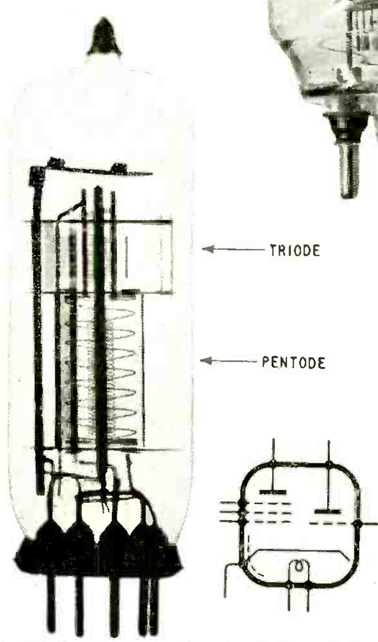
Altogether there is nothing unusual in the characteristics of miniature valves compared with the older types. The fact that they do the same job in a smaller bottle is sufficient. At e.h.f. and television frequencies, however, they definitely show their superiority, for they have short, direct connections and no moulded base to cause losses. They have been criticized as not being reliable enough for use in communications equipment and it is certainly true that manufacturers are aiming at *greater* reliability. S.T.C., for example, were showing a range of "Trustworthy" miniature valves in which the electrode structure—where most failures occur—has been mechanically strengthened and improved; they cost about three times as much as ordinary miniatures, but at what a saving in other directions!

Another design trend in communications receiving valves is towards higher and higher frequencies. Miniature types are generally used, for the reasons stated above, and the spacing between electrodes is being made smaller to reduce the electron transit time. One method of doing this is to make the electrodes co-planar instead of concentric and the tech-

The 21-in Emiscope cathode-ray tube compared with a 1-in model, and below: Rectangular tube with 17-in diagonal (S.T.C.).







Above: Ediswan ES833 general-purpose 400-W triode for transmitting and industrial applications, and left: Our observer with the X-ray eyes saw this when he looked into the construction of the Mullard ECL80 triode pentode.

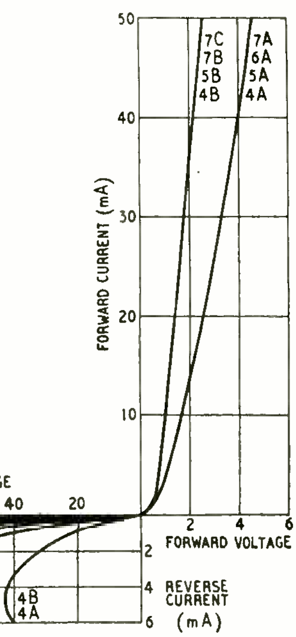
nique has now been extended from the disc-seal valves to valves with conventional connections: an example was shown on a miniature glass base.

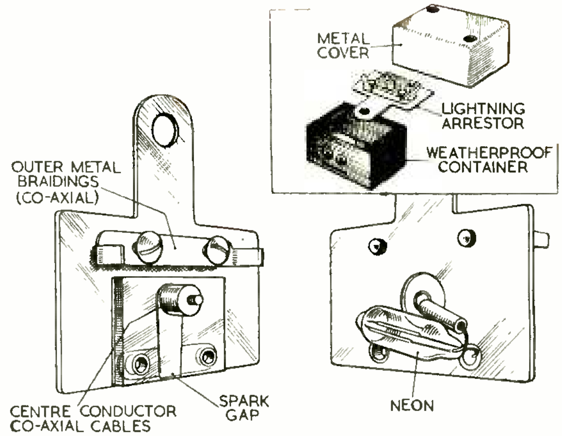
The germanium crystal has now firmly established itself as a useful rectifier and is replacing the thermionic diode in many circuit applications. Not only does it avoid the necessity for heaters but it has the advantages of small size, low self-capacitance, wide frequency range and almost unlimited life. Westinghouse have entered the field with a range identifiable by the letters WG. Much the same story applies to the ordinary metal rectifier, and this is especially noticeable in television receivers. Metal rectifiers are produced not only for the main h.t. supplies but as efficiency diodes and e.h.t. rectifiers; Westinghouse were showing a demonstration circuit giving nine positions where a thermionic diode had been replaced by either a metal rectifier or a germanium crystal.

While the 12-inch cathode-ray tube is still regarded unofficially as a kind of standard, there is a definite trend towards larger direct-viewing tubes in answer to the challenge from projection television. Hitherto, the 15-in tube has been the largest size made completely of glass, but now G.E.C. have come out with a 16-inch model. From this point the metal-cone tube seems to take over. Both English Electric and Mullard were showing their first efforts (16-in tubes) in this field, while H.M.V., in spite of a hint in this journal some twelve months ago, surprised everyone by producing a metal tube, made in the E.M.I. factory, with a 21-in screen. In all these, the metal cone forms the anode connection. Whether this trend will continue or not depends to some extent on the metal supply position. In America, shortage of metal is

U41 high-voltage rectifier made by G.E.C.

Typical d.c. characteristics of the Westinghouse range of germanium rectifiers, WG4A to WG7C.





Aerialite television aerial lightning arrester.

forcing manufacturers to drop magnetic focusing in favour of electrostatic focusing, although there is no sign of that happening here yet.

With these larger tubes one is more aware of the wasted screen space (and extra room needed in the cabinet) that is inevitable with a rectangular picture on a circular screen. Corner-cutting helps but the problem is completely solved by the new tubes with rectangular screens; S.T.C. had one on show with a 17-in diagonal. One point, however, that is noticeable about all the big models is that the overall length has been kept down to something like that of the 12-in tube, while giving a larger picture, by increasing the deflection angle from the usual average of 50 deg to 70 deg.

Anode voltages vary from about 4kV to 17kV. The 9-inch tube goes up to about 8kV, the 12-inch to 10 kV the 16-inch to 14kV while the solitary 21-inch works at 17kV. Generally speaking the smaller sizes use octal bases and the larger ones duodecal. Metal-cone and rectangular tubes make possible flat screens as a matter of course, but some of the smaller tubes also have this feature now. To prevent ion burn, some makers fit ion traps (a magnet steers the electrons on to the right road and allows the heavier ions to blunder into a cul-de-sac) while others rely on aluminized screens. Ferranti consider a better way to avoid this trouble is by suitable processing of the tube beforehand. They do admit, however, that aluminizing brings advantages in brightness and contrast and the process is, in fact, very widely used in cathode-ray tubes now.

Development in transmitting valves is concerned mainly with reaching higher working frequencies and in industrial power valves with improving the safety factors for overload conditions. For industrial control purposes the cold-cathode valve is coming into prominence, while the xenon-filled thyratron is gradually replacing the mercury type.

TELEVISION ACCESSORIES

THE provision of a usable signal beyond the normal service range of a television station continues to be one of the principal problems facing designers of television aerials. No fundamentally new systems have appeared, but many variations of well-known types are being employed. Multi-rod arrays using a number of parasitic elements remain the most popular and systems containing up to 8 elements are not uncommon.

One of the latest additions to this style is the Antiference X2D aerial consisting of two "Antex" or "X" aerials mounted side by side and spaced just under a half-wavelength apart.

A variation of an early type and of which little has been heard in recent years is the tilted-wire aerial supplied by E.M.I. It is a capacity-loaded system and is now available in a 20-foot size for erection in lofts and in small gardens. Hitherto the shortest length was not far off 50 ft.

Apart from this line of development the main changes in television aerials have been towards structural improvements, which, while not always visible to the eye, should make for greater robustness. As an example, Belling and Lee claim that their 4-element "Multirod" for fringe areas will withstand gusts of wind up to 80 m.p.h.

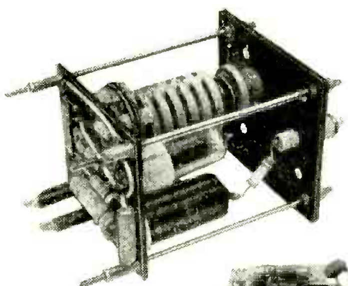
As reasonable safety precautions ought to be taken whenever an outdoor aerial of any kind is used, the introduction by Aerialite of a neat and well-designed lightning arrester is of more than usual interest. It is intended to be inserted in the co-axial feeder at a point convenient for a good earth connection and it contains a small neon bulb in parallel with which is a spark gap. These are joined between the centre conductor of the feeder and earth and little or no disturbance takes place in the impedance matching of the system. The neon flashes over whenever the static charge on the aerial (from a nearby lightning flash or charged rain) exceeds 100 V, while a heavy accumulated charge will jump the gap. This device is housed in a weatherproof rubber container.

Several improvements in the indoor fittings used with television aerials are now becoming evident. Aerialite have a neat distribution and terminal box in which the insert carrying the connections can be removed for wiring and when re-inserted automatically earths the cable braiding to the box. Belling and Lee have some new distribution boxes for "loop wiring" of indoor aerial points, in which the cable is carried from box to box and not from a common feed point. It is for use mainly in communal installations and each box contains an impedance-matching resistance pad. The loop system of wiring is usually more economical in cable.

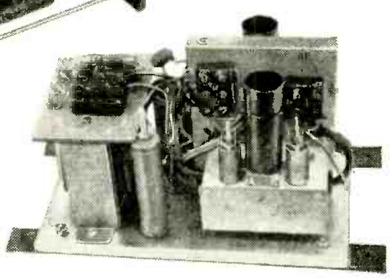
No large-scale television distribution system can be operated satisfactorily without one or more aerial amplifiers: sometimes a single amplifier at the aerial end of the system suffices, in others amplifiers have to be distributed at intervals throughout the system depending on the number of receiving points and the length of the cabling. E.M.I. have made a study of the requirements and have produced a range of one-, two- and three-stage amplifiers, self-sufficient with all power supplies and for use with a single receiver or large multi-point installation such as in hotels and blocks of flats.

A single-stage amplifier giving a voltage gain of 100 and suitable for fringe areas is now made by Scophony-Baird, while one which is tunable over the whole band of television channels is produced by McMichael. The last-mentioned model needs an external power supply.

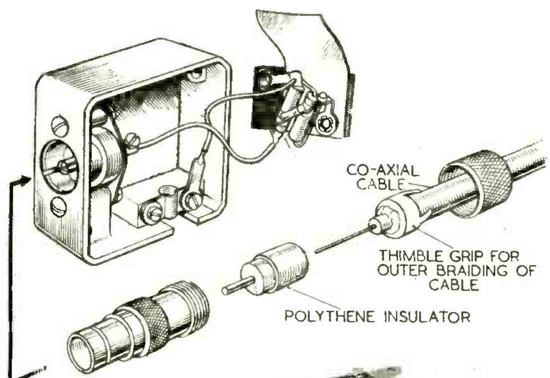
Several new signal generators for testing and aligning television receivers in the absence of a "live"



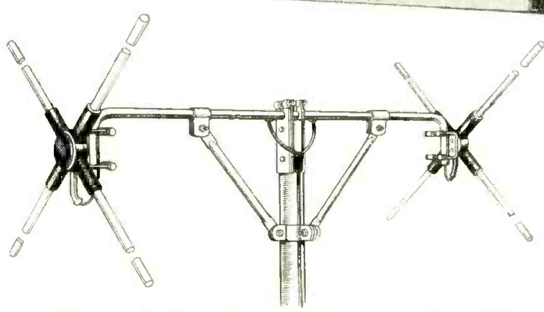
Left: Haynes Radio oil-filled r.f. e.h.t. unit removed from its sealed container.



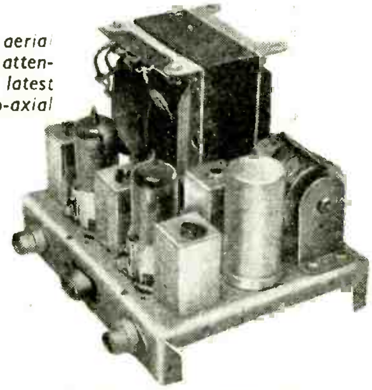
Chassis of E.M.I. 2-stage television aerial amplifier.



Belling-Lee television aerial termination box with attenuator net-work and latest "universal" type co-axial plug.

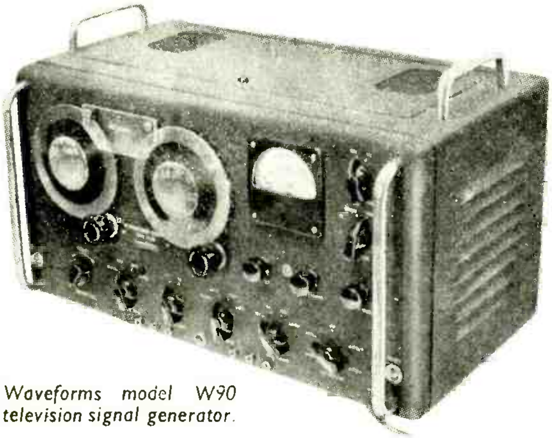


Antiference double "X" television aerial, Type X2D.



Chassis of the Scophony-Baird television pre-amplifier.

transmission have been developed recently. The Murphy Type TPG11, sold by Livingston Hogg, was described in *Wireless World* of February, 1950. It is now available in forms for testing 525- and 625-line receivers. One very versatile unit is the Waveforms



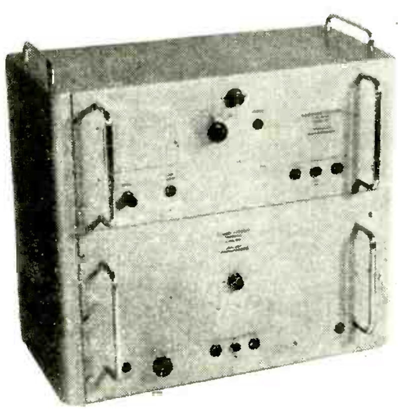
Waveforms model W90 television signal generator.

Model W90. It has two independent and tunable calibrated r.f. oscillators, one for sound the other for vision, with 1,000-c/s modulation for one and the choice of up to nine different forms of modulation for the other. These can be applied separately or in any combination. They serve for checking horizontal and vertical linearity, sync hold and bandwidth.

It is difficult to formulate an opinion of the line of development in television components from the recent show as it was by no means fully representative in this respect. Some fine examples of hermetically sealed and oil-filled flyback e.h.t. and line output units, r.f. oscillator units and e.h.t. transformers are now made by Haynes Radio and these may be a pointer to a continuation of the present trend of development in this field.

SPECIAL-PURPOSE RECEIVERS

ALTHOUGH the domestic broadcast receiver has been used more or less successfully in schools for reception of educational broadcasts, the School Broadcasting Council for the United Kingdom is strongly in favour of the use of specially designed equipment for this purpose. Some examples of this type of set were shown by Ekco, a typical installation consisting of a central radio receiver and audio amplifier with loudspeaker and remote-control units for use in classrooms. The audio output of this Ekco installation is 25 watts and it is capable of operating up to 16 loudspeakers simultaneously. Any number up to 15 can be switched off without affecting either the volume or the quality of reproduction of those remaining in operation. The radio receiver is a superheterodyne and has pre-set tuning for four stations, three in the medium waveband and one in the long, but any other combination can obviously be provided. Programme selection is effected by a rotary switch. Special care is given to the design of the audio amplifier, and a tone control is fitted to compensate for unusual acoustic qualities of different classrooms. There is a 10-watt and a 4-watt amplifier for use with the same radio receiver and also a gramophone unit with a self-contained amplifier for use in individual classrooms.



Ekco schools receiver ; this model includes a 25-watt audio amplifier.

Receivers designed for use in schools, workshops, clubs and wherever group listening is indulged in are made also by Grampian Reproducers. Three models are available giving 8, 15 and 25 watts output respectively. The radio unit of the 15-watt model is a superheterodyne with variable tuning covering either the medium and long wavebands or medium and two short wavebands according to requirements. Provision is made for use of two microphones and a gramophone turntable and separate volume controls are fitted for radio, microphone and gramophone circuits.

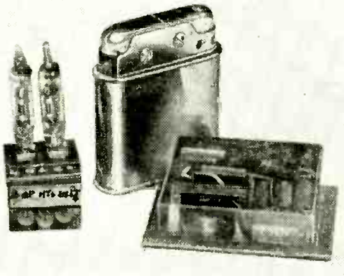
The size, shape and method of marking tuning scales are of far more importance in a communications and a special-purpose receiver than in a domestic broadcast set. The relative merits of semicircular or straight-across scales are too controversial for discussion here, but some significance may be attached to the decision made by Eddystone to standardize as far as possible on the straight-line scale for all their communications receivers. This type of dial is favoured also by G.E.C. in their BRT400 communications set.

The full-width rectangular dial with straight-line scales used by Eddystone for their Model 750 is now fitted to the Model 680 which has been modified and housed in a new cabinet and is known as the Model 680X. A number of detailed improvements has been made also in the circuit.

Conforming to the same external appearance of the Model 680X is a new v.h.f. communications set, the Model 770M. It is a double superheterodyne covering in six bands 19 to 210 Mc/s and having a die-cast rotary coil turret. The set accepts a.m., f.m. and n.f.m. (narrow-band f.m.) telephony and c.w. telegraphy signals and it operates on a.c. supplies of 110 V and 200-250 V, 40-60 c/s.

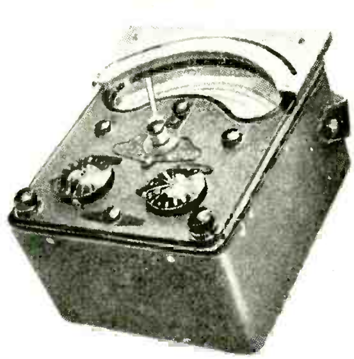
OTHER EXHIBITS

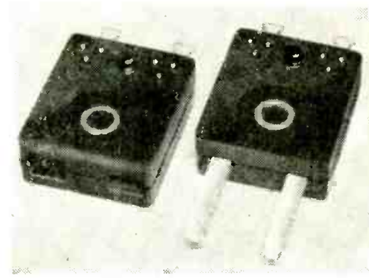
BATTERY manufacturers were not alone in reminding one that radio and electronic apparatus is somewhat useless without power supplies to work it, and a number of advances were noted in this field. A great deal of attention was attracted, for instance, by the Amplion "Activette," a small mains-driven unit which reactivates dry batteries before they run



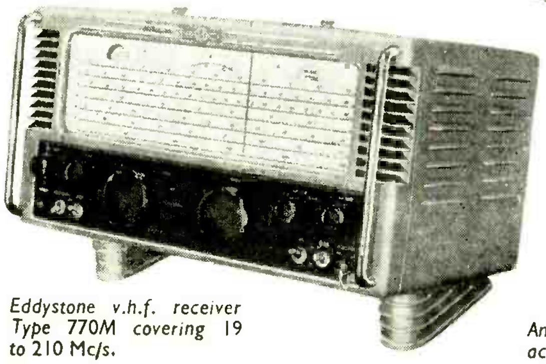
Moulded amplifier units by John Bell & Croyden.

The blind man's Avo.

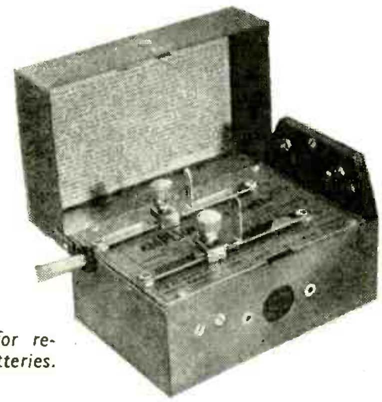




Bulgin unit connector, showing fixing holes.



Eddystone v.h.f. receiver Type 770M covering 19 to 210 Mc/s.



Amplion "Activette" for reactivating hearing-aid batteries.

down and so prolongs their life; the unit is discussed elsewhere in this issue.

Vidor, the makers of Kalium cells, which have four to seven times the life of the Leclanché type, are now concentrating on improved reliability, with X-ray examination as part of their manufacturing process. They were showing a new three-quarters U7 size on their stand. For those who have the wrong kind of power for their domestic sets, Valradio displayed a comprehensive range of vibrator converters; most of these were for obtaining suitable a.c. voltages from low-voltage d.c. supplies. Models for the higher input voltages include a commutating arrangement for switching in a surge-limiting resistor which helps to give something approaching a sinusoidal waveform. Among the stabilized power supplies on view the Ediswan general-purpose model was notable for its low price. The stabilized output is continuously adjustable over 120-250 volts, with variations of less than 0.1V for mains changes of 10V or load changes of 0.5 mA.

In the era of miniaturization it is not surprising that hearing-aid manufacturers should have something to offer towards the general technique. A notable contribution were the tiny "packaged" amplifiers shown by John Bell & Croyden in which all the parts except the valves were set solidly into a moulded block of synthetic resin. They have r.c. coupling and are available with one, two or three stages. One slightly larger model has an input stage, two phase splitters and a pair of push-pull valves giving a maximum output of 30mW. The firm applies the same technique to its miniature transformers, with the advantage of keeping the laminations insulated and at the same time rigid. Transformers generally are being reduced in size and weight by the use of the new grain-orientated C-cores, and a mains transformer shown by Whiteley was a typical example.

The other hearing-aid firm at the Show, Ossicaide, had an instrument fitted with a coil for direct inductive pick-up from sound-reproducing apparatus. Sufficient magnetic flux is set up by a loop of wire round a room fed from a loudspeaker speech coil or by the transformer in a telephone handset.

Technical aid is also a blessing to those who have lost their sight. At the Show it came, appropriately enough, to the blind technician, in the shape of a universal Avometer fitted with a Braille scale. To enable the user to take a reading by touch, an external pointer, pivoted at the same place as the ordinary pointer, is moved across the Braille scale and when it reaches the same deflection it falls perceptibly into lock.

The apparently simple task of making an electrical connection has considerable ramifications in all branches of the art. Making soldered connections is one of the biggest jobs in the production of domestic receivers, and on the Multicore stand was a complete assembly line from the Ekco works (pretty girls and all!) demonstrating at what speed this can be done with resin-cored solder. The technique of connecting complete units together was represented by various plug-and-socket systems; Belling-Lee had a new 18-way miniaturized connector, while Bulgin were showing some versatile two-pole plugs and sockets which could be bolted together and grouped in various ways for as many circuits as necessary. Dubilier showed some resistors with improved connections between the leads and the element, giving not only low-resistance contact but a means of rapidly conducting heat away.

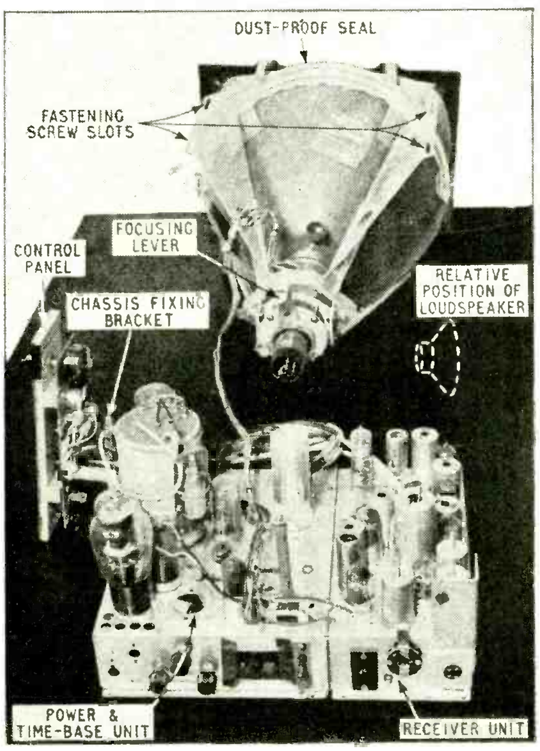
Design for Servicing

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

Examples of Better Accessibility at the Radio Show

IT is no secret that the radio industry and trade are seriously concerned about the servicing problem. The servicing problem, briefly, is this: The spread of television over the country is rapidly increasing the number and complexity of sets that are liable to need skilled attention. Many dealers have had no previous experience of television. Technicians with sufficient intelligence, skill and training reasonably expect an appropriate income, and apart from that they now possess a scarcity value. Radio dealers, who are obliged to pay the technicians (unless they do everything themselves) and a great many other expenses besides, have to make a profit or go out of business. The public, when they have parted with a substantial sum for a television set and the 66⅔ per cent tax, and the licence, and the aerial, are not unnaturally grieved if they are charged heavily for repairs and replacements, including certain costs during the guarantee period. If the sets themselves are trackless mazes of more or less inaccessible parts, difficult to remove from the cabinet and requiring various supports and mountings before they can be worked on the bench, even competent servicemen use up a lot of expensive time on them, and the less competent cannot cope at all and the set has to go back to the maker while the owner is prevented from enjoying a long series of the unusually desirable programmes that always begin on such occasions.

Ekco "Triple-Link" television receiver with units removed from cabinet.



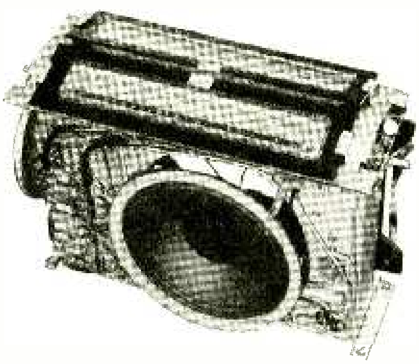
I have referred exclusively to television, because it has greatly intensified the problem, but in a less acute form it was always there.

The recruitment and training of more service technicians has been considered and discussed at length, but clearly that alone is not the whole answer, especially when it has to compete with the rearmament programme. A more effective means of attack lies with the designer to make the sets quick and easy (and therefore cheap) to service.

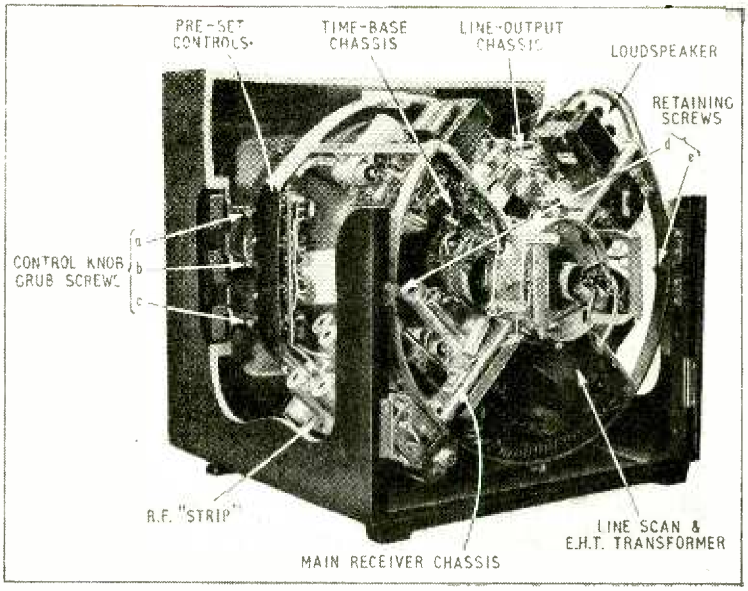
What makes a set quick and easy to service? Foremost, perhaps, all the parts must be readily accessible for adjustment, repair, or replacement. Since a television set of which this was true while still in its cabinet would be a criminally dangerous article to sell, it must be presumed that before serious work can be done on it the cabinet must be removed. This operation alone offers much scope for intelligent design. Some sets we have known left one to guess which screws ought to be removed to release the chassis and which would merely cause premature collapse. Then, when various leads had had to be unsoldered (because one did not have six or seven hands to remove chassis, control panel, loud speaker, etc., simultaneously) it was necessary to remember which lead went where and to solder them all up again, and prop the units precariously about the bench before the set could be switched on.

The aim, then, should be to enable one pair of hands to remove everything in a few moments and have it all on the bench in a connected-up condition. Without any special fitments, and without risk of damage to the parts, the whole set should be capable of being stood up in such a way that all the relevant controls, pre-set adjustments, trimmers, valves, components, metering and oscilloscope points, should be accessible, and at the same time the screen should be viewable, without having to twist oneself into awkward attitudes or run unnecessary risk of electrocution. Finally (assuming that everything can be put back into the cabinet as easily as it came out, without upsetting any of the adjustments), the whole set should be so arranged that important sub-assemblies can be quickly detached and replaced. In this way, even if the work to be done does not come within the powers of the dealer or serviceman, there is the option of plugging in a spare unit so as to let the owner have his set back with the minimum of delay.

So much for the problem and its solution in general terms; now for some actual examples. Rather than attempt to refer to every model seen at the Radio Show illustrating some aspect of the matter, it seemed better to describe in some detail a few outstanding examples of consideration for the serviceman. If most of them are television, that is not for lack of other examples but just because the problem is both more



Ferranti Model 515 receiver with cabinet removed to show accessibility.



Right : Murphy V200 television receiver (with cabinet partly cut away). Only the loosening of screws a-e is required for removal.

difficult and more recent with television. A walk round the Show gave the impression that there is now little to complain of as regards accessibility of sound-only receivers. Whereas a few years ago there was a heavy rectangular chassis on the floor of the cabinet, which had to be unscrewed from below (and was difficult to replace because there was no support for the weight while the screws were being refitted), and often could not be removed without unsoldering leads from the separately mounted loud speaker, the modern chassis is smaller and lighter, has an integral loud speaker, and there is a tendency for the components to be mounted in vertical planes, like the walls of a house. A good example is the Ferranti 515 transportable, the cabinet of which can be removed by taking out four screws, leaving the chassis standing with everything in view. The frame aerial pulls aside to give better access to the relatively few interior components.

The " baffle " type of construction that Murphy have favoured for some years now also makes for accessibility, as the chassis is necessarily very shallow. The A188C " Baffle " Console is a current example.

But good design for servicing can almost be taken for granted in this field, so let us proceed to television, where design is more fluid. There can be no doubt that a great deal of thought has been given to the problem of mounting a large and fragile c.r.t. and a vast assortment of smaller components in a conveniently small cabinet while achieving the desiderata for servicing. In what may be called the conventional or original style there is a large horizontal rectangular chassis, with the c.r.t. mounted above it, reducing the chassis area where things can project above the deck. For small table models the loud speaker has to be mounted at the side, either separately, which calls for an unplugging device, or on the chassis, in which case there may be difficulty in withdrawing the chassis through the back of the cabinet. (Ferranti overcome this difficulty by arranging for the speaker to move backwards a short distance when the mounting is slackened.)

