Wireless World

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Sound Reproduction

THIS issue of *Wireless World* is devoted largely to the subject of sound reproduction—an expression which we use to cover all artificial methods of reproducing, reinforcing or recording natural sounds. Extra pages have been devoted to articles on various aspects of the subject; unfortunately, it is impossible to deal with all of them. Of all the offshoots of radio, sound reproduction is probably the largest and most diverse. In some directions it has broken away almost entirely from the radio (and, going back farther, wire telephony) techniques on which it is so largely based, but in many respects the relationship is still close.

Among the many branches of electricity, electro-acoustics is unique in that it has attracted a large band of fervent devotees. The reasons for this are not far to seek: as a contributor points out elsewhere in this issue, the quest for perfect reproduction amounts to chasing the unattainable, and so offers a constant stimulus to human instincts. Again, art enters into it quite as much as science; that, perhaps, is why professionals in other branches become amateurs in the "audio" field, in which they find pleasurable relaxation. Here amateurism is seen at its best. Interest in the subject was never at a higher pitch than at the present time; according to correspondents in the U.S.A., the same applies in that country, where "hi-fi" tends almost to displace television.

Though there are no spectacular developments to record in sound reproduction progress is steady, but room for improvement still remains. The amplifier has perhaps approached nearest to perfection, and is now produced commercially in forms giving a degree of fidelity that would have been thought unattainable (or even unnecessary) a few years ago. This is a subject in which *Wireless World* has long concerned itself, and for many years we have regularly published designs of high-quality units. The "Williamson" amplifier, since the design was first printed, has achieved world-wide popularity. There is hardly a country in which a version adapted to local needs is not in use.

If the amplifier may at present be regarded as the strongest link in the chain of faithful reproduction, the loudspeaker is the weakest. Obviously the problems to be solved are most difficult, but there has been progress during the past twenty years or so—progress that would be regarded as phenomenal in a less rapidly developing art than our own. The loudspeaker is to some extent a war casualty; it has no special application to warfare, and so comparatively little work was done on it between 1939 and 1945. Since then, much effort has been devoted to its improvement, but the field is one in which there is still much scope for new ideas.

As many of our contributors have pointed out, the general public (as opposed to the growing band of enthusiasts) is not highly critical of reproduction quality. We find it hard to believe, however, that large sections of the public are really satisfied, and it should be easy enough to show them the pleasures they are missing. Unfortunately, however, under present conditions of broadcast distribution, it is only the favoured few who receive a signal capable of being well reproduced. This, as we have said, can only be put right by e.h.f. broadcasting, but, when that comes, the links between studios and transmitters must also be overhauled.

High fidelity, as it is called, is only part of the story. There is also high intelligibility, of greater importance for "public address" purposes and the like. A good deal of data on this subject is already available, but much remains to be done. For public address in places with a high prevailing noise level a more refined approach than mere brute force is needed. It would be fantastic to suggest a "synthetic sound" technique, akin to that demonstrated by Rudolf Pfenniger in 1933, but it is certain that highly artificial characteristics in speech reproduction can effect an improvement. And, apart from public address, we think investigation of synthetic sound production might well continue. In fact, that technique is actually employed with some effect in the Telekinema at the South Bank Exhibition. Though it may be amusing rather than epoch-making, as we said in 1933, the technique may yet provide a useful tool in the world of entertainment.

Loudspeaker Diaphragm Control

The Importance of Radiation Resistance Damping at High Frequencies

By J. MOIR*, M.I.E.E.

IN the May 1950 issue of *Wireless World* the writer reported the results of an experimental examination of the effect of the output impedance of an amplifier upon the transient oscillations of the loudspeaker cone and voice coil. A great deal of further work has been done and it is probable that some of the results may be of interest to the domestic high-quality enthusiast as well as to others with a more professional interest. First of all a brief recapitulation of the earlier results to avoid searching through your file of back numbers. It was shown that :—

1. Critical damping of the speaker voice coil is generally achieved by an amplifier having an output impedance greater than 10–20 per cent of the d.c. resistance of the speaker voice coil. For our purpose critical damping is obtained when the voice coil makes a unidirectional return (no overshoot) from an excursion to one side of its mean position.

2. Amplifier output impedance lower than 20 per cent of the speaker resistance, i.e. damping factors greater than five, produce little further increase in damping because the amplifier output impedance is in series with the d.c. resistance of the voice coil.

3. Other factors remaining constant, further reduction in the amplitude of the transient oscillation can be secured by an increase in flux density in the gap.

It is a characteristic weakness of an experimental approach, that it may do no more than show that the results obtained apply to the particular unit tested, so several units of radically different design were checked, the results being shown in Table 1.

In general a speaker having a low value of gap density will require a lower amplifier output impedance for critical damping than a unit having a high gap density. The majority of speakers with any pretension to high-fidelity performance are high flux density models used in conjunction with negative-feedback amplifiers of low output impedance ; consequently it is in just that application where low output impedance is least necessary that it is more often obtained.

In view of the results shown in Table 1 it is thought that the critical damping resistance (amplifier output impedance) for the majority of speakers at present available is greater than about 10–20 per cent of the d.c. resistance of the voice coil.

It is pertinent to enquire about the further improvement that might be secured by applying greater-than-critical damping, as this could no doubt be secured if it proved to be of considerable value in the search for the ultimate in high fidelity. If perfect damping were obtained the motion of the voice coil would at all times be exactly in phase with the current in the voice coil, apparently an ideal state of affairs.