The general outline of this construction is still followed in many makes, but almost invariably there is a tendency to subdivide the deck so that sections of it can be easily removed. This is, of course, particularly true of the stages that determine the r.f. tuning, for in many models there is an interchangeable " r.f. strip " to enable them to be fitted for the appropriate channel. Those firms that include models with or without medium-wave sound usually supply the same main chassis for both, with an optional section for the former.

If the entire set is mounted as one whole, the desire to enclose it in the smallest possible cabinet is likely to lead to cramped layout, and there are difficulties with side-mounted speakers and controls, and perhaps in seeing the screen properly while making adjustments at the rear. So some makers have decided in favour of separate units, and the question then arises of interconnections and easy withdrawal from the cabinet. A good example of an answer to this question is the Ekco T161 " Triple-Link " (see previous page). C.r.t., control panel, loud speaker, and main chassis are separate units; and the chassis itself is really two bolted together, one comprising the receiver unit and the other the time-base and power circuits. For many adjustments (including channel-setting) it is not necessary to take the set out of the cabinet at all, for the underside of the chassis can be exposed by a removable floor, and the upper parts by removing the back. But if total uncovering is necessary, it can be done in a very few minutes. C.r.t. and side-mounted loud speaker are both disconnectable by plugs. The chassis is released by two screws along the rear edge, the front being held by spring-loaded metal " upholstery buttons " on the cabinet floor, engaging slots in the chassis, which can be slid out from them. The control panel, joined by a flexible cable, comes away when a single wing fastener is turned. So that it need not float loose about the bench, it is provided with a bracket by which it can be firmly screwed to the front of the chassis. The 12-in c.r.t. is held, complete with mask assembly and dust-proof seal, in a light metal frame, which can be unscrewed from the cabinet roof. This enables the otherwise cumbersome and fragile tube to be handled easily and safely, and stood on the bench in a convenient position for viewing during the work.

Another welcome feature for the serviceman is that the component fixing screws have no loose nuts to be handled on the other side of the deck; they are integral with the chassis.

The Philips 1101U comprises four units, but although they are quite easily separated by undoing a few screws and pulling out connector plugs, it is not normally necessary to do so except for replacing a complete unit. The cabinet is so constructed that back, top and sides can be removed by undoing four coin-slot screws, leaving the "works" *in situ* with the front of the cabinet and its floor frame. The floor itself can be taken away by unscrewing, to get at the under side of the chassis. A metal framework enables the whole set to be stood on its head or sides without damage. The four units, shown in the photograph, are: (1) receiver chassis, (2) power and time-base chassis, (3) control panel and front-facing speaker, and (4) c.r.t. focusing and scanning unit. An interesting feature is the channel-changing system. On the deck of the receiver chassis there are three B9G valve-type holders, distinguished by colour coding, into which plug a set of cylinders 1in long by ¾in diameter containing tuning coils, numbered according to the television channel. The only other operation is to adjust a single trimmer for maximum sound.

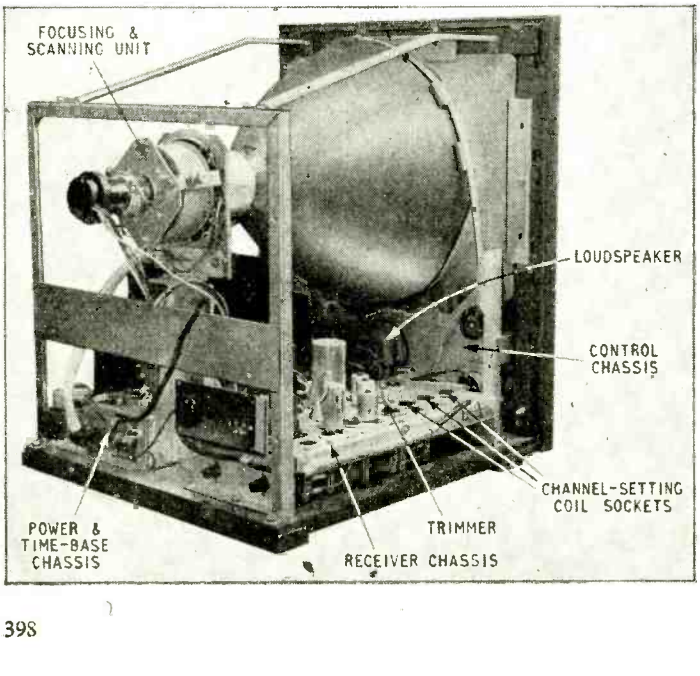
The Philips scheme neatly dodges the control-knob difficulty, which is complicated by the prevailing live-chassis technique since the control spindles must be thoroughly insulated from the user. Another solution is the English Electric edgewise knob, which does not have to be removed when withdrawing the chassis.

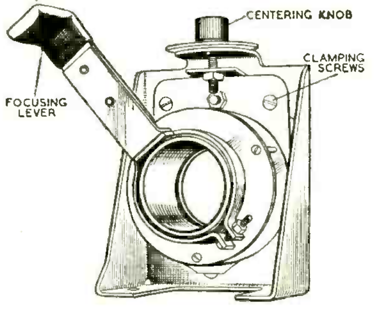
Although the Murphy V200 table model has been described in this journal quite recently,* it can hardly be omitted from a review of this kind, for it is the most unconventional of all. The underlying idea is that owing to the awkward shape and size of the c.r.t. the conventional chassis wastes a large proportion of the space in even the smallest possible cabinet. Adding an upper deck parallel to the lower conflicts with accessibility. But in the V200 the decks are at right angles to one another, four of them being arranged radially with the neck of the c.r.t. as their axis. In this way they do not obstruct one another and there is plenty of room for all the components. It would seem that there is also something to be said for the arrangement as regards cooling. The wheel-like appearance of the structure is increased by the circumferential hoops, which enable it to be rolled over on the bench without damage. As the picture shows, there is an r.f. strip along the outer edge of the main receiver chassis; this can be changed, to adapt the set to a different channel, through the removable bottom of the cabinet. On occasions when it is necessary to uncover the whole set, it is done merely by loosening two nuts, one on each side of the rear hoop, and three control-knob grub screws, enabling the knobs to be withdrawn. The whole structure can then be slid out through the back of the cabinet. The loud speaker is the only unit left behind; it is automatically disconnected by withdrawal of the chassis, which is held in the front of the cabinet by lugs push-fitting into sockets, and these serve also as speaker connections. When the set is being run on the bench these lugs should be connected to a speaker, an artificial load, or (lacking anything better) short-circuited, to avoid risk to the output valve.

The Ultra table model is less revolutionary but the designer obviously kept the servicing viewpoint prominently in mind. Among features that are likely to appeal are the prop stand (a strip of metal that pulls out from the side to enable the chassis to be rested conveniently on the bench), easily detachable e.h.t. unit, quick-release c.r.t. mounting, and an exceptionally convenient picture-centering adjustment. Slackening two screws releases a spindle by which both vertical and horizontal adjustments can be made with one hand—by screwing up and down and moving from side to side. It is then clamped by retightening the screws.

The projection type of receiver is generally not too difficult to lay out, because there is no large c.r.t. and it can be assumed that there is a console type of cabinet to roam about in. But unless the matter has been considered during design the serviceman may have some trouble in seeing the picture properly while adjusting the optical system. Etronic (for example) provide for this by a quickly removable front panel to the cabinet, giving access to the projector from that position.

* August 1951, page 324





Ultra focus unit, with knurled, insulated knob for picture centering. The picture does not shift when the knob is released nor when the clamping screws are tightened.

Left: Philips 1101U television receiver opened up for servicing. It has a metal frame, from which the back, top and sides have been removed by undoing four coin-slot screws.

"FMQ"

By W. S. MORTLEY, A.M.I.E.E. *

Circuit Giving Linear Frequency Modulation of a Quartz Crystal Oscillator

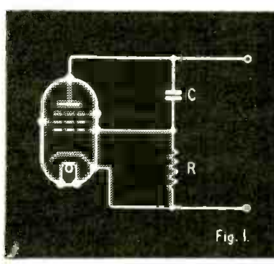
THE Marconi "FMQ" system was devised in order to obtain a simpler and more reliable frequency modulating circuit than existing systems, whilst maintaining adequate carrier frequency stability and low distortion. The title, the initial letters of "Frequency Modulated Quartz," should be interpreted literally. That is to say, in this system a quartz crystal oscillator is *frequency* modulated, not phase-modulated by a signal of modified frequency response (amplitude inversely proportional to frequency), as are many systems. Thus it is capable, basically, of being modulated by d.c. as in frequency shift keying.

The first difficulties likely to be encountered in such a system are those of obtaining sufficient frequency deviation and sufficiently low distortion. Clearly some kind of "reactance valve" circuit has to be used and it is important to consider the relation between input voltage and "reactance" of such a device. It is almost general practice to obtain the "reactance" by feeding an r.f. signal from the output of an amplifier back to the input via a quadrature network.

A simplified arrangement of one particular type of circuit for achieving this is shown in Fig. 1. The amplifier valve takes a leading current and appears to a circuit connected across the terminals as a capacitance whose value (approximately $g_m RC$) varies linearly with the value of the valve mutual conductance. Over small ranges of frequency, such as are required for f.m., linear modulation will be achieved if such a circuit is connected across an oscillator parallel tuned circuit, and the g_m of the amplifier valve is varied linearly with the applied modulating frequency. Such a modulator really results in a linear variation of susceptance, rather than of reactance, and would be more appropriately termed a susceptance modulator.

The effective electrical circuit of a crystal with plated electrodes, in the neighbourhood of a resonance, is shown in Fig. 2 and will be seen to be composed of a series resonant circuit L_c, C_c, r_c, in parallel with a capacitance C_p. The series resonant circuit is the electrical effect (as measured at the terminals) produced by the mechanical resonance of the quartz plate in conjunction with its piezoelectric properties and C_p is the ordinary electrical self capacitance. Ignoring, for the moment, the embarrassment of C_p, we find that we have a series circuit where we want a parallel one and that its impedance, in any case, is quite unsuitable. However, it is a well-known property of a quarter-wave line, and of its lumped equivalent, that the admittance measured at one pair of terminals is proportional to the impedance connected to the other pair. Series circuits are transformed, or "inverted," to parallel circuits. Thus the equivalent series crystal circuit of Fig. 2 will be inverted by an equivalent quarter-wave line (such as that in Fig. 3) to the parallel circuit of Fig. 4, if C_p is included as part of the adjacent capacitor of Fig. 3. Clearly we do not want to invert the whole crystal circuit (i.e., including C_p) because then there would be an equivalent inductance in series with the equivalent parallel circuit measured at the far end of the line and this could not be modulated linearly by a normal susceptance modulator. For this reason C_p is made to vanish by including it as part of the quarter-wave network. A quarter-wave circuit always inverts accurately, but when the frequency is changed a fixed network ceases to be a quarter-wave network and therefore introduces some distortion. However, for small changes of the order of plus or minus one or two parts in a thousand, which is all we require, the approximation resulting from fixing this circuit is sufficiently good. It is found that alteration of the value of the capacitance in parallel with C_p produces second harmonic distortion of sign depending upon the direction of the error, so some other distortions in the system could be balanced by this means although, in fact, it has not been necessary. Varying the other condenser, of course, is similar to varying the modulator susceptance, and varies the carrier frequency linearly with capacitance. It should

* Marconi's Wireless Telegraph Company.



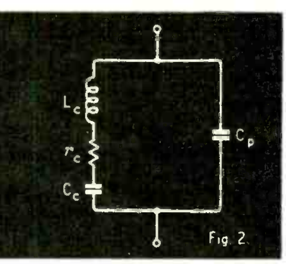
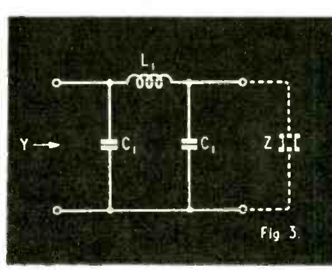


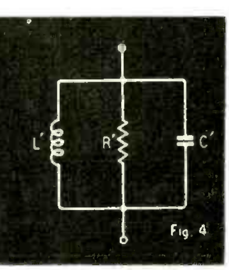
Fig. 1. Simple reactance valve circuit.

Fig. 2. Effective electrical circuit of crystal near resonance.

Fig. 3. Equivalent quarter-wave network. When $\omega^2 L_1 C_1 = 1$, $Y = (C_1/L_1)Z$, where Y is an admittance and Z is an impedance.

Fig. 4. Equivalent circuit of crystal and quarter-wave network. $L' = L_1 C_c/C_1$, $R' = L_1/C_1 r_c$ and $C' = C_1 L_c/L_1$.





be noted that variations of frequency obtained in this way do not cause any change in the value of the circuit dynamic impedance R′. Therefore oscillation may be maintained without amplitude modulation by connecting any suitable oscillator circuit presenting a parallel resistance of −R′, provided that it is connected at the modulator end of the network and not at the crystal end, where the impedance varies widely. One precaution has to be taken. That is to ensure that the oscillator feedback is less at the resonant frequency of the quarter-wave network ($\sqrt{2}f$ with no modulation) than at the crystal frequency. It tends to be greater because this mode does not include the crystal loss.

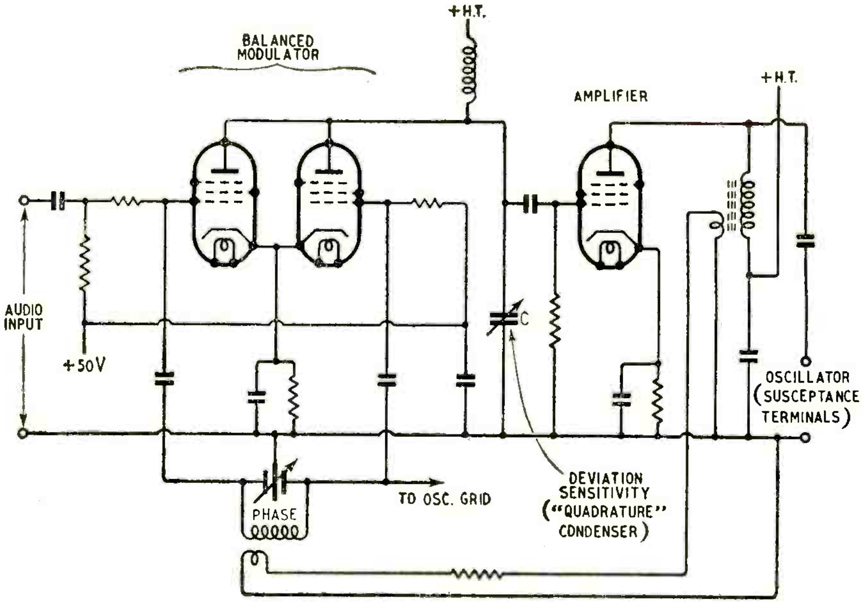


Fig. 5. Three-valve "susceptance modulator" circuit.

The other problem we mentioned was that of getting enough deviation. The maximum deviation possible is limited by degradation of frequency stability, by distortion, or by the modulator capabilities. In the B.B.C. model* the value of C′ (Fig. 4) is of the order of 0.01μF at 3.8033Mc/s. To modulate this by ± 1 part in 1,000 requires a maximum susceptance of ±0.008mho. In this case, for a modulator which can handle 10mA r.m.s. linearly, the oscillator amplitude must be kept below 2.3 volts. In this equipment it is kept to about 1 volt r.m.s. by means of an "automatic level control" circuit (this is similar to an a.g.c. system, but applied to an oscillator). This control has the further advantag of suppressing any a.m. which may arise from circuit imperfections.

Centre-frequency Stability

The next problem which arises is that of carrier frequency (centre frequency) instability, not in the oscillator itself, which is much more than adequately stable when supplied with a crystal of low temperature coefficient, but in the modulator. The current specification is that the maximum deviation should be ±100kc/s at the carrier frequency and that the centre frequency should never deviate by more than 2kc/s. This means that the modulator unmodulated mutual conductance must never change by more than ±2 per cent of its linear range, and this is a very severe requirement. The first and obvious precaution is to use a *balanced* modulator so that changes in cathode heating, for example, cause approximately equal and opposite effects. Certain design arrangements may be used to encourage balance, but, in the last resort, it is best to choose matched valves. The second precaution to take is to choose valves with a long linear range of g_m versus E_g as near the lower end of the characteristic as possible. The third precaution is to choose a valve whose mutual conductance does not change in jumps when the cathode temperature changes, as some valves do. The valve which has been found to satisfy all these requirements and, very importantly, to be a quiet valve, is the Mullard EF37A. Unfortunately, the variation of mutual conductance by a pair of these valves is not great enough by itself, and neither is their current-handling capacity, so an r.f. amplifier valve is added. This has no influence on centre-frequency stability and so it is not limited to any particular type and is chosen mainly for its current-handling capacity.

This three-valve arrangement is shown in Fig. 5, and, although it is a good deal more complex than the circuit shown in Fig. 1, it operates on the same general principles. R.f. is fed to the modulators via a phase-splitting transformer, one grid being fed in phase with the oscillator output and the other in anti-phase. The capacitor C forms the common anode load, which, in conjunction with the high anode impedances of the valves, produces nearly 90 degrees phase change. With no applied modulation, assuming perfect balance, the voltage across C is zero and the frequency is unchanged. When the balance is upset by modulation, however, the amplifier takes a leading or lagging current, depending on which modulator valve is predominant. The r.f. phase relationships for a perfect set-up are shown in Fig. 6.

The capacitor C is made variable to provide control of deviation sensitivity (i.e., kc/s deviation per volt of audio input). The centre-tapped phase-splitting transformer is tuned by a split-stator capacitor. This gives an adjustment of phase, and the presence of the tuned circuit in the reactive loop gives some protection against parasitic oscillations which might otherwise occur, particularly on over-modulation. One side of this tuned circuit is coupled back to the oscillator grid to maintain oscillation.

Only single-sided modulation input is required as the modulator pair acts as an a.f. phase-splitter, the cathode impedance being high and the second grid being virtually earthed with respect to a.f. voltages. With such a modulator it was found possible to

* Used at the Wrotham station

obtain quite linear modulation over a range of ±1 or 2 parts in 1,000, tested statically; that is to say, by applying d.c. modulating potentials and measuring the frequency. When tested dynamically, however, the story was very different. At various modulation frequencies peaks of a.m. appeared, accompanied by some f.m. distortion. It was apparent that unwanted modes of vibration more than two parts in a thousand away from the main mode were being excited by the f.m. sidebands. Efforts were made to avoid these modes by trial-and-error methods of crystal plate "dimensioning," bevelling, etc., without success. The unwanted modes varied in position in the frequency spectrum but were never absent. One significant feature was observed the unwanted modes were invariably higher in frequency than the wanted mode, usually within the range of 1 to 5 per cent higher. This was clue No. 1 to the source of the trouble. Clue No. 2 was the distribution of the amplitude of vibration over the surfaces of the crystals. In the main mode, the amplitude was always greatest in the centre of the contiguous electrodes, falling away to zero at the edges. In the first unwanted mode, the electrode area exhibited three antinodes along one axis. In the second, three along the other. In the third, three each way. In the fourth, five along one axis, and so on.

These divisions could not represent standing waves in the usual sense, as they were many wavelengths long in terms of the wavelength in quartz. Clearly they were due to an interference of waves travelling nearly normal to the surface of the plate and being reflected from the edges of the electrodes as in Fig. 7. This, with one exception, is precisely analogous to a cavity resonator terminated all round by waveguide stubs which are just smaller than the cut-off dimension. The exception is that the velocity of transverse waves in quartz varies with direction, whereas that in a waveguide or a cavity resonator is constant with direction. This remark, of course, applies to the free-wave components and not to the resultant wave, which has group and phase velocities different from this.

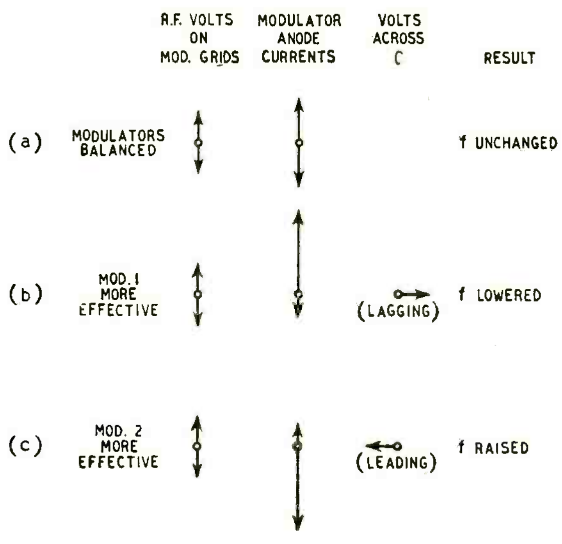


Fig. 6. R.f. phase relationships for a perfect set-up in balanced modulator.

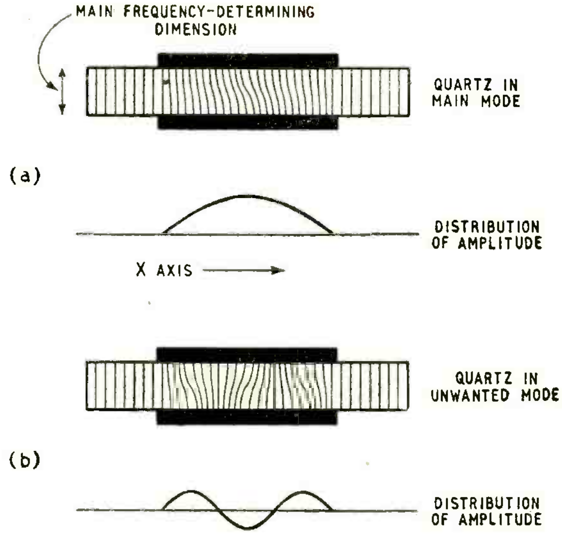


Fig. 7. Schematic diagram of section of quartz crystal showing wanted and unwanted modes of vibration.

Now the mathematics of cavity resonators and waveguides is well known, and by inserting suitable constants derived from experimental results it is possible to calculate all the unwanted frequencies and to design a plate so as to place the nearest of them outside the significant bandwidth of the system. Furthermore, by suitable choice of the weight of the electrodes (in relation to their size, the frequency and the "cut" of the plate) so that only the main mode is totally reflected at the electrode edges, higher frequencies are passed into the outer area of the plate. Thus the bare quartz surrounding the electrodes behaves as a waveguide filter. The edge of the plate is coated by a mechanically absorbent material which is a good acoustic match to quartz, so that the unwanted modes are completely damped.

It might be thought that if this absorption is so good it would be unnecessary to place the resonances outside the system bandwidth. This is not so, because were the cut-off frequency of the "waveguide" within the working band some significant f.m. sidebands would be absorbed, giving rise to distortion and a.m.

The design of these crystals is not simple, but a range suitable for broadcast f.m. with modulation frequencies up to 20kc/s has been designed for an extreme frequency range of 3.3 to 5Mc/s and a preferred range of 3.5 to 4.5Mc/s, and crystals made so far have been very successful indeed. The Q value in the wanted mode is between 100,000 and 200,000. Unwanted modes cannot be detected.

The output from the crystal oscillator is passed through a buffer stage, three doublers and a trebler (all heavily damped) to a drive output stage delivering about five watts at 85-108Mc/s to the main amplifiers of the transmitter as indicated in the block schematic diagram of Fig. 8. Thus the number of valves in the active chain, including a pre-emphasis valve, is only ten before reaching the carrier frequency. This is in contrast with the much higher numbers used in other systems, and results in greater reliability and less maintenance work.

Other valves and circuits are included in the drive unit for alignment purposes, and no external equipment is necessary. A crystal reference oscillator and beat detector are included for datum frequency adjustment and for listening to "Bessel zeros." As most readers will be aware, the amplitudes of f.m. sidebands are governed by Bessel functions, which become zero for various orders of sideband with certain amplitudes and frequencies of sine-wave modulation. These points are very useful for the calibration of a direct-reading "deviation meter" which is, in fact, a modulation input voltmeter. A sine-wave modulating oscillator of fixed frequency is included for this test.

A listening point is provided also on the automatic level control system, so that a.m. can be detected. A.m. is produced at the modulation frequency if the modulator r.f. phase is wrong and at this frequency and its second harmonic if the quarter-wave network condenser across the crystal is wrongly adjusted. These two controls may be adjusted for minimum a.m. in the same way as one would adjust a particularly amenable a.c. bridge circuit for amplitude and phase. When these adjustments have been made in this way, the distortion of the system at ±75kc/s deviation is less than 1 per cent and the shift of carrier with applied modulation is of the order of ten parts in a million or less.

The shift of carrier with modulation is a feature which cannot occur with properly designed phase-modulation systems, but in the author's opinion this does not represent an advantage for those systems. Of itself, a small shift of carrier frequency with modulation is not important. What *is* important is that, if such shift does occur, audio distortion must be occurring also. Carrier frequency being easily observed, it provides a useful check on quality of transmission in a true f.m. system.

Many readers will ask the question: "If a crystal can be varied in frequency so much, what is its advantage over a tuned-circuit oscillator?" A little thought will show that there are many advantages. In the first place, no tuned circuit yet made has as good a thermal performance as a well-made quartz crystal. Even if the tuned circuit is compensated for temperature it will not have a very low temperature coefficient of frequency over a wide range of temperatures and it is unlikely that the compensating parts will react to temperature change at the same rate. Probably one of the nearest approaches to crystal performance is that of the well-known Marconi-Franklin drive, but even this is not nearly as good as the crystal, and it is far more expensive. Another important advantage is robustness. A tuned circuit is more likely to suffer from vibration effects and might be disturbed accidentally in a number of ways. A tuned circuit, too, is more subject to frequency drift. Finally, the high Q value of the crystal makes it possible to use a large effective capacitance, C′, in the oscillator, which reduces the effects of stray capacitance changes. The high Q value also reduces the effects of phase changes in the oscillator valve caused by changes in cathode coating impedance or of electron transit time.

The performance of an actual transmitter at its acceptance tests may be of some interest, though space restrictions forbid a full report here. The tests were conducted by using a monitor receiver (also designed and built by Marconi's Wireless Telegraph Co., Ltd.) and standard transmission-measuring equipment. All distortion figures obtained by these tests include those in both the transmitter and the receiver.

At the standard deviation of 75kc/s, the maximum distortion measured at the site was 1.2 per cent at 30c/s. The only cause of increased distortion at low frequencies is the input transformer. At 100kc/s deviation the distortion was found to be less than 1.5 per cent.

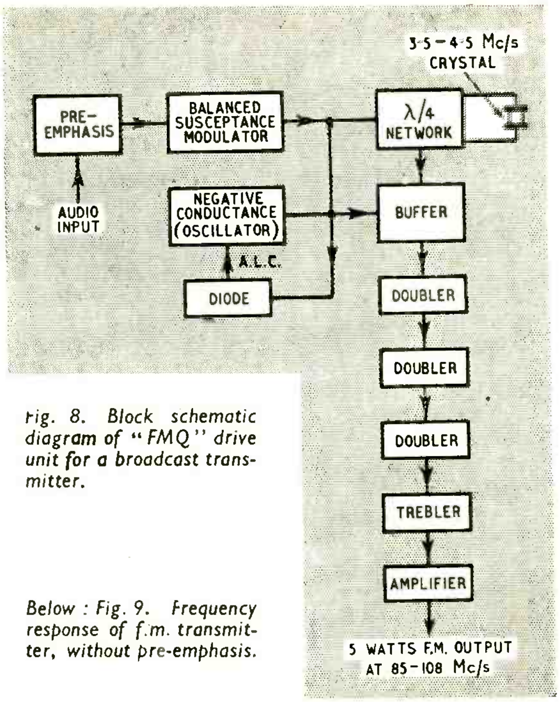
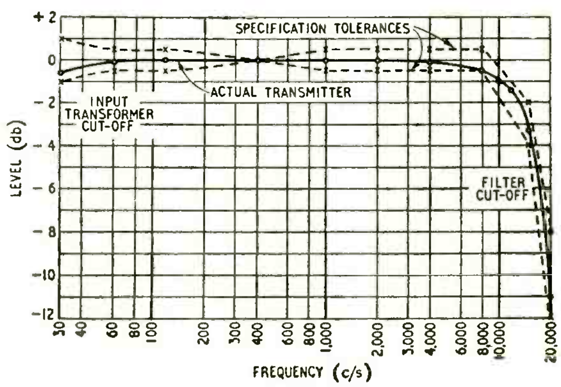


Fig. 8. Block schematic diagram of "FMQ" drive unit for a broadcast transmitter.

Below: Fig. 9. Frequency response of f.m. transmitter, without pre-emphasis.



A.m. noise measured at the site with no deviation was 60db down. With 100-kc/s deviation at 400c/s modulation frequency it was 53db down. F.m. noise at the site was 60db down.

The carrier-frequency change was two parts in a million when the deviation was raised from zero to 100kc/s. The greatest change of carrier frequency in 48 hours' run was 12 parts in a million.

The frequency response is shown in Fig. 9, with no pre-emphasis applied. The droop at the top is applied by a filter circuit to comply with the customer's specification of approximately 3db down at 15kc/s and 10db down at 20kc/s.

Although the chief interest in the "FMQ" system centres on its use for broadcasting, it must not be thought that its use is restricted to this. It may be used, also, for f.s.k. (frequency-shift-keying), "diversity f.m." (anti-fading modulation), "privacy f.m." (2-4c/s modulation) and facsimile f.m. In one design it has been possible to use only a single oscillator valve and one double-triode modulator valve to give sufficient linearity and deviation for f.s.k. and "diversity f.m." with 1 in 100,000 carrier-frequency stability.

Another use which has not been exploited much, so far, is that of a crystal oscillator, linearly variable over a frequency range up to about ½ per cent, for use as a local oscillator, a transmitter drive or an interpolation oscillator in frequency measurement. If equipped with a tuning motor and suitable circuitry a crystal drive of great simplicity and reliability can be made to follow the frequency of a highly stable but more complex oscillator, or a radiated carrier, if the signal is present, but to oscillate within Copenhagen tolerances if it is not. On the other hand, it must not be thought that "FMQ" is the answer to everything. For example, n.f.m. (narrow-band f.m.) communications equipment which does not use low modulation frequencies can make better use of phase modulation. Neither can "FMQ" be used for wide-band f.m. links for television or multiplex signalling.

The proper place for "FMQ" is for "d.c." or audio-frequency modulation applications where simplicity and reliability are of first importance.