However, before deciding to concentrate on the problem of increasing the voice-coil damping let us take a glance at the performance of one of the other links in the high-quality chain, the listening room in which the high-fidelity enthusiast enjoys the results of his efforts. Reference to an earlier article ("The Acoustics of Small Rooms" *W.W.* May 1944) will show that any enclosure behaves as a resonant structure having an infinity of resonant frequencies given by the Rayleigh equation,

$$f = \frac{c}{2}\left(\frac{A^2}{L^2} + \frac{B^2}{W^2} + \frac{D^2}{H^2}\right)^{\frac{1}{2}}$$

where c = velocity of sound in air, L = length, W = width, H = height, and A, B, D are the integers 1, 2, 3, 4, etc., substituted in turn. In a typical instance (the writer's lounge) this equation predicts the presence of eight resonant frequencies below about 100 c/s, as shown in Table 2, the presence of most of these having been confirmed by experiment. These are all in the same region of the audio spectrum as the fundamental voice-coil resonance of the majority of good loudspeakers, and there does not appear to be any good reason for believing that their effect upon the quality of reproduction will not be exactly the same as the effect of a speaker resonance when the Q factor ($\omega L/R$) of the room is the same as the Q of the speaker voice-coil system. In both cases an exponentially decaying oscillation at the resonant frequency is added to the tail of every transient signal. An accurate calculation of the acoustic Q of the room is not possible, but a direct measurement of the 51-c/s

* British Thomson Houston Company.

TABLE I

Type of Speaker		D.C. Resistance of Voice Coil	Critical Damping Resistance
High-quality 17in unit	..	9.0 ohms	2.5 ohms
High-quality 12in unit	..	9.0 „	2.0 „
Cheap 7in (Make A)	..	8.2 „	1.2 „
Cheap 7in (Make B)	..	1.5 „	0.6 „
Cheap 7in (Make C)	..	11.5 „	4.7 „

TABLE II

A	B	D	Resonant frequency (c/s)
1	0	0	36.8
0	1	0	51.1
0	0	1	68.6
1	1	0	62.9
0	1	1	85.5
1	0	1	77.6
2	0	0	73.6
0	2	0	102.3

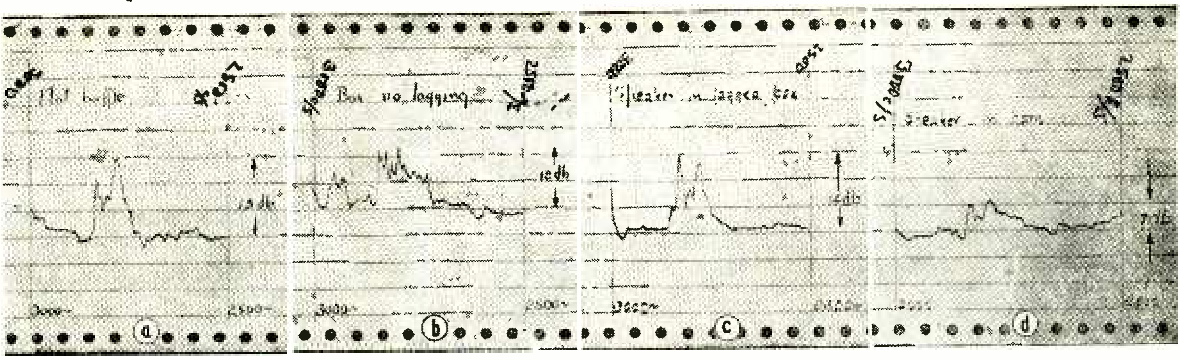


Fig. 1. Residual transient response of a 12-in. loudspeaker over the frequency range 2,500-3,000 c/s, (a) on a flat baffle, (b) in an unlagged box baffle, (c) in box baffle with hair felt lagging, (d) loaded by a short horn.

resonant mode, indicates that it has a Q between 13 and 15, whereas the Q of the damped speaker voice coil is between 0.5 and 1. Table II indicates that there are eight resonant modes below 100 c/s, and as all are known to have Q factors greater than 8, further efforts to obtain greater-than-critical damping of the speaker voice coil would appear to be a mis-directed effort, though the purist may derive some pleasure from " straining at the gnat."

Residual Transients

All the proceeding discussion has been concerned with the low-frequency resonance of the mass of the coil and cone with the compliance of the cone support, but though this is perhaps the most prominent mode, there is a very large number of resonant combinations spread throughout the whole audio frequency range. D. E. L. Shorter (*B.B.C. Quarterly*, Oct. 1946 and *W.W.* Dec. 1946) has developed a technique for checking their presence, his preferred method of expressing the result being to plot the steady-state frequency characteristic together with the frequency characteristic of the residual sound at intervals of 10, 20, 30, 40 milliseconds after the electrical input to the speaker is removed. His results indicate the presence of many high-Q modes of vibration, but in general these " resonant sub-assemblies " are not tightly coupled to the voice coil, the results being that damping applied to the voice coil movement has little effect upon the amplitude of their transient oscillations following an exciting pulse. The looseness of the coupling between voice coil and the resonant elements is shown by the absence of any indication of change in voice-coil impedance at the frequency of resonance. As these mechanical resonances are distributed throughout the whole audio range their aural effect is likely to be of greater importance than the single resonance of the cone and surround. On the other hand, the number of room resonances per octave predicted by the Rayleigh equation increases, and their amplitude decreases, as the frequency rises, and consequently they tend to be relatively less important than the higher-frequency speaker resonances, which Shorter's work has shown to be of high Q with long transient hangovers.