In conclusion, grateful acknowledgment must be made to Mr. H. R. Cantelo, who did so much to encourage the adoption of the scheme in its early stages, to Mr. A. Miller, who carried out most of the final development of the transmitter drive, to Mr. and Mrs. D. Fairweather, and Mr. N. J. Beane, who co-operated in the manufacture of a satisfactory crystal plate, and to others in the Marconi Company who were concerned.

NEW BOOKS

Radio Installations. By W. E. Pannett. Pp. 444, with 244 illustrations. Chapman & Hall, 37, Essex Street, London, W.C.2. Price 45s.

The author is an executive engineer of long standing in Marconi's Wireless Telegraph Company and has been engaged on the overall planning and construction of radio transmitting and receiving installations for broadcasting and communication purposes for some thirty years. He has produced a book which, as G. M. Wright, chief engineer of Marconi's, says in his foreword, is "unique in the extensive literature devoted to radio communication."

In the preface the author points out that while most books on radio engineering are primarily concerned with theoretical expositions of circuits and valves for the student, his own approach is to the practising engineer whose work is to plan and construct complete installations and to deal either directly or indirectly with their maintenance and operation.

In this he has succeeded remarkably well and gives information of the sort which can only be acquired after many years of practical experience. This book contains much of what, in the present-day welter of specialized techniques, is almost becoming a lost art but which, in fact, must never be lost by those concerned with the practical design and operation of the wide range of modern transmitting and receiving installations.

The early chapters of the book deal with the selection of sites for broadcasting stations in the medium, high and v.h.f. bands, and also for transmitters and receivers for commercial communication, together with the general planning of the installation, including building requirements, foundations and layout of transmitters, auxiliaries and power plant. Power supply and distribution requirements for transmitters, including sub-stations, emergency generating plant and the characteristics which this plant should possess, are discussed, as well as power distribution switchgear, cabling and wiring and the selection of cables for audio-frequency and radio-frequency interconnections.

Two chapters are concerned with valves and their power supplies, with useful information on hot-cathode and mercury-arc rectifiers and their smoothing circuits for high-power transmitting installations.

Subsequent chapters deal with amplifiers and oscillators, the basic design of complete transmitters, modulating and keying systems, valve cooling plant and control and protective equipment. This information is rarely available, except in the engineering departments of a radio transmitter manufacturer or a broadcasting authority.

The author deals also with the practical characteristics and construction of radio-frequency transmission lines, impedance matching and aerial coupling circuits.

The two penultimate chapters are concerned with the general principles of communication receivers, complete commercial receiving installations and the equipment of control centres dealing with commercial radio-telephone and telegraph traffic. The final chapter, which deals with the problems of equipment maintenance and testing, is of special interest to the installing engineer and the station operator.

The book is valuable to the young installations engineer because it records the results of real engineering experience. Furthermore, he will not wish to part with it as he becomes more senior in his profession because, as a book of reference, he will still find its contents of great value.

P. A. T. B.

Magnetic Recording. By S. J. Begun. Pp. 232+XVIII with 145 illustrations. Thermionic Products, Ltd., Morris House, Jermyn Street, London, W.1. Price 25s.

WRITTEN by the chief engineer of the British Development Company of America, this book gives a broad survey of the state of the art of magnetic recording up to 1948.

The opening chapter on the history of magnetic recording traces the subject back to an article by Oberlin Smith in the *Electrical World* of 1888 and includes a more detailed account of Poulsen's pioneer work than is to be found in most sources.

A condensed chapter on the factors in acoustics relevant to sound recording follows, and leads to a detailed examination of magnetic theory and its application to recording with d.c. and a.c. bias, the origin of background noise, demagnetization and the "gap effect" in relation to the recording and playback of high frequencies.

In dealing with magnetic recording materials, and later with descriptions of complete machines (nearly thirty are dealt with), the emphasis is on homogeneous wires and tapes, but the German Magnetophon and four American machines are included as representatives of the alternative method of using coated plastic tapes. This is only to be expected since the book went to press before the present spate of tape recorders appeared on the market.

As far as principles are concerned, however, the text is equally applicable to wire or coated tape, and the book can be recommended to those seeking an introduction to a subject which, as the author points out in his preface, is still in the stages of adolescence.

Useful references to European as well as American sources of information appear at the end of each chapter.

F. L. D.

FURTHER NOTES ON THE

T-Match Television Aerial

Choice of Materials, Method of Construction and Dimensions for all Television Channels

By B. MAYSON

THE description of the T-match television aerial[1] aroused considerable interest at the time of its publication, and more recently requests have been received for the design of one for the Holme Moss frequency, so that it seems opportune for some further notes on the subject.

As will be remembered from the original article, the general form of the T-match aerial is as shown in Fig. 1, in this case a three-element system is illustrated. To begin with, it is desired to single out two of the several features which, in the writer's opinion, make this type of aerial so very attractive. First, exact aerial-to-feeder matching is possible; second, the whole of the metallic structure can be earthed, providing not only protection against lightning but also a means of draining static charges to earth and thereby reducing receiver noise.

There is some difference of opinion regarding the theory of the T-matching device, but while a full discussion of the subject is outside the scope of these notes, a few general remarks might help to clarify the situation. With reference to Fig. 2, we know that as the tapping points B are moved towards A the impedance at the feed point D decreases; conversely, as the tapping points are moved towards C the impedance at the feed point increases. Thus, by positioning the tapping points correctly, we can match the feed point exactly to any line, or cable, of an impedance up to 300 ohms, providing the matching rods are of the same diameter as the aerial rod. Why 300 ohms? Because when the tapping points reach the extremities of the aerial rod the T-match ceases to exist and we are left with a two-element folded dipole, which is well known to have an input impedance equal to four times that of a half-wave rod of 75 ohms nominal impedance. Incidentally, by using matching rods which are unequal in diameter to the aerial rod, we can achieve a multiplication factor higher than four.

Returning to the general case, it should be noted that the addition of parasitic elements (directors and reflectors) to a half-wave dipole not only increases the gain, but also lowers the centre impedance. Table 2 gives the approximate values of the feed impedance of some typical arrays.

Dimensions.—The dimensions recommended originally for the two-element aerial have proved satisfactory in practice, as have the dimensions of a three-element system which has since been tried out in various localities. The data has now been extended to cover all the five projected television channels and is included in Table 1, which should be used in con-

[1] "T-match Television Aerial." *Wireless World*, Jan., 1950.

TABLE I.
Dimensions of Aerials

Station	Vision Freq. Mc/s.	Type of Aerial	Dimensions in inches.						
			A	B	C	D	E	F	G
Alexandra Palace ..	45.0	2-Element	134.0	129.0	42.0	3.0	26.0	—	—
		3-Element	134.0	129.0	42.0	3.0	22.0	26.3	123.8
Holme Moss	51.75	2-Element	116.3	111.7	36.5	3.0	23.0	—	—
		3-Element	116.3	111.7	36.5	3.0	19.0	22.8	107.2
Kirk O'Shotts ..	56.75	2-Element	106.2	102.0	33.3	3.0	21.0	—	—
		3-Element	106.2	102.0	33.3	3.0	17.5	20.8	98.0
Sutton Coldfield ..	61.75	2-Element	97.5	93.5	31.0	3.0	19.0	—	—
		3-Element	97.5	93.5	31.0	3.0	16.0	19.3	89.8
Wenvoe	66.75	2-Element	90.2	86.6	28.3	3.0	17.5	—	—
		3-Element	90.2	86.6	28.3	3.0	15.0	17.7	83.0

junction with Fig. 1. The approximate figures given in Col. E assume that the matching rods and the aerial rod are of equal diameter.

Comparatively few readers will require a four-element aerial, but when it is needed it will only be necessary to add a second director to the three-element type in Fig. 1. From Table 1, the spacing between directors can be as Col. F; the length of the second director as Col. G minus 3 per cent; while the initial setting of the matching adjustment, as in Col. E (three-element) minus 14 per cent. These dimensions will provide a starting point.

The Matching Section Insulator.—A modified version of the matching section is given in Fig. 3, which differs from the original in respect of the insulator only. There appears to be some uncertainty regarding the permissible length of the insulator separating the adjacent ends of the matching rods, and regarding the insulator itself. As regards length, 1 in is satisfactory and up to 2 in permissible. Obviously, a short insulator permits the cable attachment to be made without any undesirable splaying of the cable ends. As for the insulator itself, the one used on the original aerial came out of the scrap box and cannot now be identified. However, a suitable alternative can be made quite easily. Referring to Fig. 3, it will be seen that the porcelain insulator specified originally is replaced by a short length of insulating rod pushed into the adjacent ends of the matching tubes and adjusted so that the ends of these tubes are 1 in apart. Provided the insulating rod fits tightly there is no need to pin it. In order to increase the leakage path of the insulator a disc, E, may be fitted as shown.

For the insulating rod we require a material with a low loss factor at television frequencies, low moisture absorption, high resistance to the effects of outside exposure, and so forth. Now as far as the first requirement goes ordinary porcelain does not show up well since it has a high power factor at 50 Mc/s. Polystyrene or Polythene will do very nicely, the latter being the easier to work. Otherwise we can use Paxolin, which is easily obtainable. The disc need not be of the same material. Perspex has been used with every satisfaction and fixed in place with Bostik compound.

Adjusting the Matching.—Theoretically, the matching procedure is simple. First set the matching strips (Fig. 3, C) in accordance with Table 1 (Col. E). Then, with the aerial connected to the receiver, set the brightness control (contrast control fully anti-clockwise) until the raster just shows, and then advance the contrast until a picture is received. Keep the contrast as

TABLE II.

Centre impedance and gain of aerial systems with element spacings as Table 1. (Without matching section.)

Type of Aerial	Centre impedance ohms	Gain in db over ½λ dipole
½λ dipole	73	0
2-element	20–25	3
3-element	8–12	6–8
4-element	5–7	7–9

Fig. 1.

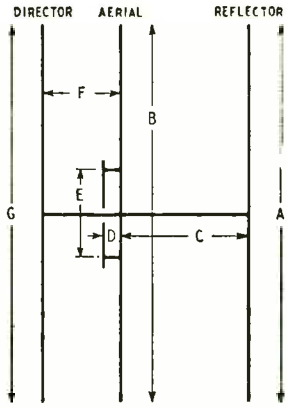


Fig. 1. General form of a three-element T-match aerial consisting of a director (G), aerial rod (B) and reflector, (A).

Fig. 2.

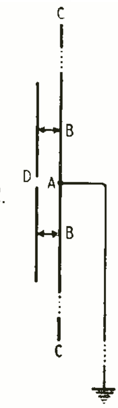


Fig. 2. Method of arranging a T-matching section.

Fig. 3.

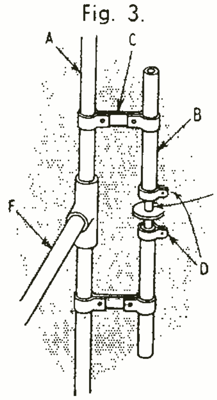


Fig. 3. Detail sketch of a T-matching section. A is the aerial rod, F the cross arm or boom, C the adjusting clips, D the cable connections, and E a disc to increase the effective leakage path of the insulator.

low as possible consistent with a steady picture. At the aerial end adjust the matching strips equally towards or away from the insulator until, at the receiver end, the best picture is obtained. Reduce contrast and repeat the process. If we remember that the contrast control of a television receiver is equivalent to the r.f. gain control of a sound receiver and that when the matching is correct the signal input to the receiver will be maximum, then there should be no difficulty in understanding the procedure.

Unfortunately the job is less easy in practice because, to get the optimum result, the adjustments must be made with the aerial *in situ*, a condition applicable to all matching systems except in the case of the aerial matching transformer.[2] If the aerial is to be mounted on a chimney, adjustment *in situ* is quite practicable with the aid of a helper who can signal from the receiver end. Incidentally, the point to watch here is to keep one's body out of the field of the aerial while the observation is being made.

If the aerial is to be mounted on a long pole the best thing to do is to devise a method of hauling the aerial up and down so that adjustments can be made. One word of advice: choose a windless day for this.

In the event of adjustment *in situ* being impracticable, the figures given in Table 1 (Col. E) will give reasonably good results. These figures, it should be noted, assume a feeder characteristic impedance of 73 ohms. But turning to Table 3 we see that we cannot be sure what the exact characteristic impedance of a given feeder will be in practice. How-

[2] "Aerial Feeder Connections," W. T. Cocking. (*Wireless World*, Dec., 1950.)

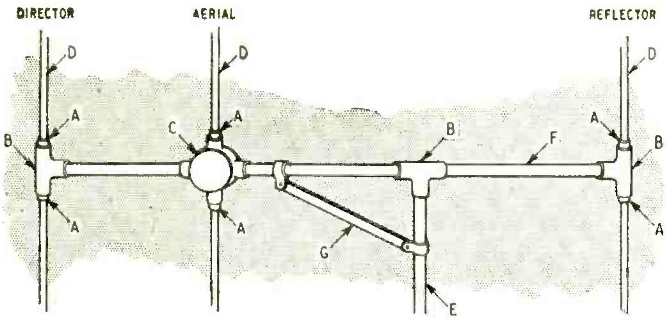


Fig. 4. Constructional details of a 3-element T-match aerial. Parts are as follows:— A, reducing socket 1in to ½in; B, 1-in screwed tee piece; C, 4-way circular junction box 1-in inlet or 4-way screwed junction socket if obtainable; D, ½-in dia conduit; E, 1-in dia conduit for mast section, F, 1-in dia conduit cross-arm or boom; G, support needed for 3- and 4-element arrays.

ever, with the T-match aerial, this point need not worry us in the least.

Construction.—Originally a heavy-gauge gas piping, gas fittings and Duralumin tubing were used, which resulted in a robust, but unduly heavy, structure. The obvious course for the constructor working with simple tools only is to use aluminium-alloy conduit and light-alloy die-cast conduit fittings, as indicated in Fig. 4. A three-element layout is shown here; the combination of parts for a two- or four-element type will be obvious from this sketch. Screwed conduit and screwed fittings are recommended. Generally, local suppliers will undertake to screw the ends of the conduit as required; the fittings, of course, are already screwed. Alternatively, if there is any difficulty in getting threads cut locally, some firms market conduit fittings which dispense with screwing. All that is necessary is to push the conduit into the fittings and tighten up with a screwdriver.

Whether screwed or gripped material is used, all points should be pinned where there is a likelihood of pivoting taking place due to the action of the winds. This applies particularly to the junction of the mast section and its "T" piece. Additionally, it is vitally necessary to pin the mast section so that it cannot turn in its lower-end holdings, and lack of attention to this detail can result in a television aerial changing its bearing subsequent to installation.

Following a study of Fig. 3, there should be no difficulty in constructing the matching section. A point to watch is to cut the matching rods some inches longer than shown in Table 1 (Col. E) to allow for adjustment. For the cable connecting clips, Fig. 3 (D), it is suggested a pair of double-screw earthing clips of ½-in diameter be used and these can be purchased along with the conduit fittings. A similar clip, but of 1-in diameter, can be used for attaching the mast section earthing wire. The adjusting strips, Fig. 3 (C), will have to be made up; for the original aerial ½-in soft brass strip of 20 s.w.g. was used.

Weatherproofing.—The necessity for weatherproofing will, of course, depend on the materials used. Most modern aluminium alloys have a high corrosion resistance, therefore painting need not be done. Where dissimilar metals are in contact, however, as in the case of brass adjusting strips and aluminium-alloy tubing, it will certainly be necessary to treat the junctions to prevent electrolytic action taking place.

TABLE III.

Characteristic impedance of some typical feeder cables.

Type	Overall size ins.	Nominal impedance ohms.	Actual impedance ohms.	Attenuation per 100ft. at 50Mc/s
Coaxial ..	¼	70	60–75	4db
Coaxial ..	⅛	50	48–60	6db
Screened twin	¼	100	90–110	4.5db
Unscreened twin ..	¼ × ⅛	80	70–90	2.2db

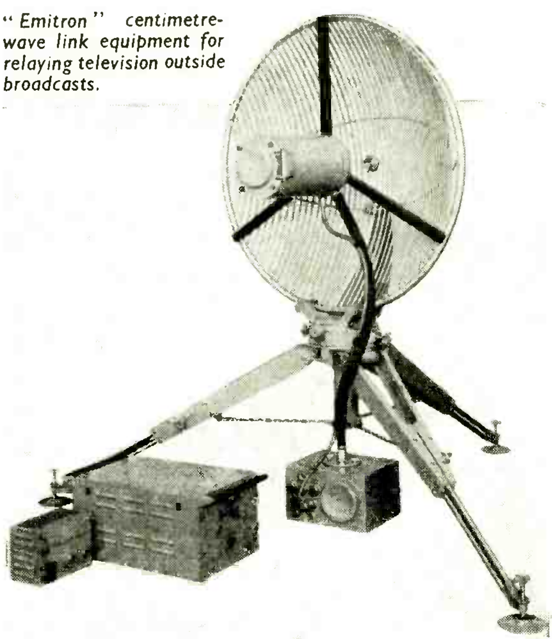
TELEVISION RADIO LINKS

EXCEPTIONALLY long ranges are claimed for a new type of television link equipment recently supplied by E.M.I. to the B.B.C. Transmitted power of the sets is from 3-5 watts, generated by klystrons of new design, and it is stated that reliable "operational" signals have been obtained at distances of well over 45 miles. The wavelength is about 7cm and frequency modulation is used.

In addition to vision and sound channels, the equipment provides for two-way communication, so the producer of a television outside broadcast can keep in touch with the station from which the programme is being radiated.

As there is plenty of aerial gain to spare, the beam can be made wide enough to minimize difficulties in setting up the parabolic reflectors.

"Emitron" centimetre-wave link equipment for relaying television outside broadcasts.



LETTERS TO THE EDITOR

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

The Modulation Battle

THE many letters to you on this subject seem to have entirely missed the obvious solution: the use of *both* systems.

A.M. can be received on existing receivers with the addition of a convertor; it would be an easy matter for manufacturers to include this in future sets. An a.m. receiver can be cheaply produced, but the f.m. system would be there for those who could afford the type of receiver which is necessary to take full advantage of it.

The export of f.m. receivers (a very important point) would be helped by a home demand.

North Harrow, Middlesex. FRANK BLACKBURN

YOUR report on Mr. Brinkley's paper (Sept. issue) appears to me to present a somewhat distorted version. For instance I cannot agree that Mr. Adorian's acceptance of a.m. on a short-term basis seemed to express the general feeling of the Convention.

This Convention was surely concerned with engineering* and not with one more display of our national rags and tatters or even with quasi-political discussions.

Dealing with the purely engineering aspect of the discussion I gathered that the only major item on which issue could be raised against the runaway superiority of f.m. over a.m. was on the band-width involved in the two systems. In my own measurements with comparative receivers for the two systems, I would emphatically point out that even where the a.m. receiver has been given a band-width of 200kc/s, the same as is required for f.m., the a.m. receiver is still at least one grade worse in its discrimination against impulsive interference. The noise limiter used with the a.m. receiver was of the rise time discriminator type, with an audio capability up to 12.5kc/s. Increasing the pass band of the a.m. receiver up to 0.5Mc/s certainly gave less difference in the response of the two systems to impulsive noise, but this can hardly be taken as favourable towards a.m. If narrow-band a.m. were to be adopted the listener could say goodbye to either high-quality reproduction or efficient noise suppression, or more likely both, in urban areas. As a town dweller myself, surrounded by all manner of impulsive noise generators, I confess to writing with some feeling

Turning now, perforce, to the economic angle of this controversy, we are all sadly aware in these islands that to expect to have the best for our own consumption is an expectation regarded as near treason in some quarters. In contrast to such ideas. I would give it as my opinion that this is one best we cannot afford to do without. If we are to continue to export our radio equipment we must supply the best. If we have no home market to create the initial demand and thus permit the low-cost benefits of a reasonable degree of mass production to be built up, we shall certainly be unable to compete in world markets, and so far as I am aware this is the only country where f.m. has not been decided upon for v.h.f. broadcasting.

If it is argued that a.m. should be adopted only as a short-term policy, I feel it is pertinent to ask with some suspicion what is a short term? F H. BEAUMONT

R. N. Fitton, Ltd., Brighouse, Yorks.

* This paper, and the discussion which followed it, was as much concerned with economics as engineering.—ED.

Legitimizing the "Puff"

I QUITE agree with A. C. Kay (August issue) that the present capacitance units could be improved, but I am stricken with horror at his proposed remedy of making the picofarad (renamed) the "practical" unit. If we accept the principle of an integrated system of units, the farad must be determined by the definitions of volt and coulomb. We have suffered and cursed for years under the triplicated burden of e.m.us, e.s.us, and "practical" units, and now at last, 50 years A.G. (After Giorgi) hope dawns. Without personal malice I wish Mr. Kay's proposed *extra* unit the worst of luck!

The problem has been wrongly appreciated. The size of the basic unit is not important if the system of sub-multiples is adequate. The solution is simple and direct: we need a metric prefix for 10^{-9}, and it is absurd that, needing it, we cannot provide ourselves with one. While this is not really a field for rugged individualism no official extensions to the metric prefixes were provided for the badly needed 10^{9} and 10^{-12} so the Americans (having 10^{9} of everything) coined "bega" by analogy with "mega," while Campbell suggested "pico" (perhaps from Ital. "poco") which was gratefully seized upon (and is now better known than the official "myria" for 10^{4}).

If we are to coin a metric prefix we may as well engineer it while we are at it. It should (i) have a distinctive initial letter for abbreviation (be warned by mega, milli, micro), (ii) two syllables at most for "wieldiness," (iii) be formed from a root suggesting its meaning in some major language, (iv) occur at intervals of 10^{3}, since this enables the common accuracy of three significant figures to be written without added noughts to position the decimal point (redundant as information). That smaller intervals are not needed is shown by the disuse of deci, deka, hecto, and myria.

The International Metric Convention does not concern itself with nomenclature, and we cannot very well revive the French revolutionary government. So it is up to us, and encouraged by Campbell's success and with due humility, may I suggest for 10^{-9} farad—LILLIFARAD; of obvious origin, fulfilling the specification above, and in the modern humorous tradition of electronics (sanatron!) 1,000pf or 0.001μF then becomes 1 lillifarad or 1LF.

This adds to the list of metric-decimal prefixes and thus serves the whole physical system of units, electrical or otherwise, whereas Mr. Kay's suggestion only tackles the local problem of noughts on a capacitor, doing in the process great damage to the integrated system of units.

Prestwich, Manchester. V. MAYES

[The prefix "nano-" (abbreviation *n*) for 10^{-9} has some currency on the Continent.—ED.]

Nomenclature

I HAVE read with interest Mr. Puckle's letter (your August issue) about the flip-flops. I did not know who had invented this term which I liked (and adopted) as soon as I heard of it, because it is so self-evident.

The Electronics Glossary and Symbols Panel of the Central Radio Bureau, which looks after the standardization of symbols and technical terms in the fighting services, has anticipated Mr. Puckle's wants. Their recommendations are given in the Interservices Glossary of Terms used in Telecommunications and Electronic Engineering.

Relaxation circuit.—A circuit arrangement, usually of valves, reactances and resistors, which has two states or conditions, *one*, *both*, or *neither* of which may be stable. The transient voltage produced by passing from one to the other, or the voltage in a state of rest, can be used in other circuits.

Stable trigger circuit (Alternative: Trigger circuit).—A relaxation circuit which has *two* stable conditions, and can be made to pass very rapidly from one to the other by applying a suitable triggering pulse or signal. The Eccles-Jordan circuit is an example of a trigger circuit.

Flip-flop circuit.—Kipp relay [deprecated]: One-shot multivibrator [deprecated].—A relaxation circuit having *one* stable and one unstable condition. By applying a triggering pulse or signal it may be made to pass very rapidly into the unstable condition whence, after a certain time interval, it automatically returns to the stable condition.

Multivibrator.—A relaxation circuit which has *two* unstable conditions and successively passes from one to the other as long as it is operating. The Abraham-Bloch multivibrator is an example.

It might be advisable to add "two-state" to the term "stable trigger," if "more-than-two-state" circuits become more common. L. BAINBRIDGE-BELL.

Haslemere, Surrey.

"Bass Without Big Baffles"

BEFORE correspondence on this subject is closed perhaps you would allow me to make a final suggestion to those wishing to experiment with my amplifier.

The upper limit of the range of frequencies subjected to harmonic distortion by V_3 is dependent on the choice of capacity for C_4. Too liberal a harmonic content would undoubtedly have resulted in reports claiming that *unpleasant* distortion products from V_3 were audible in the final output. In the April issue I specified a fixed value of 0.1μF for C_4—verging on the safe side.

However, considerable advantage can be gained by varying the value of C_4 to suit the size of baffle and speaker in use. The smaller the baffle the wider should be the range of harmonics introduced. Examples of baffle frontage areas with suitable values for C_4 are as follows:—

Areas of 1 sq ft or less; 0.03μF.
Between 1 sq ft and 4 sq ft; 0.05μF.
In excess of 4 sq ft; 0.1μF.

In each case (with the middle control turned well down) the advent of any unpleasant products in the output should be offset by an increase in capacity of C_4.

The "bass control" of the amplifier alters the level of low frequencies passing through the *linear* channel only, and is thus somewhat limited in its range of effect. Some readers may prefer to substitute a control switching in various values of C_4 instead. K. A. EXLEY.

Leeds, 6.

Screened Valves

I DEPLORE the tendency of British manufacturers of American-type valves to relegate the metal-shelled type of valve to the ranks of the "replacement type." This means that manufacture of such valves in this country will soon cease.

The advantage of the metal type of valve is, of course, that, when used in r.f. applications, no screening can is necessary; indeed the screening is far better than that which can be achieved by the use of external screens.

Scunthorpe, Lincs. KEITH R. BROOK

Crystal Menace?

IF crystal receivers become popular as antidotes to power cuts, I foresee another source of interference to short-wave reception. All such sets, including the modern version described in your September issue, will radiate harmonics of the station to which they are tuned.

A partial remedy, of course, is either to earth or disconnect the aerial when the set is not actually in operation. It might also be worth while—and practicable—to design the two-circuit tuner so as to minimize the radiation of harmonics. C. KIDD.

London, S.W.

Jointing Aluminium

I HAVE noted with interest the article in the May issue of your Journal but must protest at its casual dismissal of the method using a solder containing 90 per cent tin and 10 per cent zinc. Admittedly, when this process is used, the metal has to be cleaned carefully but not so carefully as is required for cold welding. Furthermore, provided the surface to be tinned is brushed under the surface of the molten metal, the results obtained are perfectly satisfactory and quite equal to any that may be obtained by the use of an ultrasonic soldering iron.

The principles in so far as disturbance of the metal surface is concerned and the temperatures required are substantially the same for both methods and both have their own particular application.

The ultrasonic method is obviously to be preferred for thin foils and fine wires where mechanical abrasion methods cannot be employed. However, completely satisfactory results have been obtained throughout the electrical industry all over the world by the wire brushing technique on aluminium-sheathed cables, where it is employed for tinning the sheath prior to joint wiping. The undoubted success and acceptance of this method clearly show the disparaging remarks of your contributor to be inadmissible. P. A. RAINE.

Johnson & Phillips, Ltd., London, S.E.7.

MANUAL EXPANSION

LISTENER PARTICIPATION.—A correspondent, Major F. Le Heup Salmon, has sent us this illustration of his receiving equipment which, by the use of a row of keys below the receiver, provides a simple means of volume expansion.

Exhibition Audio Convention

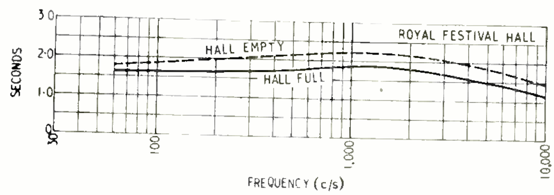
Points Raised in the Lectures and Discussions

TO those interested in electro-acoustics the list of subjects and authors (see p. 373 of our last issue) was in itself sufficient augury for the success of the audio engineering session of the British Institution of Radio Engineers' 1951 Convention. This session was held on 4th—6th September at Earls Court in conjunction with the National Radio Exhibition.

The chairman, H. J. Leak, in his opening remarks pointed out that in fifteen lectures it would be possible only to touch the fringe of so wide a subject and that in choosing topics for discussion the guiding principle had been to concentrate on subjects which were still matters of controversy or of which our knowledge was less secure—for example, electro-acoustic transducers, auditorium acoustics and, at the foundation of all matters relating to sound, the mechanism of hearing.

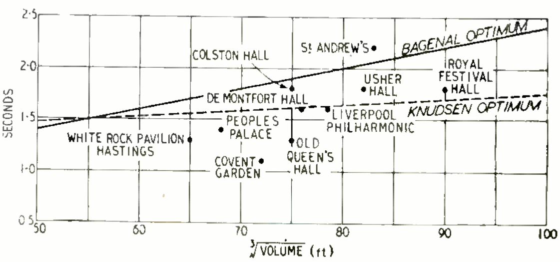
A lucid description of the anatomy of the ear, illustrated by models and microscopic sections, was given by Dr. T. S. Littler, who also outlined the present state of our knowledge of the nerve processes which form an essential part of auditory perception. The " volley " theory which presupposes the use of multiple nerves, " firing " in succession, to overcome the known frequency limitation of single fibres, and the " place " theory which rests on experimental evidence that different frequencies stimulate different regions of the basilar membrane, were described and discussed. The general opinion seemed to be that the brain does not rely on any one system of nerve impulses, but on a combination of all, and that their relative importance varies with the individual.

It was pointed out by J. Moir and J. A. Leslie in their paper on stereophonic reproduction that the ear can discriminate against reflected sound and concentrate on the direct sound, a faculty which preserves the sense of direction indoors and makes stereophony possible. This inhibitory mechanism may have some relation to the variations in rate of firing of a nerve as a function of time after the application of a stimulus—a point which was referred to by Dr. Littler. It was also pointed out that the directivity of the ear under stereophonic conditions gave the effect of a 12db increase in apparent signal/noise ratio as well as a greater tolerance for reduced bandwidth in the reproducing system. One contributor to the discussion also claimed for stereophony the equivalent of a reduction in intermodulation distortion.