A solution to the problem of damping these high-frequency resonant modes in the speaker may therefore be expected to produce a greater improvement in quality of reproduction than a solution to the problem of obtaining greater-than-critical damping of the basic voice-coil resonance.

On account of the relatively loose mechanical coupling between voice coil and the resonant regions of the cone, electrical damping of the h.f. resonances is extremely difficult (probably impossible), and it is therefore necessary to consider some alternative method. A solution having all the advantages would be to increase the resistive component of the air load upon the cone by modification to the speaker mounting. At the present time there are three main classes of speaker mounting, the flat baffle, vented cabinet including the labyrinth, and the exponential horn, each with its own particular advantages. The flat baffle makes little difference to the resistive component of the air loading on the cone over any large portion of the spectrum, whereas the vented cabinet may be designed or may just happen to increase the resistive loading over the bottom end of the range in the vicinity of the cone resonance, without making any significant contribution elsewhere. The same comment is true of the labyrinth, but the third method, the use of an exponential horn has real advantage in loading the speaker diaphragm, an advantage that is particularly marked in the region between 100 and 1,000 c/s.

Horn Loading

The acoustic resistance at the throat end of an exponential horn rises much more rapidly with increase in frequency than for a cone in an infinite baffle and at low frequency may be 50–100 times the value obtained without the horn. The increase can be calculated without serious difficulty, but the calculation involves a knowledge of the change in effective diaphragm area with frequency, information that can only be obtained experimentally with greater difficulty than there is in directly checking the reduction in transient oscillation due to the addition of the horn.

An experimental check on the correctness of the reasoning always inspires confidence and fortunately some earlier results on a typical 12in cone unit can be quoted. This was tested in a 3ft. sq. baffle, a felt-lined box, and a short exponential horn, the Shorter method of transient measurement being used. Transient oscillations in open cone speakers appear to be greatly affected by time, temperature and many other factors, so it was necessary to find a relatively narrow region of the complete response curve where a transient oscillation occurred in a stable manner, i.e., the results on a flat baffle could be repeated with consistency over periods of several hours. The amplitude of the transient oscillations 20 milliseconds after the electrical input had been cut off, was then checked with the speaker unit in the flat baffle, the box and the horn, particular care being taken to make certain that the test results for any method of mounting could be repeated.

Fig. 1 illustrates the results and it will be seen that there is little difference in the amplitude of the transient oscillation whether the speaker is mounted on a flat baffle, in an unlagged cabinet or in the same cabinet with thick hair felt lagging. Mounting the unit in a short horn reduces the amplitude of the oscillations by about 12–15 db. Though it may be a coincidence it is worth noting that in this particular case the addition of lagging to the cabinet appears to reduce the frequency band over which prominent oscillation occurs, though increasing the amplitude of the oscillation within that band. This sort of result is generally due to one of the box dimensions being a whole number of quarter wavelengths, and in this case the addition of one inch felt made the back to front dimension a whole number of quarter waves near the frequency of the transients. This point was not followed up, so this should be considered as a tentative explanation only.

Horn loudspeakers are characterized by a solidity and firmness of reproduction which within the writer's experience is not possessed by any other form of mounting, a characteristic that is believed to be due to effective damping of the cone motion. In this particular case the damping obtained appears to be about twice that expected on the basis of the usual estimations of effective cone diameter.

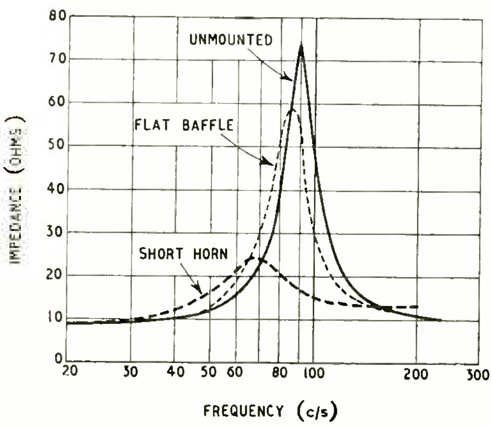


Fig. 2. Effect of loudspeaker mounting on impedance of voice coil.

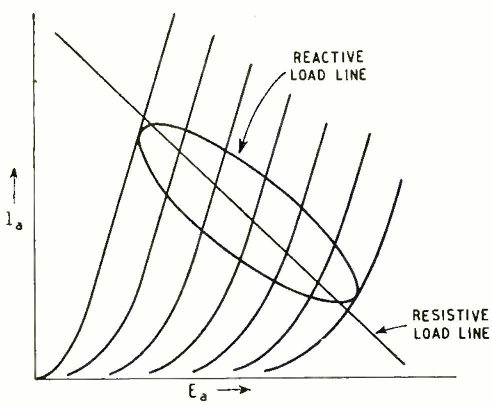


Fig. 3. Indicating the curve path followed by the operating point with a reactive load.

Earlier, we expressed the view that critical damping of the voice coil is not of particular importance when the loudspeaker is used in a small room but as all the equipment was set up, a particular 12-inch speaker was checked in three mountings to determine the amplifier output impedance required to give critical damping of the basic resonance. The results are as follows :—

TABLE III

Speaker Mounting	Source Impedance for Critical Damping
1. Open on bench	8 ohms
2. In 2,500 cubic inch box . .	2 „
3. In short horn	12 „

This indicates that the Q of an enclosure may be greater than that of the speaker voice coil (i.e., a lower source resistance is required for critical damping) confirming that it may be necessary to use some artifice similar to D. E. L. Shorter's felt partition (*W.W.*, Dec. 1950) if critical damping of an enclosure is really required.