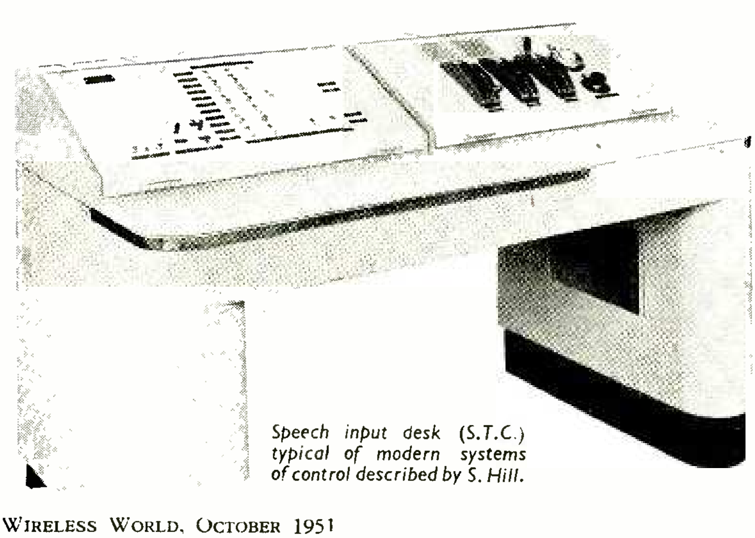


Reverberation time of the Royal Festival Hall as a function of frequency. (P. H. Parkin)

Reverberation times, at 500c/s with full audience, of some representative British concert Halls. (P. H. Parkin)



The fact that reflections with small time delays do not destroy the sense of direction (the " Haas effect ") is also made use of in the design of auditoria, as was mentioned by P. H. Parkin when dealing with the acoustics of the Royal Festival Hall. An important feature of the design is the large reflector over the orchestra which increases the apparent direct sound intensity and contributes to the excellent definition for which the Hall is noted. Mr. Parkin described the measurements made during and after the building of the Hall and showed curves of the variation of reverberation with frequency and the average reverberation time in relation to other well-known concert halls. Pulse methods of testing, although providing valuable information, involved an enormous volume of work in measurement and interpretation, and in support of this a series of pulse echoes taken at frequency intervals of a few cycles were shown which exhibited wide differences in general character. When



Speech input desk (S.T.C.) typical of modern systems of control described by S. Hill.

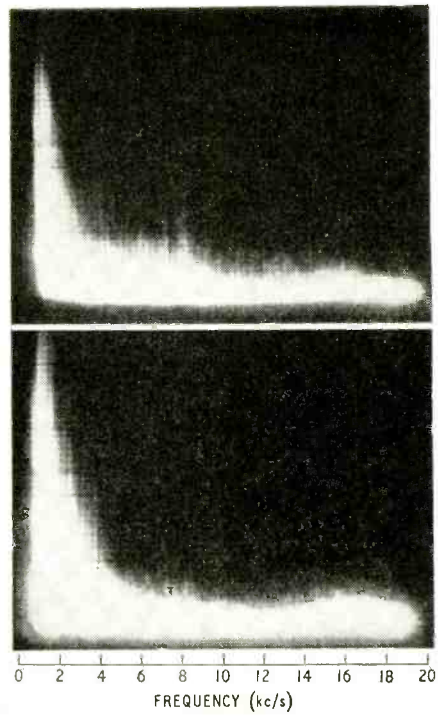
designing a new hall one had to decide on a general average reverberation time as a basis for calculating the amount of absorbent material to be used.

The problems of high-quality reproduction in small rooms were discussed by P. J. Walker who showed that reflection from the walls could be arranged to simulate a wavefront arriving from a virtual image of the sound source outside the room, sufficient directivity in the forward radiation from the loudspeaker being retained to give the impression of a smaller and nearer source over the band of medium frequencies predominating in speech. J. S. Youngmark, who spoke on the problems of loudspeaker cabinet design, demonstrated a method of producing a similar effect by using single and multiple units according to the nature of the programme. Discussion on these papers raised two interesting points—the danger of exciting all eigentones of a room when a loudspeaker is sited in one corner, and the desirability of large volume in cabinets of the "bass reflex" type in order to reduce the "Q" at the low-frequency acoustic resonance. Figures quoted by one speaker gave a Q of 120 for the case of one cabinet of 2 cubic feet volume compared with 27 for 10 cu. ft.

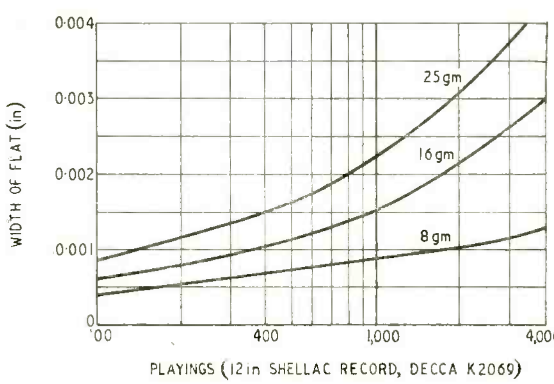
Measurements on loudspeakers and the relation of subjective to objective tests were dealt with by F. H. Brittain who advocated the use of loudness/pitch curves instead of the more usual intensity/frequency characteristic. In the discussion which followed it was suggested that complete correlation between subjective and objective tests presupposed the existence of a "standard ear" and as this does not in fact exist, any relationship between hearing and measurement must always be variable. At the end of the lecture Mr. Brittain demonstrated, by means of loudspeaker reproduction of tape recordings of his own voice, adjusted by means of a sound level meter, the incongruities which result from reproducing speech at levels differing from the original.

The importance of competent level monitoring in the control room was also one of the points raised by S. Hill in his paper on speech input equipment for broadcast transmitters. A lively discussion developed on the relative merits of peak programme meters as used in Europe and the V.U. meter favoured in the U.S.A. It was thought that the peak programme meter was best, in that it showed what was actually happening in the circuit, but that the V.U. meter had distinct advantages in large systems, as it was less troubled by phase delays, and gave similar indications at the ends of a long line. For this reason it would gain ground first in telecommunications and might be expected to invade broadcast systems at a later date.

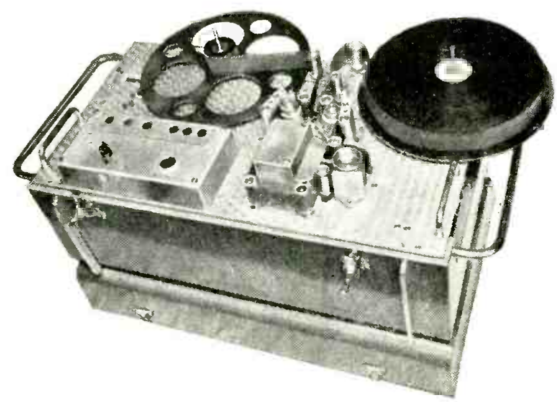
Recorded sound was represented by two papers on magnetic recording and one on microgroove disc recording. In answer to criticisms that pre-emphasis in microgroove recording might offset any advantages over standard 78-r.p.m. constant-velocity characteristics which might otherwise be obtained in the matter of tracing distortion, it was pointed out by E. D. Parchment and N. C. Mordaunt that present



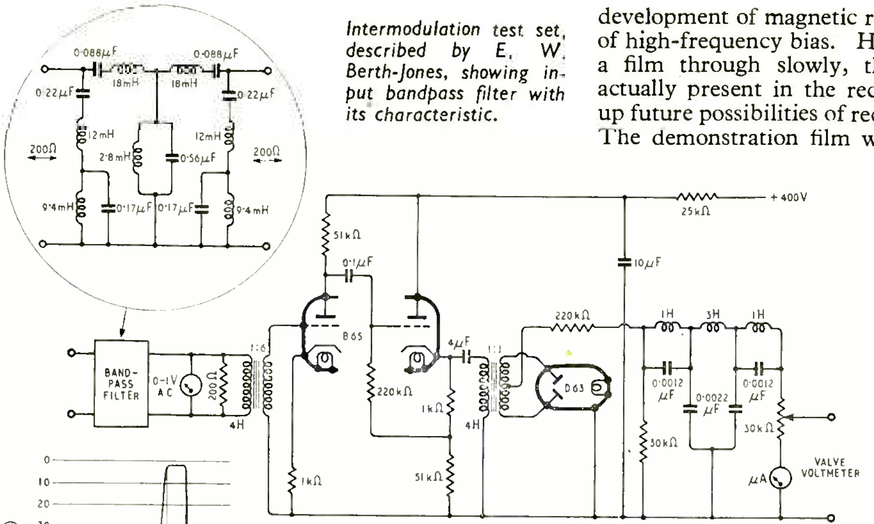
Spectra of a.f. energy, including noise, taken over periods of 1½-2 minutes on Decca standard shellac records; (top) second side of "Danse Macabre", (bottom) first side of Beethoven's 5th Symphony. (E. D. Parchment and N. C. Mordaunt)

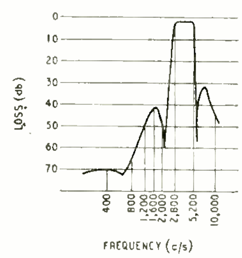


Wear on 0.0027-in radius sapphire stylus with different downward pressures. (S. Kelly)



British Acoustic "Ferrosonic" portable magnetic recorder demonstrated by Dr. Kolb.





Intermodulation test set, described by E. W. Berth-Jones, showing input bandpass filter with its characteristic.

Decca standards give a rise of 11 db at 10kc/s compared with the American N.A.B. figure of 16db and that calculations based on maximum permissible amplitudes are not necessarily valid for actual recording conditions. In support of this latter point they have recorded the energy spectra (including noise) of the louder parts of typical records which indicate the relatively small energy content at high frequencies.

Analytical methods, using equivalent electrical circuits as analogue computors, were described by K. R. McLachlan and R. Yorke for solving some of the first-order design problems of loudspeakers and pickups. Calculations of polar and torsional vibrations in tone arms have been investigated experimentally with the aid of strain gauges attached to the surface of the arm, and have shown good correlation. Problems of needle-record contact and stylus wear were included by S. Kelly in his paper on piezo-electric pick-ups. On the subject of stylus wear, Mr. Kelly underlined the variability of sapphire, which he attributed to variations in the angles between the " stress surfaces " in the synthetically-grown sapphire " boule " and the axis of the finished stylus. Typical wear curves were shown to emphasise the importance of reducing vertical pressure as far as possible.

One of the more important applications of magnetic recording is in the film industry, where its convenience " on location " has been already proved. An interesting portable recorder using ¼in. tape and synchronized by a picture frame pulse originating in the camera was described by N. Leevers. In the conventional capstan drive, slip often occurs because the capstan becomes polished and the drive is mainly indirect via the margins of the rubber pressure roller and thence to the polished side of the tape. This has been overcome by reversing the tape to bring the oxide coating in contact with the rubber.

In the magnetic sound film system demonstrated by Dr. Kolb, standard perforated 35 mm. film base is used, and slip cannot arise, though more care must be taken in the design of mechanical filters in the drive. Dr. Kolb gave an excellent résumé of the development of magnetic recording and of the theories of high-frequency bias. He demonstrated, by running a film through slowly, that the supersonic bias is actually present in the recording, a fact which opens up future possibilities of recording at video frequencies. The demonstration film was recorded at 50kc/s with a 0.008in gap to emphasise that the rapidity of decrease of field on leaving the gap rather than the gap width is the deciding factor when recording at high frequencies.

Traces of supersonic modulation could be detected in film erased with a supersonic field. Dr. Kolb favoured the use of a.c. mains for erasure which gave a 10db reduction in residual level. He described a machine for this purpose in which a full reel of tape is rotated slowly while a translatory movement of a mains-energised magnet subjects each part of the reel to a decreasing 50-c/s field.

Difficulties in measuring distortions at the low levels achieved in high-quality magnetic recording has led to increased interest in intermodulation methods of measurement. E. W. Berth-Jones gave details of an intermodulation test set capable of d.c. calibration. The design is based on a comprehensive survey of all significant intermodulation products and takes into account the importance of correct rectifier conditions. Not the least valuable lesson to be learnt from Mr. Berth-Jones' paper is that percentage intermodulation figures are meaningless without a clear statement of the conditions under which they are obtained.

Although in distortion measurement one seldom gets as far as, say, the seventh or ninth harmonics, it was interesting to learn from L. E. A. Bourn's paper on " electrophonic " organs that harmonics up to the 32nd are significant and are included when synthesizing the tone of some of the traditional organ stops. In small two-manual instruments use is now made of formant tone generators with complex waveforms in preference to the original method of combining pure tones. It is interesting to learn that phase, as well as relative amplitude of harmonics, is significant and is taken into account when developing the waveform of the generating elements. When stops are mixed, some drift of phase is necessary to simulate the " vitality " of a pipe organ and to this end the generators are belt-driven to avoid too constant a phase relationship between the ranks.

After describing the development of the modern electronic instrument from early beginnings, a short recital was given by Mr. Taylor of the John Compton Organ Company, who ably demonstrated the quality and range of traditional as well as modern tone now available to the organist.

In this brief résumé of the proceedings we have been able to select at random only a few of the many interesting matters which were demonstrated and discussed. We understood, however, that a transcript of the discussions, which were recorded throughout, will be published, together with the original papers, in the Journal of the Brit.I.R.E.

WORLD OF WIRELESS

Notes and News ◆ Radio Personalities
The Industry ◆ October Meetings

German Television

WESTERN Germany now has a television station. On September 3rd regular transmissions were started from the station recently installed in one of the wartime anti-aircraft (flak) towers in the centre of Hamburg. Operated by the Nordwestdeutscher Rundfunk, the German-made transmitter employs the standards proposed by the C.C.I.R.—625 lines, 50 frames interlaced, negative modulation and f.m. sound. The 1-kW vision transmitter operates on 189.25Mc/s and the 0.3-kW sound set on 195.75Mc/s.

Radio Shows

WITHIN a few days of the closing of the 18th National Radio Show at Earls Court, the R.I.C. announced that it would hold an exhibition next Spring in the City Hall, Manchester. The provisional dates are April 23rd to May 3rd. The next London show is planned for September, 1952, at Earls Court.

The attendance of 232,752 at Earls Court included 1,818 overseas visitors. The figures for the last two London shows were: 1947, 443,433; 1949, 395,465.

Television Convention

AS already announced, the Radio Section of the I.E.E. plans to hold a television convention from April 28th to May 3rd next year.

The whole field of television will be covered in nine sessions, each of approximately two hours' duration. The titles of the sessions, at each of which a survey paper and a number of supporting papers will be discussed, are:—Programme Origination; Point-to-Point Transmission; Broadcasting Stations; Propagation; Receiving Equipment (2 sessions); Non-Broadcasting Applications; and System Aspects.

Grad.Inst.P.

SINCE the introduction of this grade of membership of the Institute of Physics in 1949, some 400 applicants holding a recognized degree or other qualification in physics have been elected graduates. Now the Institute has introduced an examination by which those not holding a recognized university degree may become graduates. The exam will consist of three papers and a practical exam in physics, two mathematics papers and a paper on statistics or advanced, mathematical or applied physics. Those choosing the latter have a choice of electronics, acoustics, high-vacuum technology, spectroscopy, X-rays or temperature measurement. A booklet giving regulations and syllabuses for the graduateship examination is obtainable from the Institute of Physics, 47, Belgrave Square, London, S.W.1.

New B.B.C. Stations

THREE temporary low-power transmitters at Ramsgate, Hastings and Brighton were brought into use by the B.B.C. on September 16th to improve the reception of the Home Service in those localities. These are the first of twelve such stations promised by the P.M.G.

All three stations will ultimately have a power of 2kW but at present they are somewhat lower. The Ramsgate transmitter will radiate on 1484kc/s, and Hastings and Brighton on 1457kc/s.

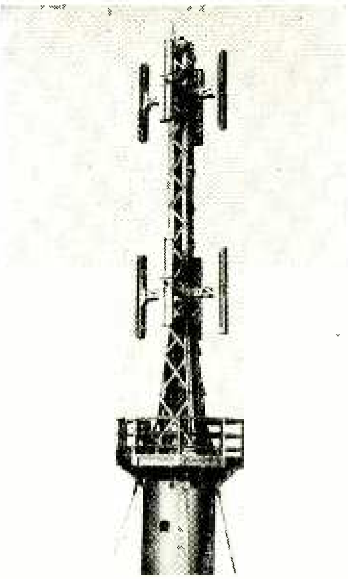
Holme Moss

PREPARATORY to the opening of the northern television station at Holme Moss, near Huddersfield, on October 12th by the Postmaster General, test transmissions on full power (45-kW vision and 12-kW sound) have been taking place daily since September 3rd. Prior to this date test transmissions had been conducted with the stand-by equipment (5-kW vision, 2-kW sound). The station operates on Channel 2 (vision, 51.75Mc/s; sound, 48.25Mc/s).

Business Radio

THE recent statement by the P.M.G. regarding the development of mobile v.h.f. radio-telephone service in this country makes it opportune to draw attention to the booklet being prepared by the Radio Communication and Electronic Engineering Association for the guidance of potential users of the service. It explains the uses of the service and gives information on the installation of equipment and licensing procedure. Enquiries for copies, which will be available shortly, should be sent to the R.C.E.E.A., 59, Russell Square, London, W.C.1.

There have been a number of outstanding successes in the use of this service in the past few months. Among them the *Daily Mail* cross-channel swimming contest in which 26 Pye walkie-talkies were used, 20 of them in the boats accompanying the swimmers.



HOLME MOSS.—The combined sound and vision array which, at the top of the 750-ft mast, is 2,500 ft above sea level. This photograph is taken from a lavishly illustrated booklet on television equipment issued by Marconi's.

Two channels were used (86.675 and 86.375Mc/s), providing separate frequencies for the accompanying boats and the subsidiary control launches. Marconi equipment was installed on the main control vessel for Press reports.

The maintenance of one of the largest main drainage systems in the world, serving an area in West Middlesex of 160 sq miles, has been made safer and more efficient by the introduction of a radio-telephone system whereby the three maintenance vans can keep in touch with headquarters. The 15-20-watt G.E.C. equipment operates on 85.375 and 71.875Mc/s.

Measuring Instruments

IN order to bring into closer relationship three associations whose interests include matters relating to the development and production of measuring instruments for radio and radar, a Joint Advisory Committee on Radio Communication and Radar Measuring Instruments has been formed.

Membership is open to any member of the three associations—Radio Communication & Electronic Engineering Association, Radio & Electronic Component Manufacturers' Federation and Scientific Instrument Manufacturers' Association—who is concerned with developing or making measuring instruments.

The joint committee will deal with both technical and commercial questions. The Committee will be administered from the R.C.E.E.A. offices.

Marine Radio

IN view of the present congested state of the spectrum, the G.P.O. has decided, after consultation with the Ministry of Transport and other marine interests, to issue revised specifications covering the technical requirements to which ships' radio equipment should conform. Revised specifications covering the various types of installation are therefore being issued. The first, "Radio for Merchant Ships: Performance Specification for an Emergency Receiver (with Loudspeaker-Watching Facility)" has been published by H.M.S.O., price 6d.

Hardy Annual

DURING the currency of this issue the *Wireless World* Diary for 1952 will make its appearance at newsagents, stationers, etc. In addition to the week-at-an-opening diary section, there are 80 pages of information and data ranging from postal rates to formulæ. The Diary, now in its 34th year of publication, is available in Morocco leather at 6s 1½d or rexine at 4s 3½d (including Purchase Tax).

PERSONALITIES

Sir Archibald Gill, who has been Engineer-in-Chief at the Post Office since 1947, is retiring on October 1st. He is succeeded by **Dr. W. G. Radley**, C.B.E., M.I.E.E., who entered the Post

DR. W. G. RADLEY, C.B.E.

Office Engineering Dept. as a temporary inspector in 1920. Prior to his appointment as Deputy E.-in-C. in 1949, he was for five years Controller of Research. He was chairman of the committee formed to advise the Medical Research Council on the design of hearing aids.

Sir Arthur Fleming, C.B.E., D.Eng., relinquished his executive duties as Director of Research and Education in Metropolitan-Vickers on his appointment to a similar post with the parent company, Associated Electrical Industries. He has been with Metrovick since 1902. He was recently appointed a member of the Government's reconstituted Technical Personnel Committee, of which Lord Hankey is chairman. Sir Arthur is succeeded by **Dr. C. Dannatt**, O.B.E., M.I.E.E., who is also appointed asst. managing director.

Col. J. Reading, M.B.E., B.Sc.(Eng.), M.I.E.E., the new G.P.O. Assistant Engineer-in-Chief, entered the Equipment Branch of the Engineering Department in 1925. From 1935 to the outbreak of war, Colonel Reading was Managing Editor of the *Post Office Electrical Engineers' Journal*, and has been secretary of the Institution of Post Office Electrical Engineers since 1935. After serving in various theatres of war from 1939 he was eventually appointed Chief Signals Officer, War Office Signals. He returned to the Post Office in 1946.

F. C. McLean, B.Sc., M.B.E., who was appointed head of the B.B.C.'s Engineering Projects Group towards the end of last year, has, in view of the prolonged illness of **H. L. Kirke** (Asst. Chief Engineer), been appointed Acting Assistant Chief Engineer. He will co-ordinate and direct the technical work of the Research, Designs, Equipment, and Planning and Installation Departments.

R. C. Patrick, Assoc. I.E.E., who joined the Research Department of the B.B.C. in 1925, has been appointed Assistant Superintendent Engineer (Recording). During World War II he was Assistant Engineer-in-Charge at the B.B.C.'s emergency headquarters.

G. Stannard, A.M.I.E.E., who has been appointed B.B.C. Assistant Superintendent Engineer (Lines) in succession to **W. G. Edwards**, who has retired, joined the Operations and Maintenance Department of the Corporation in 1932. Since 1947 he has been engaged on the design of equipment associated with the G.P.O. line networks that link the studio centres and transmitting stations.

S. Stansbridge, who has retired after more than 45 years' service with the Marconi International Marine Communication Co., had been in control of the operating and traffic activities of the company since 1928. He joined the staff at the original wireless station at Seaforth, near Liverpool. From 1908 until 1916 he was an operator in many well-known vessels. In his retirement he will act as the company's representative on the employers' side of the Radio Officers' Panel of the National Maritime Board, and various other committees.

C. L. G. Fairfield, M.A., A.M.I.E.E., who joined the Mullard Organization in 1947 as assistant to the directors on technical matters, has been appointed manager of the Valve Division of Mullard, Ltd.

IN BRIEF

Receiving Licences.—Approximately 12,434,900 broadcast receiving licences, including 915,200 for television, were current in Great Britain and Northern Ireland at the end of July. The monthly increase in television licences (18,200) was the lowest in any month since July last year.

Amateur Radio Exhibition.—The fifth exhibition of amateur radio equipment, organized by the Radio Society of Great Britain, will be held at the Royal Hotel, London, W.C.1, from November 28th to December 1st.

B.V.A. Officers.—The British Radio Valve Manufacturers' Association—one of the four constituent bodies of the Radio Industry Council—has re-elected J. W. Ridgeway (Ediswan) chairman for the tenth term of office, and G. A. Marriott vice-chairman for the third time.

Hearing Aid Reliability.—Valves, which had been expected to be the biggest source of trouble in the Medresco hearing aid, have proved to be "by far the most robust and reliable link," according to the writer of an article on the Medresco in the August issue of the Post Office *Telecommunications Journal*. The cords, however, have proved to be the most troublesome.

COL. J. READING, M.B.E., B.Sc.(Eng.) (See centre column).

Coast-to-Coast Television is now possible in the United States with the completion of a chain of 107 radio relay towers erected by the American Telephone and Telegraph Co. Four-storey concrete towers each 125 feet high and carrying four rectangular horn-type aerials are spaced at approximately 30-mile intervals.

Brit.I.R.E. Premiums. — The senior award of the Brit.I.R.E., the Clerk-Maxwell Premium, for the most outstanding paper published in the Institution's *Journal* during the year 1950, has been given to D. W. Heightman (English Electric) for his paper on "The Propagation of Metric Waves Beyond Optical Range." Rudolph Kompfner, Dipl.Ing., (The Clarendon Laboratory, Oxford), receives the Heinrich Hertz Premium for his paper "On the Operation of the Travelling Wave Tube at Low Level." The Louis Sterling Premium is presented to J. E. B. Jacob, B.Sc., (Cinema Television), for his paper on "High Performance Television Monitors," and S. W. Punnett, B.Sc., (University College, Southampton), receives the Dr. Norman Partridge Memorial Award for his paper, "Audio Frequency Selective Amplifiers."

Ionosphere Lectures.—A course of six lectures on "Radio Wave Propagation and the Ionosphere" will be given by L. Prechner, B.Sc.(Eng.), of the Engineering Division, B.B.C., at the Polytechnic, Regent Street, London, W.1, on Tuesdays from 6.30 to 8.0 commencing on October 16th. The recommended reading is the *Wireless World* book "Short-Wave Radio and the Ionosphere" by T. W. Bennington. The fee is 15/-

Educational Opportunities.—In addition to the prospectuses covering both day and evening courses in radio and allied subjects to which we referred last month, we have received details of similar courses from the Northern Polytechnic, Holloway, London, N.7; Norwood Technical College, London, S.E.27; Manchester and District

Advisory Council for Further Education, and the School of Engineering, Crawford Street, Burnbank, Lanark. We have also received additional material from the South-East London Technical College, Lewisham Way, London, S.E.4, regarding an eight-week full-time course in electrical technology and electronics which begins on October 15th.

Amateur Radio Courses.—Although by the time this issue appears the courses will have commenced, readers in the London area may like to know of evening classes which are being held at the Ilford Literary Institute, Cranbrook Road, Ilford, Essex. On Mondays there are courses covering amateur television (six months) and morse (3-6 months); Tuesdays a six-months' amateur radio refresher course; and on Wednesdays an eight-months' course for the Radio Amateurs' Examination. The courses, for each of which the fee is 7s 6d, are organized by the East London R.S.G.B. Group in conjunction with the Essex County Council.

Television Training Centres are being provided by the G.E.C. in Glasgow and Edinburgh in anticipation of the opening of the Scottish station at Kirk O' Shotts which lies midway between the two cities. The Glasgow centre has been in operation for some weeks and closes at the end of September; but courses open at Magnet House, 8, George Street, Edinburgh, on October 1st. Five courses, each lasting a week, will be provided.

Waveguide Symbols.—Supplement No. 2 (1951) to British Standard 530:1948 is entitled "Graphical Symbols used in Waveguide Technique" and is supplementary to the general list of graphical symbols used in telecommunications, issued by the British Standards Institution. The symbols are broadly of two kinds: for diagrams of actual apparatus the waveguide is represented by a pair of lines, and for theoretical diagrams by a single line. The supplement is issued by the British Standards Institution, 24, Victoria Street, London, S.W.1, price 3s post free.

Piezo-electric Terms.—The fifth supplement to the "Glossary of Terms Used in Telecommunication" (BS204) covers terms used in the preparation of piezo-electric crystal units—they are engineering rather than crystallographic terms. The supplement is obtainable from the British Standards Institution, price 1s.

Siting Precautions necessary when installing radar in merchant ships are outlined in the Ministry of Transport Notice M.352 which replaces M.317 of 1948. Copies are obtainable gratis from the M.o.T. Marine (Navigational Aids) Division, Berkeley Square House, London, W.1.

Standards Yearbook.—According to the 1951 edition of the British Standards Institution Yearbook, there were some 35 Standards relating to radio, radar and electronic equipment current at the end of 1950. This 400-page book, which costs 7s 6d, post free, gives a brief description of each of the current Standards and an up-to-date record of the work of the Institution. Standards are listed numerically and there is also a subject index which includes details of a number of codes of practice.

INDUSTRIAL NEWS

Television Exports.—Bush tunable television receivers, Type TV24, modified for reception of the American television channels 2, 3, 4, 5 and 6 (54-72 and 76-88Mc/s) have been exported by M. Falk & Co. to Brazil. The receivers, about 100, have also been modified for f.m. sound. The leader of the Uruguayan delegation to the recent UNESCO Conference in Paris spent a fortnight in August studying the organization of the television service in this country and visited the factories of E.M.I. and Marconi's. Press delegations from Chile and Spain recently visited the E.M.I. factory.

Marconi gear, operated by a Marconi Radio Officer, was carried on the English Electric Canberra during its recent transatlantic record-breaking flight.

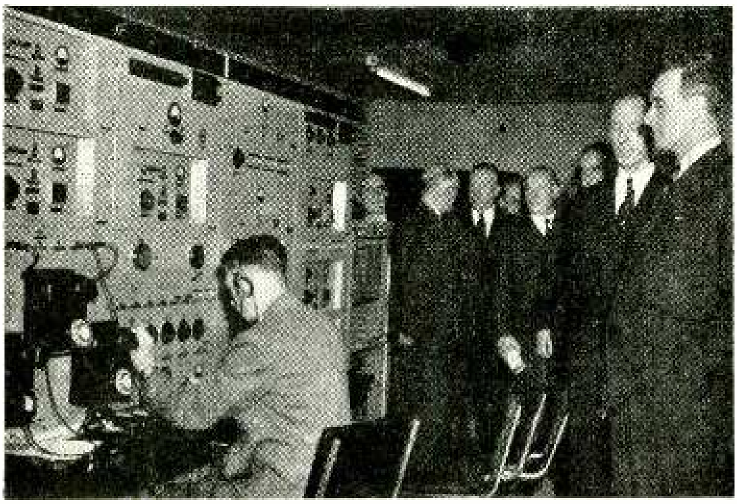
Ferranti Distance Measuring Equipment (D.M.E.) was carried by the De Havilland Comet during its recent proving trials on the Middle East route. So that the Comet will have this short-range radar navigational aid at each stopping point, ground equipment has recently been installed by Ferranti at Rome and Cairo. A D.M.E. beacon is already in use at London Airport.

Egypt has ordered from Marconi's a medium-wave 100-kW air-cooled transmitter for its broadcasting service as well as the 100-kW short-wave station previously mentioned. The Government has also ordered a 3-kW medium-frequency beacon transmitter for an airport.

South American Television.—The installation which Marconi's are supplying for the introduction of a television service in Bogota, Colombia, will consist of a 5-kW vision transmitter, 3-kW sound transmitter, studio equipment including telecine gear and an O.B. vehicle.

Tenders are being sought by the City Electric Light Co., Brisbane, N.S.W., for the supply of equipment for five fixed stations and 30 mobile stations, with ancillary gear, for the extension of the company's two-way radio-telephone communication system. Further particulars are available from the Commercial Relations and Exports Department, Board of Trade, Room 1080, Thames House North, Millbank, London, S.W.1, quoting ref. CRE (IB) 68387/51.