There is one advantage of using a loudspeaker mounting that provides resistive loading of the cone, to which we have not so far referred. A lightly damped mechanically resonant voice coil system will have an impedance/frequency curve with a pronounced peak at the frequency of mechanical resonance, a typical sort of curve being shown in Fig. 2. Over this part of the frequency range the output stage of the amplifier is presented with a load that changes rapidly both in modulus (absolute value) and in phase angle, the change being particularly violent over the few cycles near resonance. A thermionic amplifier cannot provide power for this type of load without introducing serious distortion, a result that will be understood by referring to Fig. 3 showing the anode-voltage/anode-current curves for an output valve with load lines for a purely resistive and for a reactive load added to the diagram. For a resistive load the working path is the straight line shown but for a reactive load the " line " broadens to an ellipse which may take the operating point into regions where the anode current at peak negative grid signals is dangerously near or into cut off, thus increasing the working distortion far above the values taken from the curves for a matched resistive load.

Fig. 4 indicates the results obtained using an amplifier with low-impedance triodes in push pull in the output stage, curve A being the third-harmonic distortion when the amplifier was driving a pure resistance load, and curve B the third harmonic produced when a two-unit speaker combination was substituted. Although this particular speaker assembly has an impedance characteristic which is relatively flat in comparison with the majority of high-fidelity speakers at present on the market, it will be seen to increase the distortion by a factor of two to three times below 200 c/s.

There is therefore considerable merit in adopting a speaker mounting that will reduce the inherent impedance variations of the speaker unit itself, but it is almost impossible to make any specific statement about the relative advantages of the many types of speaker mountings in this respect. In general the flat baffle has little effect upon the impedance curve of the speaker unit and is therefore worst of all in respect of impedance variation. The vented cabinet may be designed to reduce the natural impedance variation of the basic unit, though there does not seem to be any unanimity of opinion among designers as to what should be done. In the case of the horn-loaded unit considerable reduction in the impedance variation of the basic unit can be secured by appropriate design. Fig. 2 indicates the impedance variation of a particular 12-in speaker unit, in free air, mounted on a 4ft square baffle and finally in an exponential horn designed to be contained in a 10,000 cubic inch box.

As shown in the earlier article these variations in impedance are directly related to the amplitude of the transient oscillations of the speaker, a flat curve such as that for the horn indicating highly damped motion of the coil and cone. In this particular instance the horn shows up to considerable advantage in reducing the amplifier distortion due to load impedance variation and in a large room should show a marked improvement due to the damping of the coil motion.

For completeness we may summarize the conclusions as follows:—

1. Further evidence is produced to indicate that current designs of loudspeaker units are critically damped by an amplifier having an output impedance about 10–20 per cent of the d.c. resistance of the voice coil.

2. Truly aperiodic motion, i.e., greater-than-critical damping is not believed to have any advantage when the speaker is used in a small room, because the transient oscillations of the room are of the same nature and are of much greater amplitude.

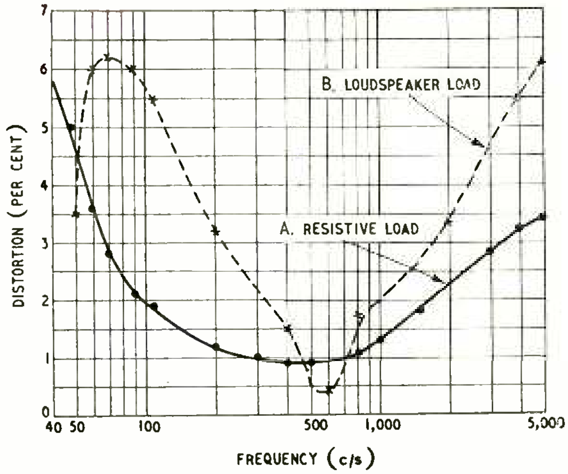


Fig. 4. Third-harmonic distortion produced by resistive and reactive loads.

3. Effort should rather be directed towards increasing the damping of the cone oscillation at the higher frequencies.

4. Further effort should be directed towards the production of speakers and mountings which give a flat overall voice-coil impedance curve.

5. One solution of both these problems is the use of an exponential horn.

POST OFFICE REPORT

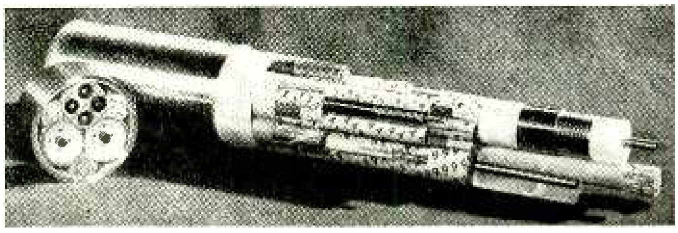
Relaying Television : Radio Interference

REFERENCE is made in the review of the activities of the G.P.O. "Post Office 1950"* to the new coaxial cable which has recently been brought into use as an alternative means of relaying television between Alexandra Palace and Sutton Coldfield. To supplement the brief details of the cable given in the report, we give some data supplied by the manufacturers, Standard Telephones & Cables, Ltd.

The main cable, forming part of the Post Office trunk telephone network, covers a distance of just over 121 miles. The cable terminates at the Museum Telephone Exchange, London, and Telephone House, Birmingham, and the end connections to the transmitters are provided by "tail" cables between the exchanges and the transmitters.