Nickel Plating.—The recent Government Order forbidding the use of nickel for plating purposes, except in certain armament requirements, has made it opportune for Metal Processes, Ltd., to bring to our notice their Niklit finish which by simple immersion imparts an imitation nickel-plate finish.



CONTROL ROOM, EARLS COURT.—Earl Mountbatten, who opened the Radio Show, is seen here inspecting the sound distribution equipment installed for the R.I.C. by Standard Telephones & Cables. He is in conversation with R. W. Addie, chairman of the Exhibition Technical Committee.

MEETINGS

Institution of Electrical Engineers

Inaugural address of Sir John Hacking, President, on October 11th.

Radio Section.—Address of D. C. Espley, O.B.E., D.Eng., chairman, on October 17th.

Discussion on "The Social Implications of Television" to be opened by F. H. Townsend on October 29th.

Above meetings will be held at 5.30 at Savoy Place, London, W.C.2.

British Institution of Radio Engineers

London Section.—"Acoustics in Relation to Radio Engineering" by E. G. Richardson, B.A., Ph.D., D.Sc., at 6.30 on October 11th, at the London School of Hygiene & Tropical Medicine, Keppel Street, London, W.C.1.

Scottish Section.—Dr. Richardson's paper will also be read at 7.0 on October 4th in Edinburgh; and at 7.0 on October 5th at the Institute of Engineers and Shipbuilders, Glasgow.

Television Society

"A Line Strobe Monitor for Measuring and Investigating Television Waveforms" by E. Davies (Marconi's) at 7.0 on October 26th.

Engineering Group.—"P.O. Cable Circuits for the O.B. Television Service" by B. H. Moore (P.O. Engineering Dept.) at 7.0 on October 11th.

Both meetings will be held at the Cinema Exhibitors' Association, 164, Shaftesbury Avenue, London, W.C.1.

Amplified Automatic Gain Control

Simple Circuit Using High-slope Pentodes with Suppressor-grid Injection

By S. W. AMOS,* B.Sc. (Hons) and G. G. JOHNSTONE,* B.Sc. (Hons)

THIS article describes an amplified automatic gain control circuit which can be embodied in a t.r.f. or superheterodyne receiver and is no more complicated than circuits currently used for non-amplified a.g.c.; no additional valves or negative h.t. supply are required. An advantage of the circuit is that the controlled valves may be high-slope pentodes giving higher gain than is available from the variable-mu pentodes used in conventional a.g.c. circuits. The performance obtainable from the suggested circuit can be illustrated by the following measurements made on a t.r.f. receiver with a single controlled valve. As the input was increased from 100 μV to 0.3 volt, the output increased by less than 2 db; in a typical 4-valve superhet with two controlled stages but non-amplified a.g.c. the output increases by approximately 15 db for the same range of input signal amplitude.

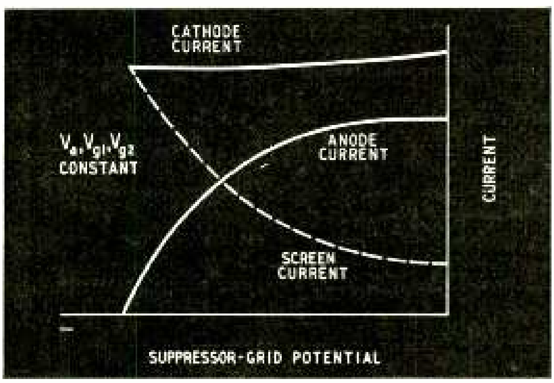


Fig. 1. Typical curves illustrating variation of screen and anode current with suppressor-grid potential.

The circuit to be described embodies suppressor-grid injection of the control voltage. The application of a negative bias to the suppressor grid of a pentode produces markedly different effects from a negative potential applied to the control grid. The effect of varying the control-grid potential is to vary the total (i.e. anode + screen) current and the curve of total current plotted against control-grid potential is similar to that of a triode. The effect of varying the suppressor-grid potential however is to vary the ratio in which the total current is divided between the screen and the anode. This is illustrated in Fig. 1, which shows that increase in negative suppressor bias decreases the anode current and increases the screen current, and provided the screen-cathode potential is maintained constant the total current is substantially independent of suppressor-grid potential. By negatively biasing the suppressor grid the anode current is reduced but—more important in the circuit to be described—the change in anode current per volt change in grid potential is also reduced in the same ratio; in other words the mutual conductance of the pentode is reduced by application of negative bias to the suppressor grid.

Thus the application of negative bias to the suppressor grid of a pentode has an effect similar to that of applying negative bias to the control grid of a variable-mu valve. There are, however, two significant differences to be noted; first, the mutual conductance of a pentode can be reduced to zero by a sufficiently large suppressor bias but the mutual conductance of a variable-mu valve can only be reduced to a low value by application of control-grid bias. In other words the anode-current/suppressor-potential curve has a sharper cut-off than the anode-current/control-grid potential curve for a variable-mu valve. However, no distortion occurs even if the valve is biased near suppressor cut-off because the control grid is still modulating the full cathode current. Second, the cathode current of a variable-mu valve is reduced to a very low value by a large negative bias on the control grid, but the cathode current of a pentode is substantially unaffected by application of a large bias to the suppressor grid. This constancy of cathode current with variation of suppressor-grid bias plays an essential part in this a.g.c. circuit and is largely responsible for the simplicity of the circuit. The use of suppressor injection enables high-slope pentodes of the EF50 type to be used as automatic-gain-controlled r.f. or i.f. amplifiers.

A disadvantage of suppressor-grid control for valves of the EF50 type is that the suppressor-grid base is usually longer than the control-grid base of a variable-mu pentode, and a.g.c. voltages of the order of 50 volts are necessary for effective control. Thus d.c. amplification of the a.g.c. voltage is essential for effective control. This amplification can be achieved without the use of an additional valve, and successful circuits have been constructed in which the necessary d.c. amplification has been obtained (without effect on their normal function) from (1) an anode-bend detector, (2) the first a.f. stage following a diode detector, (3) a second r.f. stage, and (4) an i.f. stage.

A.g.c. amplifiers are, of course, commonly used in superheterodyne receivers more elaborate than the typical 4-valve type but most circuits require a negative h.t. supply to enable the quiescent anode potential of the d.c. amplifier to be slightly negative with respect to the controlled-valve cathodes. The provision of a negative h.t. supply is disadvantageous because it necessitates additional smoothing components, and possibly requires a further rectifier.

The necessity for such a supply can be avoided if the cathode potential of the controlled valve is made

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sufficiently positive with respect to earth potential for the control electrode to be directly strapped to the anode of a d.c. amplifier with its cathode approximately at earth potential. A high value of controlled-valve cathode resistance is required to give a high cathode potential and if the a.g.c. voltage is applied to the control grid the large negative d.c. feedback produced by the cathode resistor to a large extent nullifies the d.c. amplification. In other words when the control grid is driven negative the cathode current falls, resulting in a fall of cathode potential so that the resulting change in grid-cathode potential is relatively small. It is for this reason that negative h.t. supplies are almost universally employed in receivers where it is desired to amplify the a.g.c. If, however, the bias is injected into the suppressor grid, loss of a.g.c. voltage does not occur, because the cathode current is virtually independent of the suppressor bias.

Thus a skeleton form of a practical circuit is that shown in Fig. 2 in which the d.c. amplifier V2 is also an a.f. voltage amplifier, the a.g.c. voltage being injected into the control grid as shown. V1 is a controlled valve and its cathode potential together with the anode potential of V2 are both in the region of 100 volts. This high cathode potential has two advantages : it avoids the necessity for a negative h.t. supply as already explained ; it also reduces the screen-cathode potential of V1 to a value (150 volts approximately) at which the maximum safe screen dissipation is not exceeded even when all the cathode current is flowing to the screen, i.e., when the receiver is tuned to a strong signal. A separate screen dropper must not be used because the screen potential will then vary with suppressor bias and the cathode potential will also vary. If for any reason additional decoupling is required, the dropper should be made to carry the anode current in addition to the screen current to maintain correct performance.

If V2 is to have high d.c. gain its associated component values must be chosen with care. Typical values for anode load, screen dropper and cathode resistor for an a.f. voltage amplifier are 100kΩ, 330Ω and 2kΩ respectively. A stage with such components will probably have an a.f. gain of approximately 150 times, but the d.c. gain would be very much less and is unlikely to exceed 10 times. This low d.c. gain is due to negative d.c. feedback caused by the resistance in the cathode and screen circuits. When a negative potential is applied to the grid the cathode current falls, producing a drop in cathode potential and the screen current falls causing a rise in screen potential. These potential changes both tend to maintain the anode current constant, thus reducing the d.c. gain.

The ratio of the d.c. gain to the a.c. gain in such a circuit can be calculated from the expression applicable to any negative feedback circuit, namely,

$$\text{d.c. gain} = \frac{\text{a.c. gain}}{1 + gR}$$

The degeneration due to the cathode resistor R_k can be calculated by putting $R = R_k$ and $g = g_m + g_s$ where g_m is the mutual conductance and g_s is the screen conductance, i.e., the change in screen current for a 1-volt change in screen potential. If $g = 1$ mA/V and $R_k = 2$kΩ, practical values for a high-slope pentode with a high-value of load resistor, the d.c. gain is one-third the a.c. gain.

In addition, however, there is degeneration due to the screen circuit and to calculate this g is put equal to g_s and R to R_{sg}, the screen feed resistor. For a voltage amplifier typical values for g_s and R_{sg} are 0.01 mA/V and 330 kΩ respectively. Substituting these in the above expression gives the d.c. gain as 1/4 of the a.c. gain. If degeneration is present in both cathode and screen circuits as in practice, the d.c. gain is likely to be only about 1/13 of the a.c. gain. This calculation, based on conservative values of g, emphasizes the need for low values of screen and cathode resistance in d.c. amplifiers.

The cathode potential may be stabilized by using a low-value cathode resistor through which is passed a constant bleed current which, to avoid unnecessary waste of h.t. current, can sometimes be the cathode current of other valves. The screen potential may be stabilized by feeding it from a low-resistance potential divider connected across the h.t. supply but this again implies waste of h.t. current. This loss may be avoided but the stabilizing effect retained by using a potential divider already present in the circuit, namely, the controlled valve V1 and its cathode resistor. The cathode current of the controlled valve may also be used to stabilize the cathode potential of V2. By this means a d.c. gain of the order of 100 times may be obtained from a voltage a.f. amplifier.

For correct polarity of a.g.c. voltage the grid of the d.c. amplifier must be driven positive by the d.c. component of the incoming signal; in other words if a diode detector is used its cathode must be connected to the control grid of the d.c. amplifier. For this reason a multiple valve such as a double-diode-pentode cannot be used for detection and d.c. amplification. A full version of this a.g.c. circuit is given in Fig. 3 in which the first a.f. amplifier also functions as d.c. amplifier.

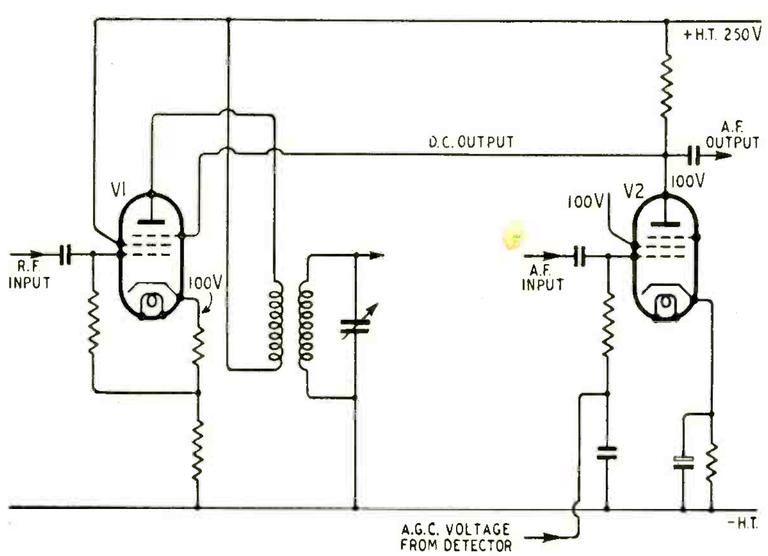


Fig. 2. Skeleton circuit showing electrode potentials in the d.c. amplifier section.

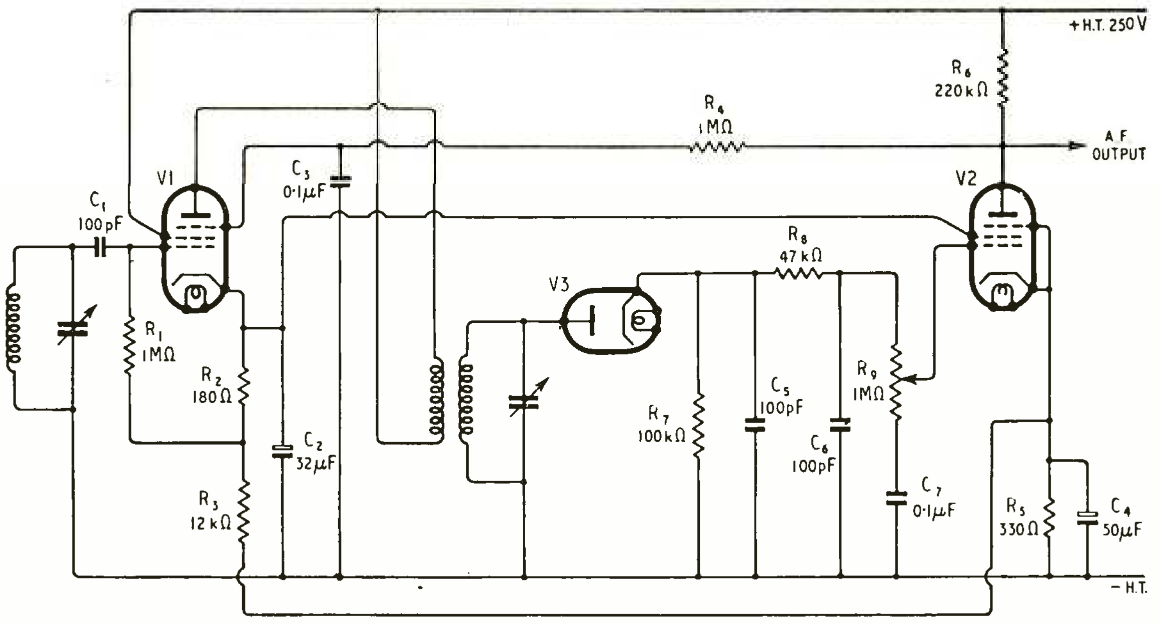


Fig. 3. One version of the amplified a.g.c. circuit in which an a.f. amplifier also functions as d.c. amplifier.

The screen of the audio amplifier must be decoupled by a large capacitor to minimize hum in the output and a 32-μF, 200-V component C_2 is used for this purpose. Moreover, to prevent a.f. signals being impressed on the suppressor grid of V1 an a.f. filter R_4C_3 is included in the suppressor feed. The detector circuit is unusual in that the d.c. blocking capacitor C_7 is included at the earthy end of the manual audio volume control R_9; by means of this circuit arrangement the full d.c. output of the diode is always applied to the grid of V2 irrespective of the setting of the volume control. R_5, the cathode resistor of V2, carries the cathode currents of V1 and V2 and is somewhat larger than might be expected; the larger value is necessary to offset the positive bias of approximately 1 volt which is given by the diode even in the absence of r.f. signals. The value of R_5 or R_6 is critical because between them they determine the quiescent anode potential of V2 and thus the suppressor potential of V1; one of these, preferably R_6, should be capable of adjustment and should be set so that the suppressor-cathode potential of V1 is zero with no signal input.

For successful results V1 must have a suitable, i.e., relatively short, suppressor grid base and the EF50 has been found satisfactory, the cut-off voltage being approximately − 50 volts. The SP41 and SP61 are unsuitable because the suppressor base is longer and the anode potential of V2 cannot, without extensive rearrangement of quiescent circuit potentials, be made to change sufficiently to give adequate control. The anode potential of V2 will not normally go less than about + 20 volts with respect to earth and a suppressor bias of − 80 volts is insufficient to cut off an SP41. Valves with specially short suppressor grid bases such as the 6F32 would appear to be suitable for use in this type of a.g.c. circuit (possibly without d.c. amplification) but have not been tried because they are of lower slope than the EF50.

Valve manufacturers generally stipulate an upper safe limit to the cathode-heater d.c. potential and this is sometimes as low as 50 volts. It is therefore advantageous to keep this potential as low as possible and in the circuit of Fig. 3 the cathode-heater potential can be reduced by connecting the heater winding of the mains transformer to a tapping point on the cathode load of V1. If the winding is centre-tapped it is not usually necessary to decouple the junction point to earth, but if there is no centre tap decoupling may be necessary; a 4-μF capacitor is generally adequate. An advantage of biasing the heater supply is that it frequently brings about a welcome reduction of hum in the a.f. amplifier.

In an alternative form of the circuit V2 may be an r.f. amplifier, in which case R_6 may be a decoupling resistor. Alternatively V2 may be an anode-bend detector and this brings about a considerable circuit simplification; it is hoped in a subsequent article to describe a sensitive t.r.f. receiver using such a circuit. V2 cannot be a leaky-grid detector because the anode potential of such a valve goes positive when an r.f. signal is applied to the grid.

The chief disadvantage of this circuit is that the signal-handling capacity of V1 is limited, and not increased by a.g.c. bias as in conventional a.g.c. circuits. A straight r.f. pentode overloads for inputs exceeding approximately 1 volt peak, but this disadvantage may be overcome by careful design. For example if V1 is a first r.f. amplifier, overloading on strong local stations may be prevented by the use of wavetraps. If some gain can be sacrificed, overloading in general can be avoided by the use of current feedback in the cathode circuits of controlled valves. Current feedback may be applied in Fig. 3 by tapping C_2 and the screen of V2 down the cathode chain of V1.

The a.g.c. provided by this circuit has an inherent delay; this is due to the shape of the $I_a - V_{g3}$ characteristic (Fig. 1) which is substantially level for the first few volts of negative bias applied to the suppressor grid. Thus there is no reduction in controlled-valve gain until its suppressor bias has fallen to the beginning of the knee of the characteristic. Because of the amplification of the a.g.c. bias this delay is not very great and can be eliminated if not required by arranging for the quiescent anode potential of the d.c. amplifier to be lower than the cathode potential of the controlled valve by a suitable amount. If a substantial delay is required it is probably best obtained from a biased diode in the normal manner, the diode output being d.c. amplified as before.

If the quiescent anode potential of the d.c. amplifier is made considerably less than that of the controlled-valve cathode, the maximum sensitivity of the receiver is limited. Such an adjustment is useful if the receiver is used only for reception of strong signal; the adjustment can be made in the circuit of Fig. 3 by suitable choice of the value of R_5 or R_6.

This circuit lends itself readily to the operation of an S-meter, which can be included in the screen circuit of the controlled valve. On weak signals the screen current is low and on strong signals it is high; thus the meter is forward-reading.

This circuit arrangement and other similar ones using the same principles are the subject of a patent application.

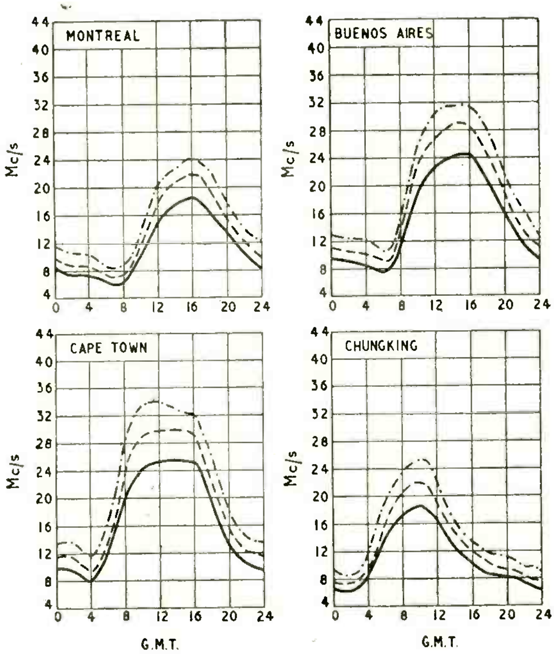
SHORT-WAVE CONDITIONS

August in Retrospect : Forecast for October

By T. W. BENNINGTON *

DURING August the average daytime maximum usable frequencies for these latitudes remained at about the same value as during July, instead of increasing as had been expected. The failure to increase was, no doubt, occasioned by the large amount of ionospheric storminess which occurred. The nightime m.u.f. decreased considerably, in accordance with expectations.

Daytime working frequencies were relatively low. Frequencies above 17 Mc/s were seldom well received over east/west paths, and over north/south paths 24 Mc/s was about the highest frequency for regular reception. Occasionally, of course, frequencies somewhat higher than these were workable over certain circuits. At night 11 Mc/s was usually workable till midnight or somewhat later, but frequencies as low as 7 Mc/s were necessary in the early morning hours.



——— 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

Sporadic E was less prevalent than during the previous month, though on a few days 28 Mc/s communication to European countries was noted as taking place by way of this medium.

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

August was a very disturbed month, and conditions remained subnormal for some very long periods. The ionospheric storms giving rise to these conditions occurred during the periods 1st-3rd, 13-15th, 17-18th and 20-28th. Only one Dellinger fadeout was reported and that was of minor intensity.

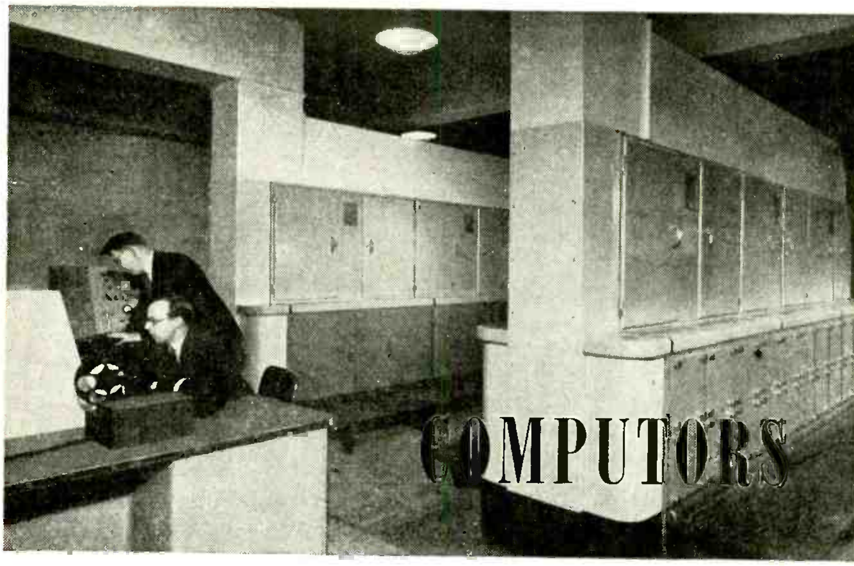
Forecast.—During October there should be a continued increase in the daytime m.u.f. for these latitudes, with a continued decrease in the nightime m.u.f.

Daytime working frequencies should, therefore, be relatively high, though on east/west circuits 17 Mc/s should remain about the highest regularly used frequency, with those up to about 23 Mc/s sometimes usable. Over north/south circuits frequencies up to about 26 Mc/s should be regularly usable during the daytime, and those up to about 33 Mc/s occasionally so. The medium-high frequencies will, however, have to be used for a larger proportion of the daily time, due to the decrease in the hours of daylight. At night 9 Mc/s will generally be of use till about midnight, but after that time 7 Mc/s, or perhaps 6 Mc/s, will be about the highest regularly usable frequency.

Sporadic E should decrease sharply in the frequency of its occurence, and little communication on high frequencies is likely by way of this medium. It is unlikely that the E or F_1 layers will control transmission at any distance and medium distance communication will therefore be by way of the F_2 layer, being possible on slightly higher frequencies by day and on lower ones by night, than during September.

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

* Engineering Division, B.B.C.



Where are the works? A computor looks like this when engineering design principles are applied to it. (The Manchester University machine built by Ferranti).

COMPUTORS

By
"CATHODE RAY"

Doing Sums Without Pencil and Paper

I HOPE the title will not lead anyone to expect a working knowledge of the subject in one easy lesson. It has already become so vast that a full-sized book could not give that. But since I had dealt last month with the binary scale, which is fundamental to most electronic computors, the Editor suggested that I might as well finish the job off by explaining computors themselves. Strictly between you and me, it sounded rather like the proverbial tramp who produced a button and asked the housewife if she would mind sewing a shirt on to it, but with ready tact I refrained from saying so. I did, however, try to make clear to him, as I now do to you, that the most I can attempt in one article is a rough idea of the principles on which automatic computors are based. I can hardly begin to go into details of circuits, still less give full instructions for making a nice little "electronic brain" at home.

Some readers may wonder why the subject comes into *Wireless World* at all. There are really two reasons. One is that wireless and its related technicalities soon lead to involved calculations, and anything which offers hope of helping with these is likely to be of interest. But anybody who would have the use of an electronic computor, and be capable of using it, would be far too learned to look to me for information.

The other reason is that these modern computors, which have caused such a stir, employ valves, neon tubes, cathode-ray tubes, relays—the familiar stock-in-trade of *Wireless World* readers. So it might seem a simple matter to explain computors on a basis of what you already know.

Unfortunately, with all due respect, this is not so. In the first place, it is a waste of time to study computor techniques before one has a clear idea of the operations of simple arithmetic—addition, subtraction, multiplication and division. I hope it is not a gross insult to *Wireless World* readers to suggest that there are any who lack this, but I do feel that most people—including even the mathematically inclined—perform these operations without thinking at all about the principles involved, just as most people who ride a bicycle would be hard put to it to explain clearly how they do it.

In the second place, the familiarity of the components and techniques is more apparent than real. But here I would probably have to make an exception of telephone technicians, because they are quite used to vast aggregations of circuits having numerous alternative connections and sequences of operation. Personally, I find that telephone engineers' diagrams rapidly induce a kind of mental paralysis. During the War the G.P.O. installed an electrical calculator at my radar station, and my mortification at seeing how confidently the G.P.O. man read the circuit diagram was only soothed when he confessed himself beaten by one little part of it—a very elementary radio adjunct!

Persons who are expert both in the theory of numbers and the practice of automatic telephone exchanges, therefore, probably take to electrical computors like ducks to water, but the rest of us are rather handicapped.

Coming now to the subject itself, I should make clear that calculating machines are far from new. Apart from the abacus, which was invented thousands of years ago, the principles of modern computors were worked out about 100 years ago by Babbage. Various mechanical calculators have been in use for many years, and one elaborate kind of electro-mechanical machine was familiar to the public long before the last war—the racetrack totalisator. The thing that is new is the enormous speeding up obtained by using electronic components instead of relays, etc. So in order of development—and speed—we have:—

(1) Mechanical.
(2) Electrical (or electro-mechanical).
(3) Electronic.

An electronic machine does not necessarily perform any additional *kinds* of calculation, but the mere fact of being a hundred or a thousand times faster makes it practicable to do calculations that would otherwise take too long. Since 1945 a succession of electronic computors has appeared, beginning with the American ENIAC, which made a bigger impression on the public mind by the fact of its incorporating nearly 20,000 valves than for any of its mathematical achievements. The Ferranti machine, which was recently inaugurated at Manchester University, is more effective as a computor, but in the eyes of the journalist it suffers from the disadvantage of doing it with one tenth the number of valves.

The Two Kinds

All computors can be divided into two distinct kinds, *analogue* and *digital*. Analogue computors represent numbers or quantities by something else—length along a scale, angle of rotation, voltage, magnetic flux, etc. Probably the best known example is the slide rule. Distance along the rule is made to represent the logarithm of a number, and since adding the logs of two numbers gives the log of the product, multiplication can be done simply by adding together lengths of scale. Division is done by subtracting lengths; taking square roots by halving them, and so on. If the scales of a slide rule were uniformly divided instead of logarithmic, it could be used for simple addition and subtraction, but that would hardly be worth while except as part of a more complex machine. The predictor is a fairly complicated analogue computor, designed for the particular job of rapidly working out gunnery settings.

The best known digital computor (apart from one's fingers) is the abacus—that frame with beads strung on wires, supplied to infants with the hopeful intention of teaching them arithmetic under the guise of entertainment. That it is capable of more than this was shown in a contest between a Japanese virtuoso of the instrument and an American exponent of a modern digital computor—the commercial desk calculator—in which the Jap won every time.

The essential difference between the two classes is that digits or numbers are separate isolated things—the mathematical term is *discrete*—whereas the analogues are continuous. For example, one third cannot be expressed by any finite number (being 0.333333 . . . for ever), but one third of a distance is possible. In practice, however, this does not mean that the analogue principle leads to greater accuracy; quite the contrary, for a scale of manageable length has to be very carefully made if it is to be read reliably to even three significant figures, whereas digital systems can be made to handle figures with any desired number of "places" simply by duplicating components, like valves or relays, which in themselves call for no unusual precision of workmanship. The automatic telephone is a digital system, and the seven twists given (in the London area) to its mass-produced dial, generating seven groups of up to ten pulses, could be used to select any one of ten million different numbers. An analogue scale capable of being read unmistakably to one in ten million would be rather a formidable proposition for the instrument maker!

The limit of precision for reasonably economical manufacture is in the region of one in a thousand, and if one's needs come within that (as most everyday engineering calculations do) an analogue device is generally the cheaper way of meeting them. A digital computor capable of doing the work of a slide rule would be much more expensive. But the cost of obtaining greater precision by finer workmanship goes up very steeply indeed and soon soars beyond all possibility, whereas the curve for digital systems rises quite slowly, so in practice they are always adopted for really precise work.

Another way in which computors can be classified is according to the types of work they take off one's hands and brain. To follow this you will have to give a little thought to what you do when you perform a calculation without external aids; that is to say mentally, because pencil and paper are very definitely external aids. Suppose you have to work out how much a dozen articles at 19s. each are going to cost you. There are various ways of doing it, of course. The most obvious is to multiply 12 by 19 and if necessary divide by 20 to bring to pounds; but most of us never learnt the nineteen-times table, and find it rather a strain to do a long multiplication in our heads—the reason being that we may forget one partial result before the other is ready to add to it. But noting that 19 is one less than 20 we may multiply 12 by 20 and then subtract 12. We do the multiplication in two stages; first by 2 and then by 10. The first stage comes within the scope of the multiplication tables embedded in the memories of (we hope) most citizens. so after planning the whole sequence as above we draw on memory for the fact that $2 \times 12 = 24$. The advantage of the selected procedure is now apparent; there is no need to park "24" somewhere in our minds while we get on with another operation. Although 24×10 is beyond the twelve-times table, we draw on another file in our memory for the fact that multiplying by 10 in the decimal system of numbers merely requires a movement of one "place" or digit to the left, a "0" being added on the right to show this. Subtracting 12 from 240 is perhaps the stickiest bit, and it may be interesting for each of us to consider exactly how we do perform this part of the job. Do we first take away 10, reducing 240 to 230, and then another 10, reducing it to 220 and (making use of the memorized fact that $10 - 2 = 8$) add to the units column to give the answer 228s? Of course, if we wanted the answer in pounds and shillings we could have eased the work by bearing this in mind from the start, converting 12×20 shillings direct into £12 and then converting £1 of this into shillings in order to deduct 12s.

Dot and Carry One

I have gone into this simple piece of mental arithmetic at such length because it illustrates the three main departments of any computing system. There are one or (usually) more *operations*, such as addition, multiplication, etc. Then there is *storage* or "memory" of two kinds—permanent stores for such things as multiplication tables, and temporary stores or parking places for partial results. Then there is the planning and carrying out of the whole computation in *sequence*.

It is as a temporary store that a piece of paper is such a valuable aid. In long multiplication and division the results of the separate single-figure operations can be recorded on it until we are ready to add them together. Even in simple addition it is difficult to carry in one's head the figures that one is not actually dealing with at the moment.

Paper and pencil leave the brain to supply the permanent stores of information, but a slide rule takes over most of that job too. It also reduces the number of separate operations by dealing with two- or three-figure numbers at one go. So it needs less temporary storage, and most of what is required is provided by its cursor. It is only when multiplications and divisions are interspersed with additions that there is need to record partial results on paper.* If a large number of similar calculations have to be done on a slide rule it is worth while spending some time and thought on sequence-planning, to accomplish each with the fewest movements of slides and cursor. For instance, if a formula such as $\frac{p \times q \times r \times s}{x \times y \times z}$ has to be worked out for numerous values of p, q, r, etc., it would be silly to do all the multiplications first and then all the divisions. It is best to divide p by x and multiply by q in one movement, and so on. And if a square or square root comes in, start on the right scale, so that there is no need to transfer from one scale to another.

The corresponding digital aid is the desk calculator. There are many varieties, but however they may be arranged mechanically the basic element is a counter. A motor car contains both analogue and digital instruments in one assembly—the speedometer uses pointer angle as the analogue of speed, and the mileage indicator, which is a counter, reckons distance in terms of figures. The usual decimal counter has for each digit a wheel bearing the ten figures 0—9 on its circumference. The wheel is arranged to be moved round one-tenth of a revolution for each unit of number. To count beyond 9 it is necessary to have a second wheel, for the tens digit, which the first wheel pushes forward one step whenever it turns from 9 to 0. Similarly for hundreds, thousands, and so on *ad lib*.

Although so simple, this device manages to do the "carrying" operation automatically at the same time as the addition. For instance, if the units wheel standing at 8 is pushed forward five steps it not only registers the correct units digit resulting from $8+5$ but it also carries 1 to the tens position. To do the same thing with electrical components is not as easy as it may seem. The carrying may have to be done as a separate operation.

Neither the slide rule nor the desk calculator is automatic. The operator not only has to plan the whole sequence of operations; he has to carry them out. The next advance in computors was to make them automatic, or sequence controlled, so that the operator has only to do the initial planning or "programming," and the machine does the rest. The more refined types are capable of varying the sequence in the light of the partial results obtained, and in this lies their chief value. To take a simple example, the machine could be made to repeat a sequence of operations until the answer became negative, or equal to a stated number, or a maximum or minimum, and then start a different series of operations. Babbage thought all this out a century ago, but he was in advance of his time, and it is only quite recently that his ideas have been made effective.

So the modern automatic computor does everything except provide the problem and the programme. It is hardly fair to call it a "brain," however, because most of the real brain work goes into drawing up the orders so that the machine can carry them out. What the machine does is to take over the laborious and tedious routine operations, and (in the electronic types) at thousands of times the possible human speed and with far less likelihood of errors. Even a mathematician needs several weeks to learn how to instruct one of the big electronic machines. The trouble is that the instructions have to be made absolutely complete and unambiguous in every detail, and yet expressed in terms the machine can "understand"—usually punched holes in paper tape.

Even the instructions for multiplying one number by another are quite considerable. But a great deal of effort can be saved by building frequently used sequences (called sub-routines) into the machine. This is rather like what is done when a complicated plan (such as a military offensive) has to be put into effect at a moment's notice—the order can be reduced to "Operate Plan B" or a simple code word or number, so long as the details have been cut and dried in advance. A code number on the tape fed in brings into operation a previously prepared and stored record of the sequence to be followed by the machine.

Representing Numbers

And now I have just a little space left to mention some of the techniques employed in electrical and electronic computors.

First the analogue kind. One way of representing the numbers in the computation is by voltages. It is easy to add or subtract them by rotation of a potentiometer, forwards or backwards. Sines and cosines are obtainable by a suitably shaped potentiometer, or (with a.c.) by the angular position of a coil in an alternating field. The output of a potentiometer is proportional to its setting multiplied by the voltage applied to the input, so if both are under control it is possible to multiply. Another method of multiplication is to represent the variables by the currents in two coils; the force between them is proportional

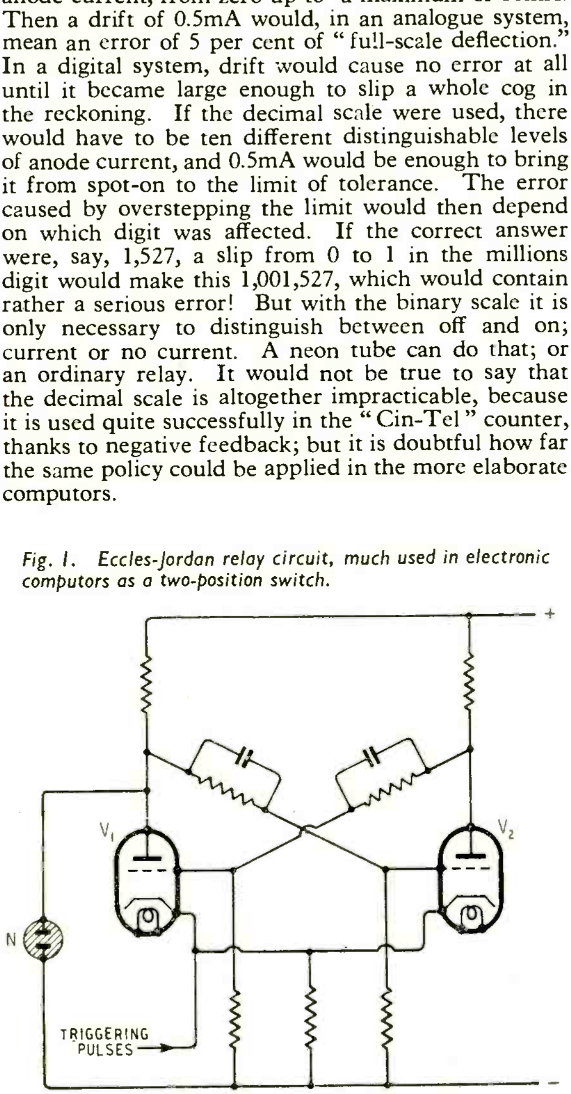
Control equipment for the pilot model of the N.P.L. automatic computing engine. Information on punched cards is fed into the Hollerith machine on the left.

* And not always even then; see "Easing Impedance Calculations," *Wireless World*, Jan., 1950.

to the product. An ordinary wattmeter goes one step farther and indicates the triple product VI cos θ, where θ is the phase angle between V and I. The current in one coil is, of course, I, and the current in the other is made proportional to V. The same scheme can be adopted in a computor by using one of the known methods of phase control to bring (say) an actual angle into the system. The household electricity meter goes still farther and integrates VI cos θ with respect to time; that is to say, multiplies VI cos θ at every moment by the infinitesimal duration of that moment, and adds the whole lot up to give kilowatt-hours. It does this by making the speed of a wheel represent the wattage; then the number of revolutions it makes is the time-integral.

Whenever a valve is used in an analogue computor it is practically compulsory to use lots of negative feedback, otherwise the readings are founded too much on the shifting sands of valve characteristics. This leads us to the point I was discussing last month when explaining the advantages of the binary arithmetical scale over the more familiar decimal one. Suppose the operative quantity in a valve circuit is its anode current, from zero up to a maximum of 10mA. Then a drift of 0.5mA would, in an analogue system, mean an error of 5 per cent of "full-scale deflection." In a digital system, drift would cause no error at all until it became large enough to slip a whole cog in the reckoning. If the decimal scale were used, there would have to be ten different distinguishable levels of anode current, and 0.5mA would be enough to bring it from spot-on to the limit of tolerance. The error caused by overstepping the limit would then depend on which digit was affected. If the correct answer were, say, 1,527, a slip from 0 to 1 in the millions digit would make this 1,001,527, which would contain rather a serious error! But with the binary scale it is only necessary to distinguish between off and on; current or no current. A neon tube can do that; or an ordinary relay. It would not be true to say that the decimal scale is altogether impracticable, because it is used quite successfully in the "Cin-Tel" counter, thanks to negative feedback; but it is doubtful how far the same policy could be applied in the more elaborate computors.

Fig. 1. Eccles-Jordan relay circuit, much used in electronic computors as a two-position switch.



Reducing the number of figures, or distinguishable states, from ten to two is such an enormous simplification that it is well worth having even though it means about three times as many digits, and also "translating" from and into decimal notation. For example, if numbers up to 9,999,999 are to be handled, it is easier to do it with twenty-four 2-way (on-off) switches than with seven 10-way switches.

Electronic Totting-up

The basis of a digital computor, as I said before, is a counter. The binary equivalent of the ordinary wheel counter would have only two figures on its circumference, 0 and 1. Each impulse to be counted would have to move it half a turn, so every second (instead of every tenth) impulse would carry one to the next wheel, pushing it round half a turn. And so on. The electronic version of this is the Eccles-Jordan relay (Fig. 1), published as long ago as 1918, and now often (not strictly correctly) called a flip-flop. This has two possible states: V_1 conducting and V_2 cut-off, or *vice versa*. Whichever state exists, a negative pulse applied to the cathodes reverses it; the action being rather like the overhead type of electric light switch in which one pull at the cord turns the light on and the next pull turns it off. If a neon tube N is connected as shown, the voltages can be arranged so that it lights up (indicating "1") when V_1 is cut off, and goes out (indicating "0") when V_1 conducts. By coupling the anode of V_1 to the cathodes of another pair, the change from 1 to 0 in the first pair can be made to cause a change from 0 to 1 in the second pair, making the indicated total rise from 01 (one) to 10 (two). The next pulse makes the first pair 1 again; total reading: 11 (three). To count beyond three, a third pair is needed. So it is easy to imagine why the ENIAC (which uses this system) needed 20,000 valves, bearing in mind the need for numerous storage arrays as well as those actually used for operations. There are more economical methods of storing numbers, but in the meantime let us see how some of the operations can be worked.

For simplicity, let us assume only five binary digits, capable of counting up to $16+8+4+2+1=31$. Suppose we want to add 9 to 13. The machine would be fitted with a switch for clearing all the registers (the rows of flip-flops) so that every digit is 0. Then "9" is fed into the machine. A special department converts this into the binary equivalent, 01001, and signals one of the registers in such a way that the first and fourth flip-flops from the right are triggered over into the "1" state. The 13 is then fed in, and the machine (acting all the time, of course, on the coded instructions issued by the programmer) translates it into 01101 and supplies it to the same register. By writing these numbers in the usual form for addition

01001
01101

we can see that the first flip-flop (extreme right) receives a second impulse, which will change it back to 0 and at the same time trigger the second to 1. The third is triggered to 1, and the fourth receives a second impulse which makes it 0 and carries 1 to the fifth. Result: 10110, which the binary-to-decimal translater interprets as $16+0+4+2+0=22$ and passes it to the output of the machine, either as light signals or (in the more expensive models) typed figures.

More often the numbers to be added are those that have been stored as results of other operations, and the machine has to be able to respond to instructions such as "Take the contents of store X and add them to those in store Y."

Subtraction can be brought within the ability of an adding machine if the number to be subtracted is replaced by its *complement*. To take an example in decimal notation, subtract 127 from 26,454. The 5-figure complement of 127 is 99873, and adding this to 26,454 gives the right answer, 26,327 (ignoring the last 1 because it is outside the 5-figure limit). The binary system obviously makes this much easier, because all one has to do to get the complement is to reverse all the digits and add 1. Try it and see!

Multiplication is also very easy in the binary system, because it too reduces to the operation of adding, combined with shifting to the left. Suppose we want 9×13, or 1001×1101 in binary. If you write this out in long multiplication

```
   1001
   1101
   ----
   1001
  0000
 1001
1001
-------
1110101
```

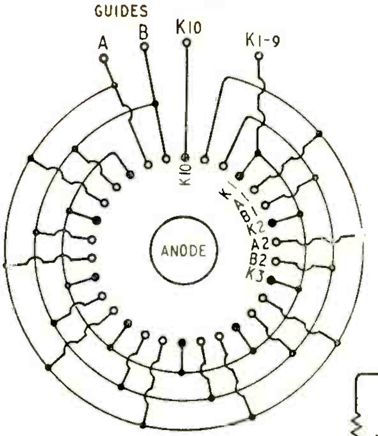
you will see that the first (units) digit in the multiplier (1101) requires the multiplicand (1001) to be taken as it stands. The second digit, being 0, requires nothing at all. The third requires the 1001 to be shifted two places and added, and the fourth requires it to be shifted three places and added. This is a comparatively easy extension of the adding circuits.

Division is a little more difficult, but if you try some binary long division, using the complement method to turn subtraction into adding, you will see that the only new thing the machine has to do is to time some steps of the programme for itself, depending on the result of the previous step.

Memory

Lastly, storage systems. If every binary digit to be stored either permanently or temporarily necessitates a pair of valves, the size and cost of the computor become alarming. That was the fault of ENIAC. Another fault is that if there is a power cut the machine is instantly afflicted with total loss of memory. So for permanent or long-period storage it is better to use magnetic recording, on tape or drum. The Ferranti Mark I computor contains a drum six inches by eight, which can store the impressive total of 650,000 binary digits. It also has eight cathode-ray tubes, each with a capacity of 1,280 digits, for more immediate use. All this is in addition to a moderate number of valve registers. The cathode-ray stores are a special feature of this machine, and obviously appeal strongly to me, but I have only room to hint that their working principle is very similar to that of the television camera tube. Since a charge pattern on a c.r. tube screen quickly fades, arrangements are made to "repaint" the whole lot about 30 times every second, but this does not prevent the machine from being able to pick out any line of digits on any tube in, at most, 0.00024 sec.

Other computors that have been built make much use of mercury storage. Pulses corresponding to the numbers to be stored are applied to one end of a tube filled with mercury, and they travel to the other as waves. When the waves reach the far end, which they



Left: Fig. 2. Arrangement of electrodes in the Dekatron tube. The ten cathodes are numbered K1 to K10. The two sets of guides, A and B, are for shifting the glow discharge from cathode to cathode.

Below: Fig. 3. How a Dekatron is shown in circuit diagrams.

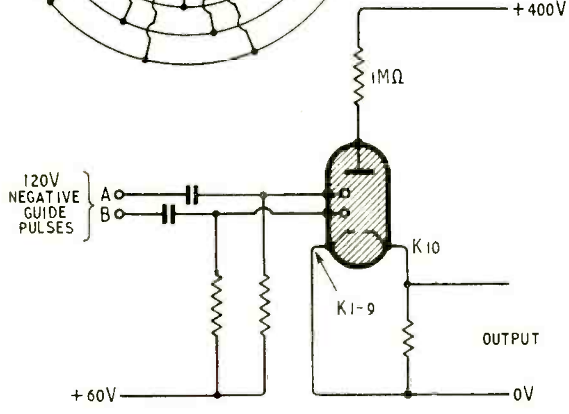
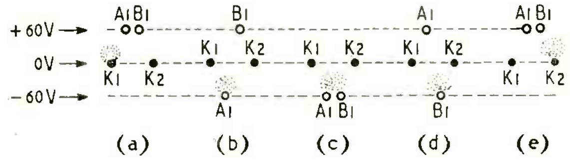


Fig. 4. Voltage diagram showing how the glow is passed from cathode to cathode by negative pulses on the guide electrodes.



do in about one thousandth of a second, they are received, amplified, and reintroduced at the input. In this way a record lasting one millisecond can be kept in existence indefinitely, and can be referred to any time it comes round.

One other device is, I think, worth mentioning, because it looks as if it would be very useful for less ambitious electronic computors than those we have been considering. It is a special kind of neon tube—the Dekatron—and is capable of recording numbers in decimal form. There is one central anode, with ten cathodes standing round it in a ring. The particular cathode that is taking the discharge is shown by the glow. The glow can be passed from one cathode to another, round the ring, by applying pulse signals to guiding electrodes, two of which stand between each pair of cathodes, and are connected together as in Fig. 2. All the cathodes, except the last, are also connected together, so the discharge can take place equally well to any of them. The guides are normally about 60V more positive (Fig. 3) so there is no tendency for them to act as cathodes, and the voltage is too low for them to act as anodes. Suppose the discharge has been established to cathode K1. If the A guides are all made momentarily more negative than the cathodes, the discharge passes from K1 to A1 (Fig. 4). Just as the A guides are about to return to positive, the B guides are momentarily made negative, attracting the glow from A1 to B1. Finally the return of the B guides to positive shifts the glow to K2. The next pair of pulses on A and B shifts it to K3; and so on. The process is very like the party game in which the members of a team sitting side by side pass a ball along the line from one pair of feet to the next. When the glow reaches K10, this cathode (being separately connected) can be made to cause a signal that will carry 1 to the next tube, as in a mechanical counter.

I could use up a good many pages explaining how this and other electronic devices function in circuits, but I am expected to leave room for somebody to make at least a passing reference to the affair at Earls Court.

Eidophor Projection Television System

AMONG the papers read at the Television Engineering Session of the 1951 Radio Convention of the British Institution of Radio Engineers was one on the eidophor system. Sometimes known as the Fischer system after its inventor, who died in 1947, the eidophor system depends on the use of a film of oil as a modulator for a beam of light.

The equipment described in the paper by Professor E. Baumann, of Zurich, is the third prototype and was first operated in December 1950. The first model was tried out in 1944.

A film of oil is scanned by the electron beam of a cathode-ray tube which produces on the oil an electrostatic-charge pattern corresponding to the picture. The surface of the oil is deformed by this charge pattern and this deformation, in effect, turns the oil into a pattern of tiny prisms. In conjunction with a Schlieren optical system a light beam is thereby modulated.

The video signal modulates a 20-Mc/s carrier and the modulated carrier is applied to the c.r. beam. As a result a form of velocity modulation is obtained. The light source passes through a series of parallel bars to the oil film of the eidophor. It passes through the film, is reflected from the rear surface and passes through a second time back to the parallel bars of the Schlieren optical system. The adjustment is such that if the eidophor is unmodulated the light hits the bars and passes no farther. The prisms formed in the oil by the modulation, however, deflect the light in greater or lesser degree, with the result that the emergent light is intercepted to a varying extent by the bars and so a varying quantity of light passes between them. This is, of course, focused on the screen to form the picture.

The cathode-ray tube operates at 20 kV with a beam current of 80 μA. It is of the continuously evacuated type. The light source is an arc providing 45,000 candles per sq cm. The eidophor is of 75 sq cm and gives an effective light storage of about 70 per cent. It is slowly rotated so that a fresh surface is exposed for use and is maintained at constant temperature by a refrigerating plant. The final picture has an illumination of around 4,000 lumens.

The definition obtainable is independent of the light capacity and the equipment has been used up to 729 lines. The limits are stated to lie in the picture source rather than in the projector.

New Radar Display Unit

Details of the Type 12 Decca Marine Radar

THE 5-inch display unit (Type 159B) originally fitted in the Decca marine radar had the virtue of instant adaptability to all types of vessel from fishing craft to passenger liners, and was undoubtedly one of the reasons for the success of the original design (over 1,000 have already been installed).

To meet the requirements of the Navy, and also the demand from owners of the larger vessels, for bigger p.p.i. display, the Type 12 unit has been developed.

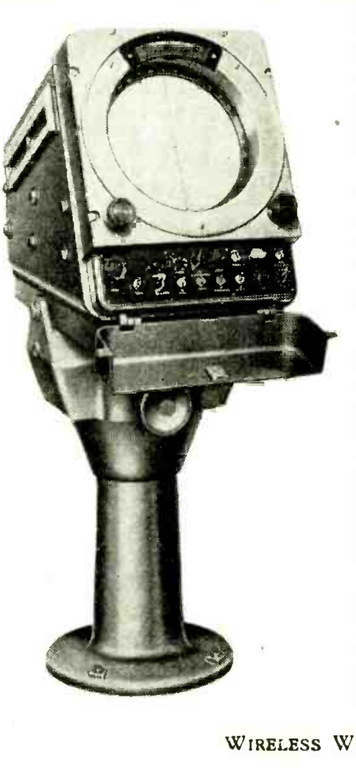
The 12-inch tube not only gives a high-definition display which can be read without the aid of a magnifier, but the larger mounting has enabled the designers to incorporate several new and interesting features in the circuit. Foremost among these is a new differentiating circuit which effectively analyses the returns from rain or snow areas and throws into relief targets which would otherwise lie hidden in a confused overlapping train of responses. This circuit, which can be switched out to give higher maximum sensitivity when not required, is effective up to maximum range and can be regarded as complementary to the sea clutter control at short ranges.

Dual-pulse-length transmission, automatically switched from 0.1 μsec for the 1- and 3-mile ranges to 0.2 μsec for 10 and 25 miles, is now employed to improve responses at long distances while retaining the high discrimination and minimum range of 25 yards on the short ranges. The range scales, which are logarithmic for constant percentage accuracy, are automatically selected by a shutter, coupled to the range control switch.

Mechanically, the Type 12 display unit is extremely robust. The housing is a machined aluminium-alloy casting with internal runners which enable the display chassis to be drawn forward for servicing, and is attached to the trunnion base by four resilient rubber mountings.

The rest of the equipment—scanner, receiver unit and power supply — is the same as in the Type 159.

A new factory has been equipped with special machinery to turn out this new set in sufficient quantities to supply the needs both of the Navy and the mercantile marine.



Pedestal mounting for Decca Type 12 display unit, which can also be supplied for shelf-mounting if required

Efficiency Line-Scan Circuits

(*Concluded from page 350 of the September issue*)

Part 3—Transformer Coupling

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

As soon as a transformer or auto-transformer is included in the time-base circuit its operation becomes much more complex. If h.t. boost is not used the only benefits to be gained by using a transformer are the absence of a d.c. component in the deflector coil, the ability to use a deflector coil of any required inductance and the ability to operate the diode with its cathode earthy. This last benefit is only obtainable with a double-wound transformer. To offset these advantages, the transformer reduces the efficiency of the circuit. It does this in three ways: energy is needed to establish the magnetizing field in the core; energy is needed to establish the inevitable leakage field; and energy is needed to provide for the eddy-current and hysteresis losses of the core. In addition, the equivalent circuit becomes that of a coupled pair of resonant circuits instead of that of a single circuit; it has two natural frequencies of oscillation instead of one and it is not possible to control both by means of a single diode.

The inductive effects of the transformer are on the scan exactly equivalent to a change in the effective value of the $L_L I_L^2$ figure of the deflector coil and the efficiency may be reduced by as much as 50 per cent. The core losses affect the total Q of the circuit and, hence, the amount of overshoot, which in turn affects the current efficiency of the output valve in the manner already described.

The total effect of a transformer on circuit efficiency can be very considerable. The basic efficiency of a circuit using a transformer is always less than that of one embodying a directly-fed deflector coil but, of course, the latter is not always practicable.

When h.t. boost is used, however, conditions are rather different. The energy recovered in the diode auto-bias circuit, and otherwise dissipated as heat in the bias resistor, is then utilized as part of the h.t. supply to the driving valve. This power fed back may exceed the loss introduced by the transformer and result in the total input power with the transformer-fed coil being less than with the directly-fed coil in spite of the transformer losses. This condition is most likely to pertain, and h.t. boost is certainly most valuable, when the h.t. supply is limited to a low value, as when it is derived directly from the mains without a mains transformer.

There are several different equivalent circuits of a transformer but the most suitable one for the present purposes is shown in Fig. 9. The real transformer of primary and secondary inductance L_p and L_s and mutual inductance M has a ratio of primary/secondary turns n. It is equivalent to (b) in which an ideal transformer of ratio $nk : 1$ is connected to the network of inductances which simulate the field deficiencies of the real transformer. The leakage inductance is represented by $L_s(1-k^2)/k^2$ and the finite inductance of the transformer winding by L_s, where k is the coupling coefficient and equals $M/\sqrt{L_pL_s}$. The primary inductance is $L_p = n^2L_s$. This diagram does not take into account core losses.

Now if a deflector coil of inductance L_L and requiring a peak-to-peak current I_L is connected to terminals 3, 4 in Fig. 9 it is obvious that L_s must draw a similar current. A voltage L_LI_L/τ_1 exists across the deflector coil and also across L_s, but it cannot do this unless L_s is taking a current I_s such that $L_sI_s/\tau_1 = L_LI_L/\tau_1$; therefore, $I_s = I_LL_L/L_s$. The total current flowing in the ideal transformer secondary and through the leakage inductance is thus

$$I_{sT} = I_s + I_L = I_L(1 + L_L/L_s) = I_L/\eta_i \quad .. \quad (7)$$

where η_i is the current efficiency factor of the transformer. The primary current is, of course, $I_p = I_{sT}/nk = I_L/nk\eta_i$

The back e.m.f. across the deflector coil is $E_L = L_L I_L/\tau_1$. The back e.m.f. across the secondary of the ideal transformer is greater than this by the back e.m.f. across the leakage inductance and this is $L_sI_{sT}(1-k^2)/k^2\tau_1$. The total voltage on the ideal transformer secondary is thus

$$\frac{L_LI_L}{\tau_1}\cdot\left[1+\frac{L_s}{L_L}(1-k^2)\right]\frac{1}{k^2} = \frac{L_LI_L}{\tau_1}\;\frac{1}{\eta_v} \quad (8)$$

where η_v is the voltage efficiency factor of the transformer. The total primary voltage is, therefore, $E_p = nkE_L/\eta_v$

The product $I_p.E_p = E_L I_L/\eta_i\eta_v$ is a measure of the input power, just as $E_L I_L = L_L I_L^2/\tau_1$ is a measure of the deflector coil power. From the point of view of efficiency, therefore, the circuit behaves during the scan as though the deflector coil had a figure of merit of $L_LI_L^2/\eta_i\eta_v$ instead of $L_LI_L^2$. It is quite easy to show from these relations that the efficiency is a maximum when

$$L_s = \frac{L_L}{\sqrt{1-k^2}} \quad .. \quad .. \quad .. \quad (9)$$

and that then

$$\eta_i = \eta_v = \frac{k}{1+\sqrt{1-k^2}} \quad .. \quad .. \quad .. \quad (10)$$

The coupling coefficient is thus very important. On

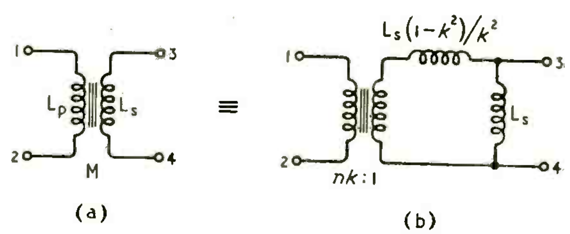


Fig. 9. Transformer (a) and its equivalent circuit (b).

account of the need for high insulation and low self-capacitance it is difficult to use many interleaved sections for the primary and secondary windings, which is the usual way of reducing leakage. In some cases it is not easy to make k greater than 0.98. With this value $k^2 = 0.96$ and $\sqrt{1 - k^2} = 0.2$, so that the optimum value of $L_s = 5\ L_L$ and $\eta_i = \eta_v = 0.98/1.2 = 0.817$. The " power " efficiency of the transformer is thus only $0.817^2 = 0.66$.

Viewed from the transformer primary the total effective inductance is

$$L_{pT} = n^2k^2\left[L_s\frac{1-k^2}{k^2} + \frac{L_L L_s}{L_L + L_s}\right] \quad \ldots \quad (11)$$

and when L_s has its optimum value this reduces to $L_{pT} = n^2L_L$.

If a transformer-coupled deflector coil is used in the circuit of Fig. 1 (Part I), therefore, the effect is to a first approximation the same as if a coil of inductance n^2L_L were used and this coil had a figure of merit of $L_LI_L^2/\eta_i\eta_v$. An example may help to make this clear. In Part I we considered the case of $L_LI_L^2 = 2.9$ mH-A² and with the overshoot $x = 0.8$ we found $L_L = 22.3$ mH and $i_a = 46.6$ mA. Suppose we now wish to make $L_L = 5$ mH, $L_LI_L^2$ remaining unchanged, and the peak current of the valve is still 200 mA. If the coupling coefficient of the transformer is 0.98, $L_s = 5L_L = 25$ mH. The effective $L_LI_L^2$ figure is $2.9/0.66 = 4.4$ mH-A². If the overshoot is unchanged the mean anode current is unchanged and so the current output of the valve and circuit is still 360 mA. The effective inductance $n^2L_L = 4.4/0.36^2 = 34$ mH and so $n = \sqrt{34/5} = 2.6:1$. The primary back e.m.f. is $34 \times 10^{-3} \times 0.36/82.77 \times 10^{-6} = 148$ V.

As compared with the directly-fed coil, therefore, the use of a transformer results in the primary scan back e.m.f. being increased from 96 V to 148 V and the h.t. supply voltage must be increased by the difference, 52 V. The peak voltage on the fly-back also increases in the same proportion but the currents are unaffected. The necessary increase of power input has here been taken purely as a voltage increase because the peak current of the valve has been considered as the current-limiting factor. If this limitation did not apply the increase of power could be taken in the form of current rather than voltage.