The London-Birmingham cable incorporates two 0.975-inch and four 0.375-inch coaxial tubes. The larger tubes are used, with repeaters at 12-mile intervals, for two-way transmission of 405-line television signals requiring a video bandwidth of approximately 3 Mc/s. The Hankey Television Committee (1943), however, recommended, among other things, that developments be planned on the assumption that a higher definition system, perhaps incorporating colour, would for some time be operated side by side with the present system. The larger tubes may therefore be required for frequencies up to 26 Mc/s, and, in view of this, repeaters have been included at intervals of three miles, although at present only 11 of the 43 are employed. The 0.375-inch tubes are used for broadband telephony purposes, each pair being capable of carrying 600 speech circuits. One section of the "tail" cable (Birmingham to Stoke) uses 0.375-inch tubes for the 405-line transmissions, the repeater stations being spaced six miles apart.

* H.M. Stationery Office, 2s. 6d.



Radio Interference: Whilst complaints of interference with sound broadcasting dealt with by the Post Office increased during 1949 by 68 per cent, those relating to television increased by 350 per cent. The comparative figures were: 1948, sound 40,000; vision 2,000. 1949, 67,000 and 9,000 respectively.

It is interesting to note the principal causes of interference as recorded in "Post Office 1950." Commercial and industrial electrical machinery accounted for 20 per cent of the complaints, inefficient aerial and earth systems, 18 per cent; faulty receivers, 13 per cent; domestic appliances, 12 per cent; and house wiring faults, 8 per cent.

Intermodulation Distortion in Gramophone Pickups

By S. KELLY*

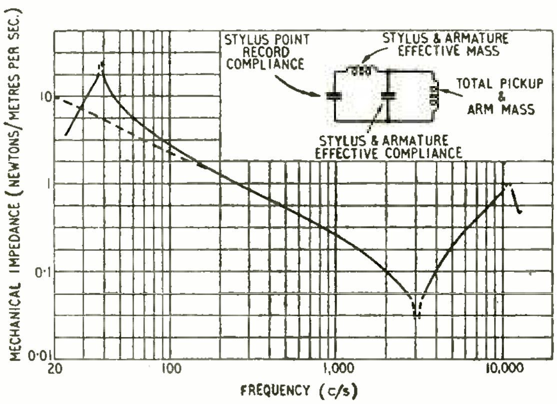
Methods of Measurement Using Special Test Records

IN general, the criterion of the fidelity of a reproducing system has in the past been expressed in terms of two major forms of distortion, namely, variations of amplitude with frequency for constant input, and non-linearity of the transfer characteristic relating output to input over a wide range of amplitudes. Later, recognition was given to phase distortion and transient distortion.

Amongst the earlier methods of specifying performance were those relating the gain of the amplifier to the frequency of the input wave, and usually any components of the output wave differing in frequency from that of the input were neglected. This gives only a rough and ready check of the performance of the amplifier, because the distortion due to a variation in frequency response, as perceived aurally, is usually not very serious. A more distressing form of distortion is that due to non-linearity of the response to input waves of varying amplitude. In this case, the amplitude of the output wave is not directly proportional to that of the input, and it can be shown, where non-linearity exists, that for a pure sinusoidal input the output will contain, in addition to the fundamental frequency, other frequencies harmonically related to it. For the past two decades, the system of assessing non-linearity has been to measure the ratio of the total (r.m.s.) harmonics produced in the device to the fundamental frequency.

Where the harmonics are concordant with the fundamental, the aural effect is less distressing than when inharmonic frequencies are present. As a matter of interest, taking the series as far as the tenth harmonic, only the seventh and ninth harmonics are not musically related to the fundamental. Harmonic distortion, as far as it goes, gives a good measure of the fidelity of the unit but, unfortunately, in most forms of aural communication, two or more frequencies are transmitted simultaneously, and it is generally agreed that simple harmonic distortion is not nearly so distressing as forms of distortion where waves other than those harmonically related to the fundamental are generated. If two different frequencies are applied to a non-linear network, the output wave, in addition to containing the two original and their harmonically related frequencies, produces also combination tones of these two groups, and the majority of these combination tones will not bear any simple harmonic relation to any of the fundamental tones.

Fig. 1. Variation with frequency of the mechanical impedance at the needle top of a popular commercial pickup (1Newton = 10^5 dynes).



Intermodulation is the production of new components having frequencies corresponding to undesired sums and differences of the fundamental and harmonic frequencies of the applied waves. By generally accepted definition, the intermodulation distortion is the arithmetic sum of the amplitudes of the modulation products divided by the amplitude of the high-frequency carrier. The intermodulation system of testing was first described by Harris[1] and was further developed by Frayne and Scoville[2]; a recent analysis is given by Fine[3].

In a gramophone pickup, distortion can take place due to non-linear flux variation in the pickup coil, caused by the armature moving through a non-linear magnetic field; hysteresis in the iron magnetic circuit; and various other design faults; or, more generally, due to the stylus not tracking the groove correctly. (In this article, the "tracking" capabilities of a pickup refer to the ability of the stylus to maintain contact with both walls of the groove under normal operating conditions.)

Under ideal conditions, the stylus would maintain constant contact with both walls of the groove, and the force acting on the stylus would be symmetrical about the vertical centre line. If, however, the vertical force on the stylus is insufficient, the stylus will tend to ride up one or other of the groove walls. This is particularly noticeable on loud passages, and if the acceleration is sufficient, it is possible to throw the stylus completely out of the groove and for it to come to rest one or more grooves away. This distressing phenomenon is only too apparent to most users of the gramophone.

* Cosmocord, Ltd.
[1] J. H. O. Harris *Wireless Engineer.* Vol. 14, pp. 63-72. Feb., 1937.
[2] J. G. Frayne and R. R. Scoville. *J. Soc. Mot. Pic. Eng.* Vol. 32, pp. 648-674. June, 1939.
[3] R. S. Fine. *Audio Engineering.* Vol. 34, pp. 11-14. July, 1950.

Fig. 1 shows the mechanical needle tip impedance of a popular commercial pickup. It will be seen that it consists of two high-impedance points corresponding to high-frequency and low-frequency parallel resonances and a series-resonant frequency (minimum impedance) at 3 kc/s. The high-frequency resonance is determined by the effective mass of the armature and stylus system and the total compliance of the stylus system (the needle tip to record compliance, and the compliance of the stylus itself), and the low-frequency resonance by the mass of the pickup head and the total armature and stylus compliance. When the needle pressure is insufficient, the stylus will "jump the groove" on heavy low-frequency passages, and rattle, or in extreme cases, also "jump the groove" because of the large accelerations often experienced at the high-frequency end.

This particular phenomenon has been evident since the earliest days of recorded sound and is one of the major problems in pickup design to-day; and the advent of long-playing records has done nothing to ease the design problem. The tracking capabilities of a pickup are determined to a large extent by the mechanical impedance at the stylus tip and, as stated before, if the lateral thrust exerts a force greater than that due to the downward pressure, the stylus will tend to ride up the walls of the groove and the symmetrical deflection of the stylus will be lost. This form of distortion is probably the most serious encountered in present-day gramophone reproduction. Unfortunately, the measurement of the mechanical impedance at the stylus point is an extremely difficult matter, but in view of the very high accelerations to which the stylus is subjected, a simple statement of its mechanical impedance is not always sufficient, and some system is required which will show the slightest form of distortion arising from failure to maintain contact between stylus and groove wall. The measurement of intermodulation is about three to five times more sensitive than the measurement of simple harmonic distortion, and this system can easily be adapted to check the tracking capabilities of the gramophone pickup.

The starting point for intermodulation measurements on gramophone pickups is, of course, a record which is engraved with the necessary frequencies and which, in itself, possesses negligible intermodulation components. The intermodulation test record No. JH 138 produced by E.M.I. Studios, Ltd., has been developed for the specific purpose of checking pickups. It runs at 78 r.p.m. and is cut with a standard groove shape, for use with 0.0025in radius styli. One side is cut at 60 c/s and 2,000 c/s, and the reverse side at 400 c/s and 4,000 c/s.

It is intended that the test records be used with a correct bass compensating circuit, so that the equalized output from the pickup is flat when played from a standard recording. The difference level of the two frequencies will then be 12 db on the JH 138.

The specification of the record is as follows:

1st side: The outer band consists of 400-c/s tone at a level of plus 22.5 db, referred to a lateral velocity of 1 cm/sec (r.m.s.), with approximately 4,000 c/s at a level of plus 10.5 db superimposed additively. The difference in levels is 12 db, and an exact integral frequency ratio has been avoided in order to facilitate visual observation of the envelope on a cathode ray tube screen.

The peak lateral velocity of the combined wave is equal to that of a sine wave at a level of plus 24.5 db.

The succeeding ten bands each have the level of both tones (and hence of the combination), reduced by 2 db below that of the foregoing band.

2nd side: The outer band consists of 60-c/s tone at a level of plus 8.6 db, with 2,000-c/s tone at a level of plus 10.3 db superimposed additively. When the 2,000 c/s is reduced in the pickup bass-correction equalizer by the correct amount relative to 60 c/s (i.e., 13.7 db) its effective level will be minus 3.4 db (and not 1.4 db as stated on the record information sheet), i.e., 12 db below the level of the 60-c/s tone.

On a velocity basis, the peak lateral velocity of the combined wave is equal to that of a sine wave at a level of plus 15.5 db.

The peak combined amplitude is equivalent to that of a 60-c/s sine wave having a level of plus 10 db.

The succeeding ten bands each have the level of both tones (and hence of the combination) reduced by 2 db below that of the foregoing band. NOTE: The level in decibels above a zero of 1 cm/sec r.m.s. lateral velocity has been measured by the Buchmann and Meyer optical method.

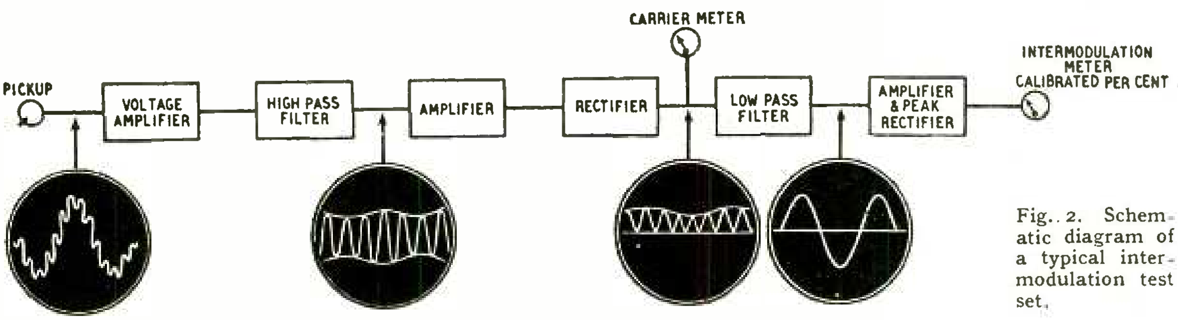


Fig. 2. Schematic diagram of a typical intermodulation test set.