To a first approximation the same equivalent circuit holds on fly-back and the effect of the transformer losses on the overshoot can be taken into account quite simply. If the deflector coil losses are represented by a shunt resistance R_L it has $Q_L = R_L/\omega L_L$; similarly, if the transformer losses are represented by a shunt resistance R_s to L_s, the transformer has $Q_s = R_s/\omega L_s$. The Q of L_s and L_L in parallel is thus,

$$Q_T = \frac{R_LR_s}{R_L + R_s}\Big/\omega\frac{L_LL_s}{L_L + L_s}$$

$$= Q_L\frac{1 + L_L/L_s}{1 + Q_L\ L_L/Q_sL_s} \quad \ldots \quad (12)$$

This is only an approximate relation since no account has been taken of the leakage inductance. It should be noticed that the total Q does not depend only on the individual Q values but also upon the relation between L_L and L_s and in consequence a low transformer Q will not affect matters very much if L_s is high enough in relation to L_L.

We found previously that for an overshoot of 0.8. $Q_L = 7.05$. A transformer with a ferrite or dust-iron core will have a higher Q than this, but one with a core of 0.014-in silicon-iron laminations may well have a Q of no more than unity! With this value, and when $L_s = 5L_L$, the total Q becomes,

$$Q_T = 7.05\frac{1.2}{1 + 7.05/5} = 3.5$$

and the overshoot $x = \epsilon^{-\pi/7} = 0.64$

This, of course, changes all the other conditions and the primary current drops to 328 mA, while the mean anode current rises to $84/1.64 = 51$ mA. The effective primary inductance becomes $4.4/0.328^2 = 41$ mH and so $n = \sqrt{41/5} = 2.86:1$. The primary back e.m.f. becomes $41 \times 0.328 \times 1000/82.77 = 163$ V. The input power needed, apart from the anode dissipation of the valve is $163 \times 0.051 = 8.3$ W instead of the 4.56 W needed by the directly-fed coil. It must again be emphasized that because of the idealized approach these figures, although comparative, are appreciably smaller than practice indicates.

Oscillations with Primary Diode

The circuit diagram of this transformer-coupled stage is shown in Fig. 10. In this the actual transformer shown is the ideal one with the elements of Fig. 9(b) added to represent the real transformer. Also the primary and secondary circuit capacitances C_p and C_s have been added. So far it has been considered that C_s is negligible, but in practice it is not. When the diode V_2 is conductive over the initial part of the scan it can control only the voltage on the left-hand side of the leakage inductance and the current through it; the resonant circuit to the right is not under its full control.

It is true that if the currents in L_L and L_s decay linearly the voltage across them will be constant and C_s will draw no current. Because the leakage inductance separates these components from the diode, however, the current is not forced to decay linearly and, in fact, it will not do so. The decay tends to be oscillatory. Ignoring any effect of the resistance losses on frequency, and regarding the diode as an effective short-circuit on the primary, the natural frequency of unwanted oscillation occurs at the frequency for which C_s resonates with the secondary and leakage and deflector-coil inductances all in parallel. When the optimum value of secondary inductance is used this frequency is given by :—

$$f = \frac{1}{2\pi\sqrt{L_LC_s}}\sqrt{\left[\frac{1+\sqrt{1-k^2}}{\sqrt{1-k^2}}\right]} \quad \ldots \quad (13)$$

In the example considered earlier we had $L_L = 5$ mH, $k = 0.98$, if we assume $C_s = 200$ pF, — a probable value, since it includes the deflector-coil self-capacitance, we get $f = 390$ kc/s. The time of one cycle of oscillation is 2.6 μsec and so on a 10-in picture the effect would be to produce bright bars $2.6 \times 10/82.77 = 0.31$ inch apart with dark bars between them.

In practice such oscillations are liable to occur but are modified by the losses in the components. There is a damped sine wave of oscillation superimposed on the linear scan current and it is rare for more than about four bars to be visible on the picture.

It is not an easy matter to avoid this form of oscillation. What is required is a method of damping the subsidiary resonant circuit without damping the main one but this cannot be done by components connected to the circuit. However, the general circuit losses increase with frequency and so are more effective in damping this subsidiary circuit than the main one, which is set at about 32 kc/s by fly-back considerations. The aim in design should be, therefore, to make the natural frequency of the subsidiary circuit as high as possible. The first step is obviously to keep C_s as small as possible, but no great improvement here is practicable—it would be at most about 2 : 1 in frequency.

The deflector coil inductance L_L can be reduced, in theory, without limit. In practice, however, there is a limit since if the inductance is too low the wire needed will become too thick for easy manufacture. Coils of less than 1 mH are rare. The improvement here seems limited to about 2 : 1 in frequency. The other factor affecting frequency is the coupling coefficient k and again quite a large increase is needed to increase the frequency very much.

Since h.t. boost cannot be obtained with a primary diode and since it seems so much better to dispense with the transformer entirely and use a directly-fed coil when h.t. boost is not used, it would not seem profitable to pursue the operation of the primary diode further. The invariable modern practice is to have the diode on the secondary side of the transformer and very often connected to the deflector coil. With a double-wound transformer this permits the diode cathode to be earthy and avoids difficulties in the heater supply; however, with an auto-transformer, which is now the common practice, the diode cathode is still " hot."

The circuit with a secondary diode is shown in Fig. 11. The transformer has again been shown by its equivalent circuit and the windings of the ideal transformer in it have been drawn end-to-end to bring out clearly the phase-reversing connections. The secondary circuit is shown as " floating "; in practice, some point is made earthy, but this point can be anywhere.

The equations of Part 1 need slight modification to cover this circuit, because the valves operate on the two sides of the transformer instead of both on the same side. The formula for the anode current i_a of V_1 is unchanged. As V_2 is now in the secondary circuit it carries part of the secondary current instead of part of the primary and this is nk times the primary current. The equation for the mean diode current thus becomes

$$i_d = \frac{i_p}{2} \cdot nk \cdot \frac{\tau_1}{\tau} \cdot \frac{x^2}{1+x} \qquad (14)$$

If h.t. boost is to be used it is necessary for the mean currents of V_1 and V_2 to be equal and this requires

$$n = 1/x^2k \qquad (15)$$

so that the transformer ratio is dependent on the overshoot obtained and hence on the Q of the circuit. This value of the ratio is really a minimum one; it can always be higher at the expense of boost voltage, for a resistance can be provided to absorb the surplus diode current.

With this additional information we can compute the requirements of a secondary diode circuit. We had before $k = 0.98$, $x = 0.64$, $i_p = 200$ mA, $L_L I_L^2 = 2.9$ mH-A², $L_s/L_L = 5$, $\eta_i = \eta_v = 0.817$. The total peak-to-peak current referred to the primary remains unchanged at 328 mA.

The transformer ratio is $n = 1/0.4 = 2.5$ and so the peak-to-peak secondary current is 0.328 (2.5 × 0.98) = 0.8 A and the deflector coil current is $0.8\eta_i = 0.65$ A. The inductance must be $L_L = 2.9/0.65^2 = 6.8$ mH and $L_s = 34$ mH. Since the transformer conditions have been chosen to be optimum the effective inductance at the primary is $n^2L_L = 42.5$ mH and the primary scan back e.m.f. is 42.5 × 0.328 × 1000/82.77 = 169 V. This is the same as with a primary diode, as it should be (the actual figure obtained was 164 V —the difference is negligible and is brought about by working to a slide-rule accuracy only). If h.t. boost is not used, the power input is therefore the same whether the diode is on the primary or the secondary.

Since the diode V_2 is across the secondary, the voltage appearing across R_1 is limited to the back e.m.f. across L_L; that is, to 6.8 × 0.65 × 1000/82.77 = 53.5 V. This is the maximum boost voltage available. If it were possible to connect the diode to the other side of the leakage inductance the boost voltage would be 69V. It is not, however, and the energy stored in the leakage inductance is lost.

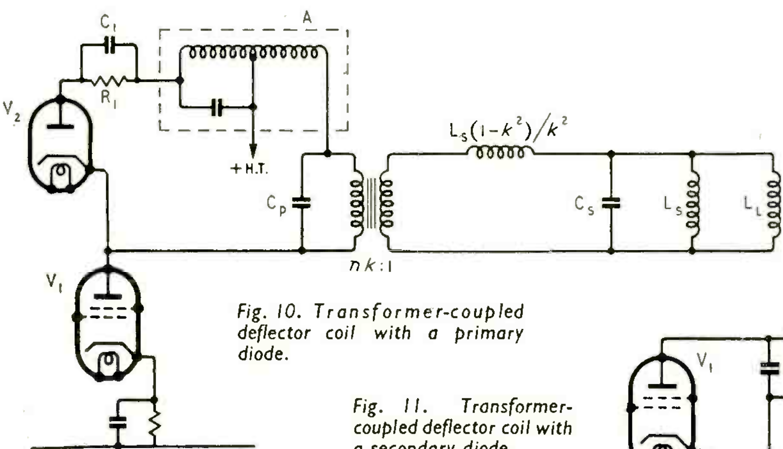


Fig. 10. Transformer-coupled deflector coil with a primary diode.

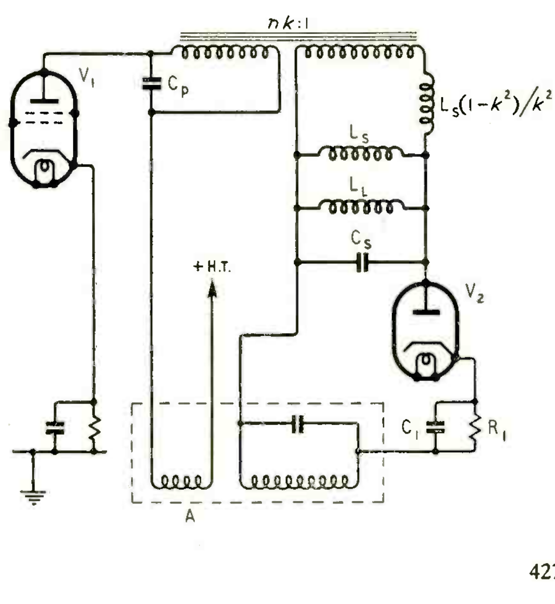


Fig. 11. Transformer-coupled deflector coil with a secondary diode.

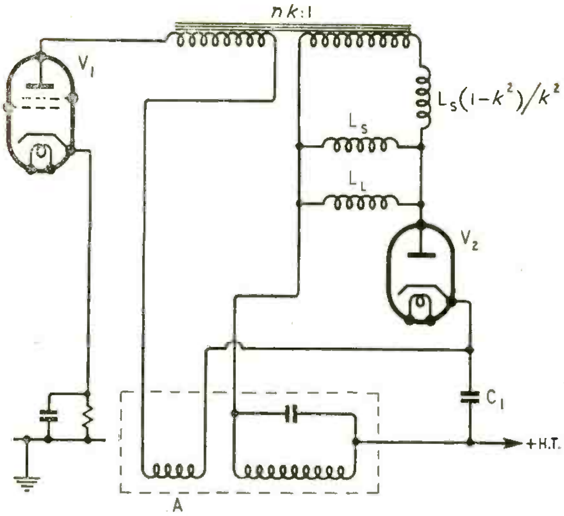


Fig. 12. Circuit of Fig. 11 re-arranged to give h.t. boost.

The circuit arranged for h.t. boost is shown in Fig. 12; the resistor R_1 has disappeared since the power previously dissipated in it is now taken by V_1. The voltage appearing across C_1, 53.5 V in the example, adds itself to the h.t. supply, so that this can be 53.5 V lower than without boost. In effect, therefore, it is as if the back e.m.f. on the transformer primary were this much lower than it really is, or $169-53.5=115.5$ V only. This makes the input power $115.5\times 0.051=5.8$ W.

Oscillations with Secondary Diode

Comparing the three conditions investigated we find the power is 4.56 W for the directly-fed coil, 8.4 W for a transformer feed without h.t. boost and 5.8 W with h.t. boost. Again it must be emphasized that these figures are based on an idealized approach and will be appreciably greater in practice; also that they do not include anode dissipation in V_1, which will be at least 5 W.

It has been said that the energy in the leakage inductance cannot be recovered. It must, however, be dissipated and it is liable to expend itself in a damped oscillation in the resonant circuit formed by the leakage inductance and the primary capacitance. The frequency of this oscillation is given approximately by

$$f=\frac{1}{2\pi\sqrt{[n^2L_sC_p(1-k^2)]}} \quad \ldots \quad (15)$$

It is usually difficult to make C_p less than 50 pF and so for our example $f=1/[6.28\sqrt{(6.25\times 34\times 10^{-3}\times 50\times 10^{-12}\times 0.04)}]=2.46\times 10^5$ c/s $=246$ kc/s.

The effect of this oscillation on the picture is much less serious than in the case of a primary diode for the deflector coil is not a part of the oscillatory circuit. In fact, the oscillation occurs in a separate circuit and is only coupled to the deflector coil by the internal resistance of the diode. If the diode is of low enough resistance, therefore, the effect on the picture may be negligible. The oscillation itself can be prevented only by the same means as with a primary diode, namely by making its frequency high enough for the circuit losses to be effective in damping it out.

One effect of the oscillation is profoundly to modify the waveform of the current through the diode. Consider Fig. 13, which shows the essentials of the circuit during the conductive period of the diode. At the start of the scan when the diode becomes conductive there is a peak (electron) current i flowing in the direction shown and it is in magnitude $x\,I_L/\eta_i$. The current is being driven around the circuit by the energy stored in the magnetic fields of the inductances. The back e.m.f. across L_1 is at this instant equal to the voltage across C_1, so that if the diode is regarded as a switch which closes at this instant, there is no current in it. The current in L_1 is forced to decay linearly by the diode but that in L_2 is not and decays more rapidly and in oscillatory fashion. The current in the diode, therefore, grows gradually, reaches a maximum and falls off again; this process is repeated while the oscillations persist.

The action is more easily visualized by considering the current as made up of two independent currents i_1 and i_2. Initially, when the diode conducts they have the same amplitude and flow in opposite directions in the diode. Now i_1 is the current in L_1 and decays linearly; it has the usual triangular waveform shown in Fig. 14(a), but i_2 is a damped oscillation. The total current is the sum of the two, Fig. 14(b).

Initially, the two currents always have the same amplitude. The scan current i_1 falls linearly with the proper rate for the scan. The oscillatory current decays as a damped oscillation and the amplitudes of successive peaks follow an exponential law. It is essential to the proper operation of the circuit that the decay of the oscillatory current shall not be slower than the decay of the scan current. If it is slower, one or more positive peaks of the oscillatory current will be of greater magnitude than the values of the linear current at the same instants. The required total current is then a reverse diode current which the

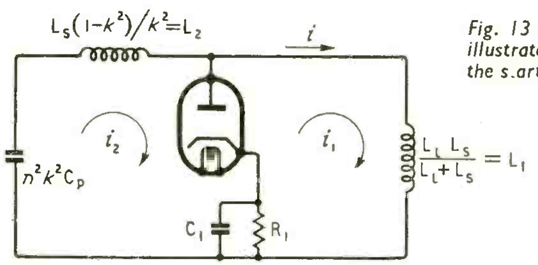


Fig. 13 (left). This circuit illustrates the conditions at the start of the scan.

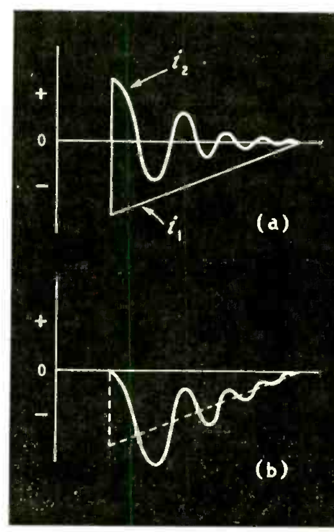


Fig. 14. The diode current is the sum of the scan current i_1 and the oscillating current i_2 shown at (a). The sum is indicated at (b).

diode cannot pass. The diode then cuts off and there is a severe disturbance of the scanning waveform.

The ratio of the amplitudes of successive peaks in the oscillatory current is $\epsilon^{\pi/Q}$ where Q is the effective value for the oscillatory circuit. The rate of decay between the first and second peaks is thus $I_1(1-\epsilon^{-\pi/Q})f$ where f is the frequency of oscillation and I_1 is the amplitude of the first peak. The slope of the linear current is $I_L/\tau_1\eta_1 = I_1/x\tau_1$. The first must be greater than the second, therefore, we must have

$$x\tau_1 f(1-\epsilon^{-\pi/Q}) > 1$$

This is a sufficient requirement to avoid diode cut-off on the second cycle of oscillation but not on later cycles, for the exponential decay means that the slope is continually decreasing. In practice, this is not very important for the "linear" diode current also changes with decreasing slope because in normal operation the driving valve comes into action before the diode cuts off. This results in an increase in the magnitude of the diode current and a delay in its cut-off point. Usually, therefore, the above simple relation is adequate.

As an example, we found earlier for $x=0.64$, $\tau_1=82.77$ μsec, $f=246$ kc/s. Therefore, we require $1-\epsilon^{-\pi/Q} > 1/(0.64\times82.77\times0.246) = 0.077$; therefore $\epsilon^{-\pi/Q} < 0.923$, or $\pi/Q > 0.08$ which gives $Q < 39$ approximately. In actual fact the Q is not likely to reach this figure, but the writer has had trouble from an excessive Q. It is most likely to occur when the natural frequency is lower—perhaps 100 kc/s only.

The Auto-Transformer

From the point of view of efficiency in transformer design it is necessary to keep the leakage inductance and losses as small as possible. The auto-transformer has an inherent advantage over the double-wound transformer; the advantage is very small with a high turns ratio but very large with a small ratio. In fact, the leakage inductance becomes zero with a 1 : 1 ratio, for then the transformer degenerates into a shunt choke.

Consider a transformer (a), Fig. 15, with primary and secondary inductances L_p and L_s and mutual inductance M. As already mentioned this has the equivalent circuit (b) and the equivalence is established by equating the open and short-circuit impedances of the two networks. This leads to the relations:—

$L_2 = L_s$

$L_1 = L_s(1-k^2)/k^2$ where $k^2 = M^2/L_pL_s$

$a^2 = k^2L_p/L_s = n^2k^2$ where $n^2 = L_p/L_s$

which make Fig. 15(b) identical with Fig. 9(b).

An equivalent for the auto-transformer, Fig. 15(c), can similarly be derived. The first step is to re-draw it as in (d). The equivalent circuit (b) still applies and the elements will be distinguished by a tick (′) when applying to the auto-transformer. Equating open- and short-circuit impedances gives:—

$L'_2 = L_s$

$$L'_1 = L_s\frac{n^2(1-k^2)}{(1+nk)^2} = L_s\frac{(n'-1)^2(1-k^2)}{(1+n'k-k)^2}$$

$a^2 = (1+nk)^2 = (1+n'k-k)^2$

where n' is the auto-transformer turns ratio; i.e., the ratio of $\frac{\text{turns between 1, 4}}{\text{turns between 3, 4}}$ in Fig. 15(c).

The ratio leakage inductance of $\frac{\text{auto-transformer}}{\text{transformer}}$ is given, therefore, by

$$\frac{(n'-1)^2k^2}{(1+n'k-k)^2}$$

Since $k \approx 1$ and $n' > 1$, $1-k \ll n'$ and the ratio is nearly $\left(\frac{n'-1}{n'}\right)^2$. If $n'=2.5$, we get $(1.5/2.5)^2 = 1/2.76$ which is not a very large improvement. However, if $n'=1.5$, we get $(0.5/2.5)^2 = 1/25$, which is very considerable.

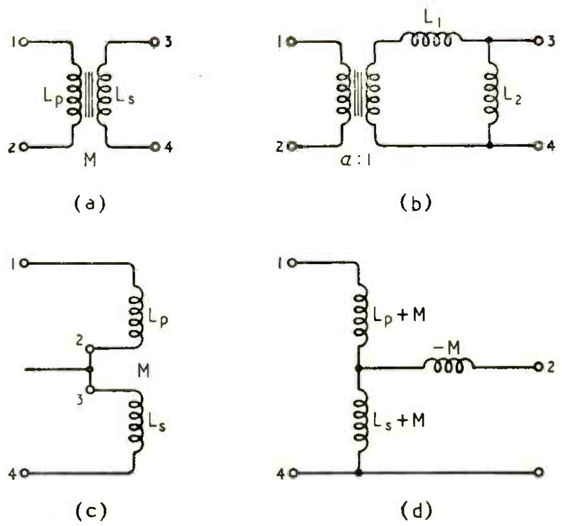


Fig. 15. Transformer (a), with its equivalent circuit (b). In auto-transformer connection (c) applies and has the equivalent (d) which can be reduced to the form of (e).

As long as the step-down ratio is small, say under 2 : 1, the auto-transformer is greatly superior to the double-wound transformer because a much smaller leakage inductance is obtained with the same form of construction. This not only improves the field efficiency of the transformer, since less energy need be provided to establish unwanted fields in it, but by raising the natural frequency of unwanted modes of operation it makes them much less likely to be troublesome. If h.t. boost is to be employed, and it is most valuable when the transformer ratio and leakage inductance are low, the use of a low ratio demands a large overshoot and, hence, a high Q circuit. If the ratio is to be under 2 : 1, the overshoot must exceed 0.7. It becomes almost essential to use a low-loss core material for the transformer and desirable also for the magnetic circuit of the deflector coil. Materials such as Caslam, dust-iron and Ferroxcube are needed.

The one practical inconvenience of the auto-transformer lies in the fact that the cathode of the diode is fluctuating at a high potential to earth and so must nearly always have its heater fed from a low-capacitance well-insulated winding of a supply transformer. Sometimes, too, the required inductance for the deflector coil becomes inconveniently high when the transformer ratio is low. This can be overcome by connecting it to a tapping on the secondary, so that there is in effect a double auto-transformer with one ratio between the driving valve and the diode and another between the driving valve and the deflector coil. Since there is then a further leakage inductance involved there are further possibilities of spur-

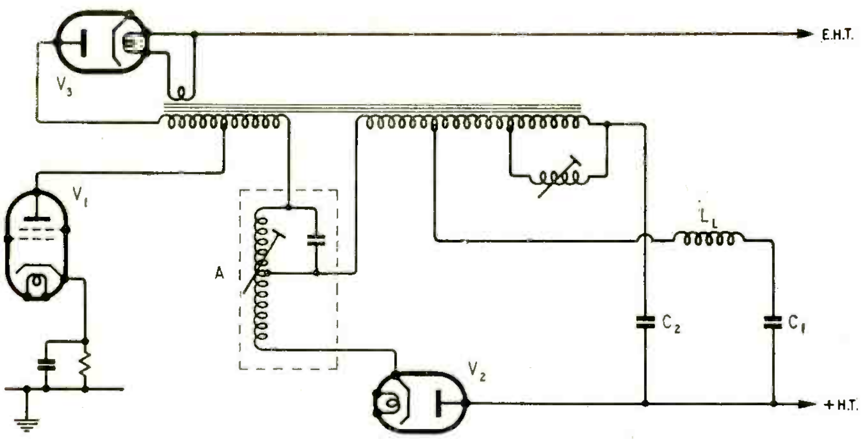


Fig. 16. Typical American scanning circuit using an auto-transformer and h.t. boost.

ious oscillations. In all cases with a transformer or auto-transformer it is possible to make the primary a step up auto-transformer to feed an e.h.t. rectifier.

Circuits of this nature are used to scan 70° cathode-ray tubes operating at 14 kV and a typical one is shown in Fig. 16 in its essentials; V_1 is the driving valve and draws about 95 mA from an h.t. supply of 280 V. The damping diode is V_2 and the e.h.t. rectifier is V_3; it provides up to 16 kV on no load. An auto-transformer with a ferrite core is used and the winding is split for the insertion of the linearity control, which is the device A controlling the diode. Width control is obtained by a variable inductance shunted across a part of the transformer winding. The deflector coil L_L is tapped down from the diode connection and has a series capacitor C_1 to block any direct current. Although not shown in the previous circuits this is often necessary. Much depends on the precise arrangement of the components. The capacitor C_2 is the one across which the boost voltage is developed. Although not shown here, up to 12 mA at the boosted voltage can be drawn off for operating the frame time base.

Until recently British practice has favoured the double-wound transformer, but in general the output is only required to scan a 50°-tube at 9 kV. It is possible, therefore, to tolerate the higher leakage inductance of the double-wound transformer and it is not necessary to be so fussy about core losses. Laminated cores can, therefore, often be used, although the tendency is undoubtedly to abandon them. With the advent of 70° tubes, however, the tendency is undoubtedly towards the type of circuit shown in Fig. 16.

These economy circuits are quite complex in their operation and are affected by many factors. Thus, to quote only one example, a change in the quality of the transformer core material affects the Q of the circuit and so the overshoot. In its turn this affects the transformer ratio needed for proper matching of the currents when h.t. boost is used. There is, of course, some latitude permissible but, in general, they do demand more critical control over the circuit elements than the older heavily-damped circuits. This appears to cause no serious difficulty in production, but then it is possible to keep a close watch on the quality of materials.

The experimenter is in quite a different position and many of the economy circuits are unsuitable for him unless he can obtain the proper components for them. The components are not easy to make by hand and also it is sometimes hard to obtain special materials in small quantities. The line-scan transformer is a particularly difficult component to make because it really requires a wave-winding machine.

Taking everything into account, the directly-fed deflector coil with a diode appears to be a very attractive form of circuit for the experimenter. H.t. boost is not possible with it, but this is of little moment in view of the absence of all transformer losses. It demands a special deflector coil, it is true, since the inductance must be unusually high, but a deflector coil is not difficult to make, only tedious.

CLUB NEWS

Brighton.—The programme arranged for the coming months for the Brighton & District Radio Club (G3EVE) includes the Mullard television film-strips and a demonstration of recording and reproducing by the Decca Record Co. Meetings are held at 7.30 each Tuesday at the Eagle Inn, Gloucester Rd., Brighton, 1. Sec.: R. T. Parsons, 14, Carlyle Avenue, Brighton, 7, Sussex.

Edinburgh.—Meetings of the Lothians Radio Society have recommenced and are held on alternate Thursdays at 7.30 at the Edinburgh Chamber of Commerce, 25, Charlotte Square. Sec.: I. Harris, 24, Braid Hills Road, Edinburgh, 10.

Leicester.—At a recent meeting of the Leicester Ham Radio Society it was decided to drop the word "Ham" from the title and to cover every aspect of radio. The club meets at the Holly Bush Hotel, Belgrave Gate, on the first and third Mondays of each month. Sec.: L. Milnthorpe (G2FMO), 3, Winster Drive, Thurmaston, Nr. Leicester.

S. Manchester.—Until such time as new premises for the club headquarters can be secured meetings of the South Manchester Radio Club are being held in Tatton Arms, Northenden, on alternate Fridays. The next meeting is October 12th. Sec.: E. R. Taylor, 12, Marton Avenue, Didsbury, Manchester, 20, Lancs.

Southend.—The winter session of the Southend & District Radio Society (G5QK) opened with two Mullard film strips on cathode-ray tubes, the second of which, covering construction and manufacturing processes, is scheduled for September 28th. A lecture and demonstration on projection television will be given by a representative of Mullards on October 12th. At the following meeting (October 26th) Mr. Walters (Belling-Lee) will demonstrate a paradiagram plotter. Meetings are held at 7.45 at the Municipal College. Sec.: J. H. Barrance, M.B.E., (G3BUJ), 49, Swanage Road, Southend-on-Sea, Essex.

Five clubs in the counties of Lancashire, Cheshire and Denbighshire have co-operated in the formation of the Association of North Western Radio Societies, the main object of which is to co-ordinate corporate activities. The societies participating are, Chester & District A.R.S., Liverpool & District S.W.C., Wirral A.R.S., Merseyside R.S., and Wrexham & District A.R.S. Other north-western clubs interested are invited to write to W. G. Lloyd, 124, Tarvin Road, Chester.

Telecommunications Research

Fundamental Investigations Undertaken by the D.S.I.R.

AS in many other subjects, research in telecommunications may be broadly divided into two fields: (i) fundamental research designed to improve and extend our knowledge of the various basic phenomena upon which the practice of telecommunications rests; and (ii) research designed to use this knowledge for the development, operation and maintenance of telecommunication systems. In this country the first objective is met by the work of the Department of Scientific and Industrial Research, while the second category includes the activities of the research establishments of all Government departments, and associated organizations such as the B.B.C. and Cable & Wireless, and the industrial research laboratories.

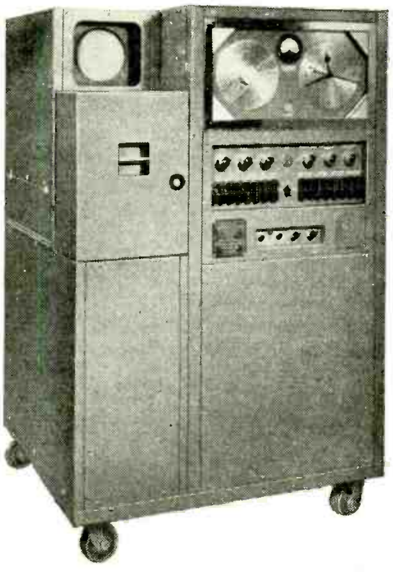
It is not intended, however, to suggest that all work of a fundamental nature is conducted by the D.S.I.R. Many investigations of a very basic character have, of course, to be conducted in, for example, the research stations of the Post Office or the B.B.C., but such investigations are designed to fulfil the needs of the present or future services operated by these organizations. In a similar way, a large amount of basic research is carried out in industry, particularly in the sphere of the various kinds of materials and components, used for the manufacture and construction of telecommunications equipment. We will, however, confine ourselves to a description of the work of the D.S.I.R. which is conducted in close co-operation with all the various other interested organizations.

Mention should also be made of the fundamental research in progress at various Universities. Some of this is concerned with the study of radio wave propagation and radio-astronomy, while other parts of it involve a detailed study of the properties of materials of special interest to the telecommunications engineer and of the fundamental theory of the transmission of intelligence. Most of this work at the universities is supported financially by the D.S.I.R.