Tolerable Distortion Levels

Frequencies of 400 c/s and 4,000 c/s were chosen because these lie between the two usual resonant frequencies of the pickup system, and are located in the area where high peak energies of speech and music are usually met with. Much practical work has been done, using these frequencies, in the film industry, and it has been shown that if the 400-c/s component has an amplitude 12 db greater than the 4,000-c/s component, extremely good correlation exists between aural and measured distortion. Direct listening tests show that when using 400-4,000 c/s, 10 per cent is a good practical limit for tolerable distortion. Below 10 per cent the distortion is not readily detectable unless directly compared with the original source. The majority of commercial pickups have the low-frequency resonance between 40 c/s and 80 c/s and it is usually the mechanical impedance of the needle tip at this low resonant frequency that finally determines the tracking capabilities of the pickup. The reverse side of the record is therefore cut with a 60-c/s low frequency component and a 2,000-c/s high frequency component in order to meet these particular tracking test requirements.

The output from the pickup is connected to the intermodulation test set shown in Fig. 2. This consists of a preamplifier of variable gain and minimum distortion (less than 0.5 per cent), a high-pass filter which eliminates the 60-c/s or 400-c/s wave, a buffer amplifier and a rectifier. The output of the rectifier is taken through a low-pass filter to a further buffer amplifier and a peak-reading voltmeter. The carrier level is monitored on the output of the rectifier. It may be possible to give constructional details of this equipment in a subsequent article.

Whilst an intermodulation test set is a very desirable piece of laboratory furniture, it is not absolutely necessary, and much information may be gained by direct listening to the output from the pickup when played on the intermodulation record. The distortion produced when the pickup is not tracking correctly, or when there are any other faults in the amplifier, is much more easily detectable than by listening to single-tone records—the overload point can be determined to a precision of approximately 2 db, these being the amplitude differences between each band.

Fig. 3 shows a very simple set-up using standard laboratory components and a cathode ray oscilloscope. The percentage distortion is given by:

$$\frac{A-B}{A+B} \cdot 100$$

and gives reproduceable results within a few per cent. The c.r.o. trace is shown in Fig. 4.

The inductances indicated in Fig. 3 were constructed with Mullard "Ferroxcube" cores in order to reduce distortion to a minimum. Using Type Y25/11.3 core and former assemblies, 1,750 turns of 42-s.w.g. enamelled wire gave 1.5 henrys and 3,400 turns of 45-s.w.g. were required for 5 henrys. Final adjustment of inductance to give resonance at the required frequency with the actual circuit capacitance was made by rubbing down the centre core or the outer ring to vary the effective air gap. An alternative method would be to use fixed inductances (e.g., Salford Electrical "Gecalloy" toroidal coils on Type GIA cores) and to make any necessary adjustments in the capacitance. If the core is constructed from Stalloy or equivalent material, it must be of adequate cross section and well gapped to reduce iron distortion to the minimum.

In operation, the record is played (starting at the lowest velocity on the inside band) using various needle pressures, and the distortion noted for each band. Typical results are shown in Fig. 5. These were obtained using a medium-priced, general-

	f+ 60c/s	f+ 400c/s
C_1	0·1μF	0·02μF
C_2	1·5μF	0·15μF
L_1	5H	1·5H
R	5kΩ	8kΩ

ADJUST FOR MAX. ATTENUATION AT TEST FREQUENCY (C_2, L_1)

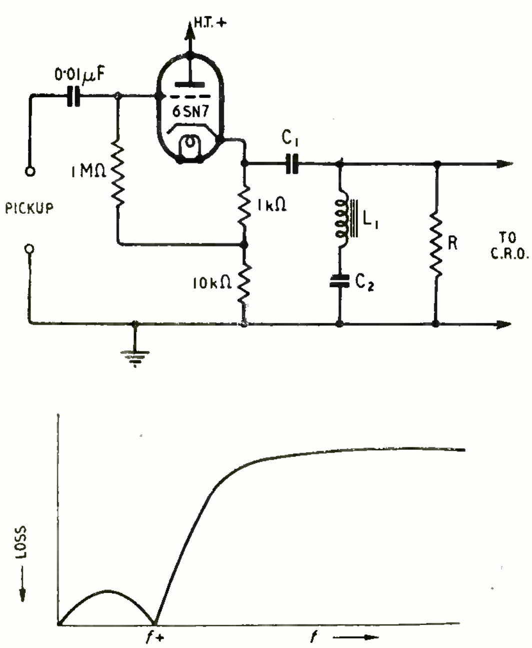


Fig 3. Simple cathode-follower coupling circuit for measuring intermodulation with a cathode ray oscilloscope. The shape of the response curve is shown inset.