As is well known, the D.S.I.R. was established during the first World War to promote and organize scientific research, with a view especially to its application to trade and industry. In the field of telecommunications the term "industry" is deemed to cover operating organizations as well as those manufacturing apparatus and equipment. With the exception of medicine and agriculture, the Department embraces in its scope all branches of natural science and their application to industrial processes. Its activities fall under three main headings:— (a) research in the national interest for the benefit of the community as a whole and to meet the requirements of Government Departments; (b) the encouragement of research and the application of scientific knowledge in industry; and (c) the encouragement of fundamental research at universities and elsewhere, and the maintenance of an adequate supply of trained research workers for laboratories of all kinds.

To provide for the discharge of these functions in the radio field, the Radio Research Board was established in 1920 to advise the D.S.I.R. on the nature and scope of a programme of research work of a fundamental nature in directions where it was lacking and where it would be likely to lead to useful applications.

The constitution of the Board provides for representation at the highest technical level of those Government departments with an intimate interest in radio applications and of the B.B.C. with, in addition, several independent members, who may be from universities or industrial organizations. The present membership numbers 19, with Sir Stanley Angwin as chairman. To assist the Board in its work a number of technical committees are formed from time to time.



Automatic Recorder used by the D.S.I.R. for investigating the ionosphere and demonstrated at Earls Court is made by the Union Radio Co. of Croydon.

There are seven such committees constituted at present, each dealing with a different field of research: Ionospheric Wave Propagation; Tropospheric Wave Propagation; Direction Finding; Radio Navigational Aids; Radio Noise; Sub-standard Radio Measurements; and Radio Materials.

Much of the programme of work in the past has been conducted at the National Physical Laboratory, where a separate Radio Division was formed in 1933 with Sir Robert Watson-Watt as its first Superintendent. Following a consideration of its post-war programme, the D.S.I.R. in 1948 appointed Dr. R. L. Smith-Rose to the new post of Director of Radio Research to take charge of all the radio research work of the Department, a large proportion of which is now conducted at the Radio Research Station, Slough.

In 1948 a Standing Conference on Telecommunications Research was established under the chairmanship of Sir Stanley Angwin. It is hoped that the work of this conference will enable fundamental research to be directed towards meeting the most urgent needs of those engaged in any way in the development and practice of telecommunications. The Radio Industry Council, Telecommunications Engineering and Manufacturing Association, Cable and Wireless, B.B.C., I.E.E., Post Office and the Service and Supply Departments are represented at its meetings.

So much for the organizational side. Now a few details of the investigations being conducted at the present time. For the purpose of investigating the ionosphere the D.S.I.R. maintains and operates two recording stations in the U.K., another in the Falkland Islands and a third in Singapore. It also has plans for assisting in the setting up of other stations at Ibadan, Nigeria, and at Khartoum, Sudan.

At the Earls Court National Radio Show a recorder was demonstrated which continuously probes the ionosphere with pulses at frequencies ranging from 0.6 to 25Mc/s. Height of reflection is automatically recorded. This apparatus allows investigations of the main characteristics of the ionosphere to be made and records their variations with season, time and place. Measurements are made at some 60 observation points all over the world on similar recording equipment, and through international co-operation results are collected by various national laboratories. This data is collated at the Research Station at Slough and made available to the communications industry each month, giving forecasts for a monthly period six months ahead of publication.

A comparatively new item on the research programme at Slough is the investigation of the behaviour of frequencies from 30 to 300Mc/s in relation to the troposphere (lower atmosphere). This is being conducted in co-operation with the B.B.C., G.P.O. and Meteorological Office. This study of the changing conditions of the troposphere will provide new knowledge on the behaviour of television signals, especially in fringe areas. For example, fog may produce an artificial reflecting surface which will give satisfactory reception well beyond the service area.

Still Higher Frequencies

Two types of research have been undertaken at frequencies above 3,000Mc/s. In one of these the electrical properties of constituents of the atmosphere, such as water vapour, water and ice, have been measured at the frequencies in question; while in the other, the results of actual propagation measurements over both land and sea are being studied in relation to the meteorological conditions observed simultaneously over the same paths. In the course of the latter investigation a study has been made in co-operation with the New Zealand D.S.I.R. of centimetre wave propagation over the Canterbury Plains in South Island, where somewhat special meteorological conditions exist.

In the field of direction-finding an investigation is being conducted with the aid of a continuous study of ionospheric conditions. Certain aspects of polarization error in direction finding at high and very-high frequencies are still being studied; and the present state of knowledge of the effect of siting conditions and local topography on the accuracy of direction finding at all frequencies is being reviewed.

In addition to investigations into the conditions which influence propagation, the Radio Research Station has given a great deal of consideration to the problems of signal/noise ratio. A theoretical study of the various types of noise has been made—that is, atmospheric, cosmic, man-made, receiver and thermal—and measurements obtained of their intensity and characteristics. Of the meteorological noises which affect reception, that from the atmosphere is produced by radiation from lightning discharges, and thunderstorms within 3,750 miles are potential sources of interference.

While the National Physical Laboratory is generally responsible for the development and maintenance of electrical reference standards which form the basis of all precision measurements at radio frequencies, there is a continuing need for the study of measuring technique, particularly at the upper end of the radio frequency spectrum. The development of new or more accurate measuring techniques and instruments is a necessary part of some of the investigations already referred to. For example, the study of propagation at increasingly higher frequencies has involved the development of field-strength measuring apparatus at frequencies up to, and above, 600Mc/s, and this in turn leads to the need for measuring power and voltage at such frequencies. In a similar way the use of transmission lines and aerial systems, as well as the development of new circuit techniques, assumes that facilities exist for measuring impedance at the working frequency.

Studies such as these lead eventually to the development of instruments of a sub-standard type, which Government and industrial laboratories need as their local reference. The Measurements Committee of the Radio Research Board has concerned itself mainly with making an appraisal of the present position of measuring techniques and instruments, with a view particularly to seeing to what extent existing designs evolved by research workers have been carried to a stage at which they may be developed by industry for general use.

One of the most pressing problems in the radio industry is the need for a basic study of the properties of the various materials—conductors, insulators and component parts of valves and their circuit attachments. The properties of certain materials of current interest are being examined at millimetre wavelengths, and much research work is in progress in university and industrial laboratories on the relation between the electrical properties and the chemical and physical structure of various dielectric and magnetic materials.

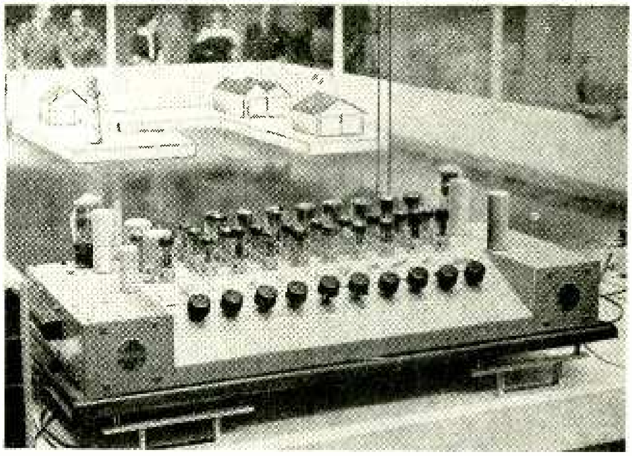
So much research work has been carried out in the past few years in this field that the Department has considered it desirable to prepare for publication a statement of present knowledge and the outstanding problems most urgently requiring research.

"Abstracts and References"

One of the consequences of the rapid spread of scientific research throughout the world is that the literature which, in effect, contains the increased knowledge resulting from this research effort has become greatly magnified. In the radio field, as in other branches of science, this literature, published either in periodicals or as the proceedings of scientific and technical institutions, has become so vast that it is increasingly difficult for the scientist and engineer to keep abreast of the progress being made in his own subject. In this connection an important factor is an efficient abstracting service; and so mention may be made here of the work undertaken by the Radio Research Board in the preparation of abstracts of the world's scientific and technical literature relating to all aspects of radio and its applications. These abstracts, totalling some 3,000 a year, have for many years been published monthly in our sister journal, *Wireless Engineer* and, more recently, also in the *Proceedings of the Institute of Radio Engineers* in the U.S.A.

Telearchics on Show

Developments in Control Systems



Control desk for one of the Philips radio-controlled boats at the Radio Show. In the background is the demonstration tank.

SOME of the principles outlined in our article on radio control last month were to be seen in practical form at two London exhibitions recently, the Radio Show and "The Model Engineer" Exhibition. At the first, Philips were demonstrating a couple of radio-controlled boats in a large tank specially built for the occasion. The smaller of these was quite a simple affair with only two control functions but the larger boat impressed everyone with the astonishing complexity of orders it was capable of carrying out. Not only could the engines and rudder be controlled, but lifeboats could be raised and lowered, a crane rotated, a seaplane catapulted off and various other devices put into operation.

All this is done on the one 100-Mc/s radio link by a multichannel system using pulse modulation. Each "order" is arranged to modulate a separate train of pulses of 9kc/s repetition frequency and the trains are interlaced and transmitted together with a sync pulse. Upon being received in the boat they are separated in the usual way by gate-pulse generators controlled by the sync pulse. For telearchics, the main advantage of this system is that it avoids weighty filter or tuning circuits at the receiving end. Furthermore, no interference can take place between the various control channels.

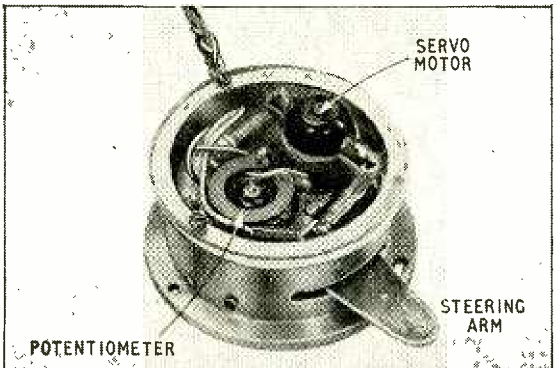
The rudder and other positioning controls were worked on the variable mark/space-ratio method described last month. At the transmitting end, each positioning channel has a square-wave generator with a variable control for altering the mark/space ratio and the output of this is modulated on to one of the 9-kc/s pulse trains. The modulation is 100 per cent, so the 9-kc/s pulses are either all there during a mark or completely absent during a space.

The same mark/space-ratio method was used in an aircraft shown at "The Model Engineer" Exhibition by the Low Speed Aerodynamics Research Association—but in rather a different way. In the receiver, instead of the square wave being used to switch a motor backwards and forwards all the time, it is smoothed out by means of a storage capacitor into a steady d.c. potential, which varies in proportion to the mark/space ratio. This potential, varying above and below a certain value, provides order signals for a servo-mechanism, which drives the control surface in one direction or other about its neutral position.

At the transmitting end the controlling square waves are generated in the form of bursts of oscillation from a transitron circuit, the variation of mark/space ratio being achieved by triggering the oscillator (which is normally biased off) at various levels on a 40-c/s saw-tooth waveform—a bias control does this. The output from each oscillator then forms a subcarrier for the associated control channel and is modulated on to the main carrier.

Besides being rather more elegant for control purposes, this system improves on the basic method of pulse-width variation in that it does not waste power by switching the driving motor backwards and forwards all the time. Power is applied only when a change is introduced in the signal. The aircraft on show was provided with four channels: three positioning controls for rudder, elevators and ailerons and a channel for stopping and starting the engine.

Servo unit made by the Low Speed Aerodynamics Research Association for operating control surfaces.



Incidentally, the servo-mechanism mentioned above was a closed-sequence system, containing an amplifier, a motor and a potentiometer, arranged to balance against the variations of input controlling voltage. A positive or negative order signal causes the amplifier to energize the motor; this drives the potentiometer which feeds back a voltage error-signal to the input to neutralize the original increment or decrement, whereupon the system is restored to balance. The L.S.A.R.A. find this type of mechanism useful for a number of purposes so they have produced a more or less standard servo unit, containing a midget motor, potentiometer and actuating arm (see illustration), which can be fitted almost anywhere. At the Exhibition, they were demonstrating one of these in conjunction with a magnetic-compass potentiometer (a liquid device) to show how an aircraft can be kept on a set course—in fact, an automatic pilot. A deviation from course swings the compass needle (which forms the wiper of the potentiometer) away from its neutral position, and in this way a proportional voltage signal is produced to actuate the servo-mechanism and correct the deviation. Owing to the continuous and proportional nature of this arrangement, it is not so prone to hunting as the basic system described last month (see page 344) in which the steering motor is switched directly from two segments.

Re-activating Dry Batteries

The Amplion "Activette"

By R. W. HALLOWS, M.A. Cantab., M.I.E.E.

THE dry battery represents "portable power" in its most convenient—but, unfortunately, in a distinctly expensive—form. Hence any device which can prolong the useful life of such batteries is sure of a welcome.

One reason why the dry battery is an expensive kind of power supply is that no way has ever yet been found of designing one in which the process of transforming chemical energy into electrical energy is able usefully to run its full course. Most batteries are discarded long before the zinc of the negative electrode has been used up, or the chemicals of the electrolyte and the depolarizer have become altogether inactive.

The main source of the trouble is that the depolarizer can never fulfil entirely the job assigned to it. Rising internal resistance *may* be due to loss of liquid from the electrolyte through evaporation; but that is a comparatively rare cause nowadays. In the vast majority of cases the rise is brought about by the failure of the depolarizer to deal sufficiently rapidly or sufficiently thoroughly with accumulations of hydrogen in the neighbourhood of the positive electrode.

It is not, then, surprising to find that the action of the Amplion "Activette," which is stated to be capable of endowing a given dry battery with five or six times its normal service life, is to speed up and intensify the process of depolarization within the cells. There seems, in fact, to be no other way in which service life could be prolonged, for the reaction of the electrolyte and the zinc is a non-reversible one: you cannot put zinc back on to the walls of the can or restore the condition of the electrolyte.

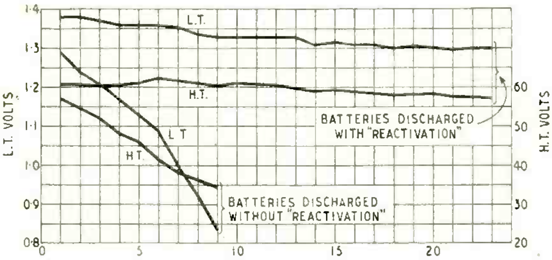
How the apparatus does its work has not yet been disclosed, on account of the position regarding patents. There can, however, be little harm in hazarding a possible explanation, and I will give you my guess in a moment.

The apparatus is contained in a metal box $4\frac{1}{2} \times 3\frac{1}{2} \times 1\frac{3}{8}$in in size. From the box comes one length of twin flex with a connection intended for 230-V 50-c/s a.c. mains, and two other lengths, one of which is to be connected to the terminals of a 69V—100V h.t.b., and the second to those of the single cell used for the l.t. supply of "all-dry" portables.

When the "Activette" is brought into action the mains power consumption is of the order of 3 watts. The working instructions are that after a battery has been in use for 2, 3 or 4 hours, the apparatus should be switched on for about the same length of time. It is of no use to apply it to a "dead" battery or cell, for it cannot re-animate.

This was done in the National Physical Laboratory tests, which, at the moment of writing have been in progress for 52 days. Reactivation took place for two hours before the first 2-hour run of the day, and for two hours again before the second daily run of the same duration.

The N.P.L. tests are comparative and, as the accompanying discharge curves show, they give one something to think about. Six batteries, bought from the same manufacturer, were used, all being of the 69-V h.t., 1.5-V l.t. type. The h.t. portion was discharged through a 10,000-Ω resistance, giving a drain of 6.9mA, and the l.t. portion through a 6-Ω resistance, taking 250mA.



Discharge curves, taken from an N.P.L. interim report, giving the results of the first 23 days' test of the "Activette." The terminal voltages shown are the average of those measured on load at the end of each day's two-period discharge.

Three of the batteries were "reactivated"; the other three were run in the normal way with no reactivation. At the end of the first run on the 52nd day the average voltage of the reactivated h.t. batteries was better than 57 and of the l.t. better than 1.2. All the untreated batteries were down to cut-off at the end of the 9th day's test.

How is it done? The metal case is stated to contain a transformer and my guess is that it contains also h.t. and l.t. half-wave metal rectifiers. It is conceivable that the application to a cell of a current consisting of a forward peak in one half-cycle, followed in the next by a slight reverse flow, may have a depolarizing action by its "shock effect" on the unwanted molecules of hydrogen.

The N.P.L. tests have shown that the "Activette" produces remarkable results on, at any rate, one make of h.t.b. There seems no reason why it should not prove equally effective on others.

I have referred only to the apparatus designed for dealing with the batteries of portable receivers. Another type has been evolved for the batteries of hearing aids. It is, I understand, likely to be at least a couple of months before either type becomes generally available.

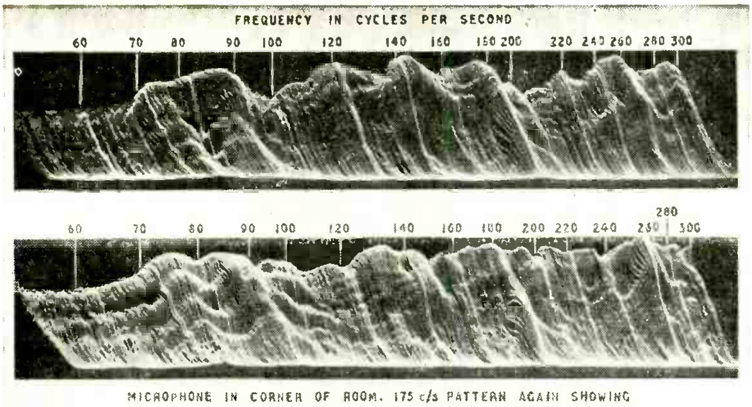


Fig. 1. Pulsed gliding tone reverberation records of a studio taken from two microphone positions.

Studio Acoustics

New Technique of Measurement Used by the B.B.C.

THE assessment of studio quality and the diagnosis of faulty acoustics are problems of great complexity, and whether judged by ear or investigated by measurement, often require long and intensive study before conclusions, capable of translation into practical remedies, can be reached.

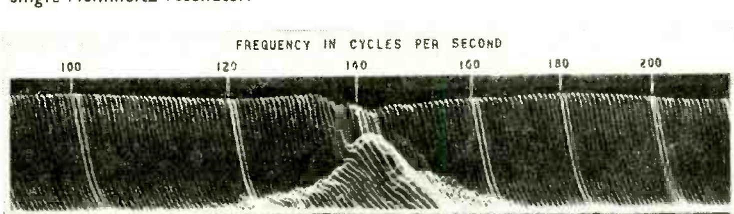
With pressure on studio space, for rehearsal as well as performance, the engineering staff of the B.B.C. is forced to make the best use it can of odd gaps in the programme schedule, and to this end has developed a new system of comprehensive measurement which can be recorded in a few minutes and subsequently studied at leisure in detail.

The source of sound is a pulsed gliding tone and a decay curve of the reverberation is displayed on a cathode-ray tube, the time base of which is triggered by the end of each pulse. A continuous record is made by a camera with slow film drive on 35mm film, and the succession of reverberation curves so produced presents the appearance of a relief model of a mountain range. The contour of the ridge, which represents the steady state level of sound built up by each pulse is of secondary importance to the pattern of the slopes. These reveal anomalies in the decay curve which may or may not be apparent in subjective listening tests. The curves of Fig. 1, which are for two different positions in the same studio, both show a sustained hangover in the region of 175 c/s the source of which would be subsequently located by detailed exploration at that frequency.

Work is proceeding on the interpretation and classification of typical patterns in terms of their aural effects. One approach has been to introduce elements of known acoustic properties into an echo-free room and to observe the distortion of the uniform pattern of practically vertical sound decay curves which is characteristic of highly absorbent test chambers. Fig. 2 shows the effect of a single Helmholtz resonator under these conditions.

The complete apparatus for acoustic tests of studios was shown recently at the open day of the Kingswood Warren Research Department of the B.B.C. It includes, in addition to the new pulsed gliding tone method, a rotatable graticule for giving direct readings of average reverberation time from the slope of the decay curve displayed on the c.r. tube, and circuits for short-pulse investigation of echo patterns. For ease of transport, miniature components have been used wherever possible and the equipment has been subdivided into units measuring 17in × 10in × 6in. There are six of these and the oscillograph, which is slightly larger.

Fig. 2. Disturbance of response of an echo-free chamber by the introduction of a single Helmholtz resonator.



RANDOM RADIATIONS

By "DIALLIST"

At the Show

KEEPING UP my proud record of having attended every major Radio Show in this country since the first held long ages ago in the Horticultural Hall (except that of 1939 when I had "gone for a sodger"), I duly clocked in—or clicked in—at the turnstiles at Earls Court on the preview day for a first look round. I like Earls Court. It is easy to get to and it seemed to provide more space for the stands than there has been in the past. I have never enjoyed myself more at a Radio Show.

A Good Sign

One's first general impression was that cut-throat, cut-price competition had been abandoned, let's hope for good. There were, in fact, few examples (if any) of a type of receiver that has been over common at times in the past: the one designed on the lines that quality, finish, factor of safety in components and so forth do not matter two hoots so long as the thing works and is cheaper than the next man's. Many of the best firms have, of course, never descended to this kind of thing and it is encouraging to see that their good example has at last forced the rest into line. The goods on show this year were such that the radio industry and the country could be proud of them without "ifs" and "buts." First impressions were confirmed by more detailed examination and by talks with exhibitors. Wireless and television are now where they should always have been, in the class of semi-luxuries, though not unduly expensive ones.

The Bigger Picture

With the exception of one bedside miniature television set, those seen at the Show gave evidence of a tendency towards larger images. I doubt whether there will be more than a handful next year with tubes smaller than the twelve-inch, which is so much to the fore now. Sixteen, twenty, and even twenty-one inch tubes were to be seen at Earls Court, though I was rather surprised to find spot-wobble used with so few of the larger sizes. The other school of thought in the matter of bigger pictures backs the small, super-brilliant tube and projection by means of a lens system. As things are, I am rather inclined to be a projectionist, for, with purchase tax at its present iniquitous level, the outlay that may possibly be necessary to replace a broken down c.r.t. of large size is rather frightening. There may be a little less depth in a projected image and possibly it is not quite so sharp as a direct one; but this system does bring the big picture within the range of the citizen of moderate means.

GREAT AND SMALL—The largest and smallest cathode-ray tubes at Earls Court. The H.M.V. receiver employing a 21-in tube compared with a miniature set incorporating a one-inch cathode-ray tube.

Puffs and Things

INGENIOUS though it is, I am afraid I cannot support A. C. Kay's suggestion (Letters to the Editor, August, p. 321) that the picofarad or "puff" should be made the basic unit of capacitance. It is open to the same objection as the farad: if the farad is much too big, then the puff is much too small to fit nicely into the general scheme of the extended metric system in use to-day. In that system the basic unit is normally something of medium size, capable of being multiplied usefully by 10, 10^2, 10^3, etc., or 10^{-1}, 10^{-2}, 10^{-3}, etc. Thus kilogram and milligram, megawatt and microwatt, kilometre and millimetre are all useful quantities, based respectively on the gram, watt and metre. But a micropuff or even a millipuff seem as little likely to be encountered in any electrical or electronic calculation as a megafarad or a kilofarad! What we seem to want is a basic unit equal in value to the present microfarad. How about the capital "C"? Then a farad = 1 MC and a puff = 1 μC. There's not much difficulty about typing μ, by the way. Just type a small "u" and lengthen the first downstroke when correcting the script. Americans don't even bother to do that. They write "50 uuF"!

Is the Pentode Innocent?

A LANCE, I feel, must be broken with that doughty champion of the pentode, Thomas Roddam. I agree wholeheartedly that, as he states in his letter in the August issue, it is not the car but the driver that does the killing. Nevertheless, I cannot help thinking that Aunt Jane is far less of a menace to life and limb when driving her battered "Seven" than she would be at the wheel of a super-sports speed model. With the pentode the stage gain is as nearly as makes little matter $g_m \times Z_a$; in the output stage Z_a is mainly inductive reactance, whose value rises with the frequency. Owing to its enormous amplification the pentode is something akin to the sports model car and with a not-so-hot designer as the Aunt Jane in charge of its circuitry it becomes a menace to good quality by producing a rich crop of odd-numbered harmonics, horribly amplified. To some designers negative feedback is the panacea for every ill. Too often it is misused, with dire results. I agree that with good design and the use of suitable components the pentode can be rendered almost distortionless; but even if the designer of a commercial broadcast receiver knows how to bring about this desirable state of affairs, his style may be cramped by considerations of cost. Hence the pentode, as the wet-nose listener knows it, is apt to give a performance that pains the ear—unless the tone-control knob is turned far enough anti-clockwise to produce the mellowness favoured in so many homes to-day. Unpleasing though it may be to the lover of good quality, such mellowness is not so distressing as shrillness.

" *Triodophile* "

Is one to gather that Thomas Roddam regards all users of the triode as reactionaries? If so, I am a reactionary, for I confess, frankly, to a liking for a pair of matched triodes in Class A push-pull in the output circuit. As a *triodophile* I am not in bad company. Valve makers have developed not a few special types for v.h.f. work and no fewer than sixteen triodes in the output of the modulator and the final amplifier of the B.B.C.'s newest medium-wave station help to bring the Third Programme to T.R.'s aerial.

No Dull Uniformity !

SOME TIME AGO I mentioned, rather wearily, that lack of international standardization extended even to such things as mathematical signs. One example that I then gave was the Continental habit of using commas where we and the Americans put stops and stops where we have commas in writing or printing numbers. In most Continental countries, for instance, 10^3 is written as 1.000 and 10^{-3} as 0,001. I have just come across an even more remarkable divergence from what I hoped and believed was accepted practice. In an article in a Danish publication I was startled to see something like:

$$2\,(x+y)\div y=2x+y.$$

The writer clearly meant "minus" and not "divided by." Printer's error, I thought, and passed on—only to meet a few lines later the weird looking sign $\overset{+}{\div}$! In other articles the minus sign was always ÷. I do not know whether this is the normal practice in Denmark, but if it is, it must be confusing for any student who dips into a foreign text book.

UNBIASED

By FREE GRID

Bottled Broadcasts

I HAVE been asked by an acquaintance to advise him on the best way to spend £80 and I should like your help. But in order to forestall facetious suggestions from any of you with low leanings toward beer and blondes, I had better state at once that I am speaking in all seriousness and should greatly value your counsel.

Briefly, my acquaintance, who already possesses a first-class radiogram, is desirous of spending a further £80 or so to improve his radio enjoyment. He is a commercial traveller and therefore keeps rather irregular hours—no coarse comments please—and quite frequently misses his favourite programmes. He is, therefore, inclined towards spending the money on a time switch and a tape recorder so that he could pre-set the apparatus to bottle his favourite programmes during his enforced absences from home.

His family, however, is anxious that he should spend the money on a television set, since they are always at home and have, therefore, no need of bottled broadcasts. Unlike many commercial travellers he does spend some of his evenings at home and so he too, as well as the family, would enjoy the television programmes. But, putting aside all question of his plain duty to his family, he cannot decide which piece of gear would bring the greatest enjoyment to him personally.

He could, of course, for conscience sake, buy a comparatively inexpensive television set and spend the balance of the cash on parts to construct a magnetic-tape recorder. But, quite frankly, he has neither the time nor inclination for home construction, and, as £80 or so is his limit, he certainly cannot have both pieces of equipment. The question is, therefore, which shall it be? In the words of the late Syd Walker, "What would you do, chums?"

Beer and Blondes.

Televentriloquism

THE success of ventriloquism depends on subtle psychological suggestion coupled with the ability to speak without moving the lips, skill in which some of you may, like myself, have acquired when serving in what has been aptly described as "His Majesty's Other Service." The voice certainly seems to come from the ventriloquist's dummy, the illusion being greatly assisted by skilful manipulation of its lips and limbs. Of course, subtle psychological suggestion by itself is really all that is necessary as is amply demonstrated by the Brough "Educating Archie" broadcasts, but, nevertheless, visual aids and labiostatic speech help a lot.

The powerful principle of suggestion also plays a tremendous part in enabling us to enjoy the television programmes, for, by its means, voices and other sounds do seem to come from the screen even though we know very well that they are coming from the adjacent loudspeaker. There is, however, a limit to the distance between c.r. tube and loudspeaker over which this suggestion process works. There is the same limit to the permissible distance between a ventriloquist and his dummy quite apart from the necessity of having it in a position where he can manipulate it.

I see, however, that according to one of the many American magazines devoted to "popular" science—and you know what that implies—the ventriloquist's distance - limitation problem has now been solved. The method employed is ingenious but in my opinion unnecessarily complicated. The innards of the dummy in this newly invented televentriloquial system consist of a magnetic tape recorder, amplifier and loudspeaker. Prior to the performance the ventriloquist records in his ventriloquial voice the backchat and repartee to which he wishes the dummy to give utterance; gaps are left in the recordings for him to put in his own part of the dialogue during the actual performance. All that remains, therefore, after the apparatus has been switched on and the show started, is that the performer should carefully time his utterances to fill in the gaps between the dummy's mouthings.

Surely it would be far simpler to employ the method which I have used for many years when giving a ventriloquial turn in the village hall but have hitherto thought too trivial an "invention" to talk about. A small battery-operated decimetre-wave transmitter is distributed about my person with the microphone strapped around my midriff. My dummy, of course, houses a receiver and loudspeaker. Its lip and limb movements, as well as its voice, are also operated radio-telearchically. In the latter part of the idea I must certainly claim no originality as my system of control was evolved from the series of articles on radio-telearchics published in this journal as long ago as 1926.

H. M. Other Service.

Musical Murder

MANY people beside Mrs. Free Grid and myself must feel annoyed when at the end of a broadcast talk which has been coming from the loudspeaker at pleasantly audible volume a nerve-shattering roar heralds the beginning of a musical item. Many of us who are steeped in musical Philistinism, and content to remain so, and who care as little as Gallio for scale distortion and suchlike things, often wonder why the B.B.C.'s control engineer doesn't turn the wick down when musical items start and so keep the average volume from our sets on an even keel; if I may be permitted to mix my metaphors. But to do so, of course, would be unfair to music lovers who like their favourite fare faithfully rendered as in the concert hall. But is there any reason at all why the B.B.C. should not accompany broadcasts of music with a special signal—occupying minimum bandwidth—which would actuate an electronic music-muffling relay fitted on our sets? The principle is already used in the American cackle-cutting service about which I wrote in the August issue. Music lovers would, of course, simply switch off the relay.