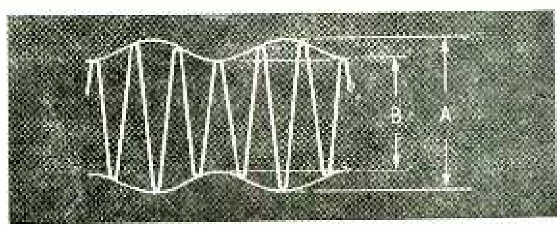
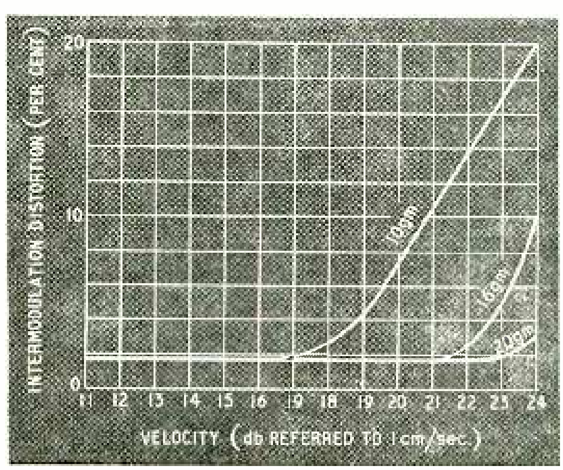


Fig. 4. Form of trace obtained with circuit of Fig. 3.

Fig. 5. Typical results with different needle pressures for a medium-priced general-purpose pickup using test frequencies of 400 and 4,000 c/s.



purpose pickup. On the 400-4,000 c/s side, it is seen that the distortion is low at low velocities, but at a critical velocity the distortion increases very rapidly. Increasing the needle pressure increases the velocity at which the break-up occurs and, for a given needle pressure, this point may be defined as the maximum velocity the pickup will track. Fig. 6 shows results on the same pickup when used on the 60-2,000 c/s side: (A) with the moment of inertia of the pickup adjusted for a resonant frequency of 60 c/s, and (B) for 25 c/s. This was achieved by weighting the head and counterbalancing the arm until the correct needle pressure was obtained. The necessity for reducing the low-frequency resonance as much as possible is certainly brought home in the test. It may be worth while mentioning here that where spring counterbalancing is used, extreme care must be exercised in measuring the needle pressure; during weighing, the height of the stylus from the baseboard must be exactly the same as the top of the record, otherwise large errors will be experienced.

In order to assess the tracking capabilities of the pickup, one determines the highest velocity with which the pickup will track for an intermodulation distortion of less than, say, 10 per cent. Of course, if two pickups are compared, one of which shows a minimum intermodulation distortion of, say, 7 per cent, and the discontinuity at plus 24 db, and the second pickup shows distortion of only 1 per cent, and discontinuity at 20 db, it will generally be considered that the second pickup is the better.

The maximum velocities recorded on the JH 138 approximate to those of commercial 78 r.p.m. recordings (except with pre-emphasis), and it is suggested that the needle pressure required to track successfully *all* bands of the record should be the one specified for general use; of course, good engineering practice requires that some safety margin be allowed, but that is a question for the individual designer.

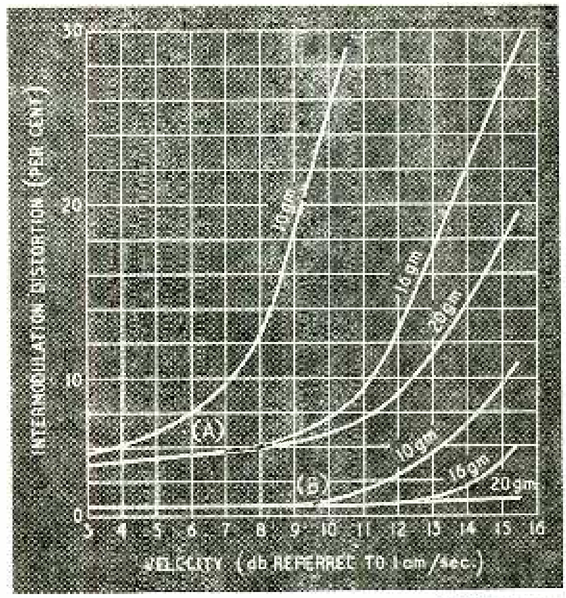


Fig. 6. Results with frequencies of 60 and 2,000 c/s for same pickup as Fig. 5. Low-frequency resonance adjusted (A) to 60 c/s and (B) to 25 c/s.

Acknowledgement is made to W. S. Barrell, B.Sc., and E. W. Berth-Jones, B.Sc., of E.M.I. Studios, Ltd., who produced the record used for these tests.

A.P.A.E. Exhibition

Technical discussion during the morning session.

THE second annual exhibition of the Association of Public Address Engineers was held on May 31 at the Horse Shoe Hotel, Tottenham Court Road, London, W.C.2. Fourteen firms prominent in the field of sound reproduction and distribution took stands and gave demonstrations. Many of the new products shown are described on another page in this issue.

The highlight of the day was the establishment of radio contact with the liner *Caronia*, then about 900 miles out in the Atlantic, and the distribution of two-way conversations over loudspeakers in the exhibition. The demonstration was arranged by A. W. Middleton, of the Post Office Radio Branch, and members were able to discuss the P.O. requirements for the use of land lines Alternative equipments provided by G.E.C. and by National Sound Reproducers were used.

The Chief Radio Officer of the *Caronia* introduced P. Adorian (President, Brit.I.R.E.) and other distinguished passengers aboard, who exchanged greetings with H. J. Leak (President, A.P.A.E.), C. Clarabut (Chairman), A. J. Walker (Hon. Sec.) and members of the Association. A very steady signal of excellent quality was maintained throughout the session, which lasted for about half an hour.

The exhibition was well attended and visitors included representatives of Government Departments, the B.B.C., British Railways and the technical and national Press. The Association are to be congratulated on the success of this exhibition and the work they are doing in the interest of higher standards in sound distribution.

Sir Ian Fraser, C.B.E., M.P., speaking at the official opening of the exhibition of sound reproducing equipment.

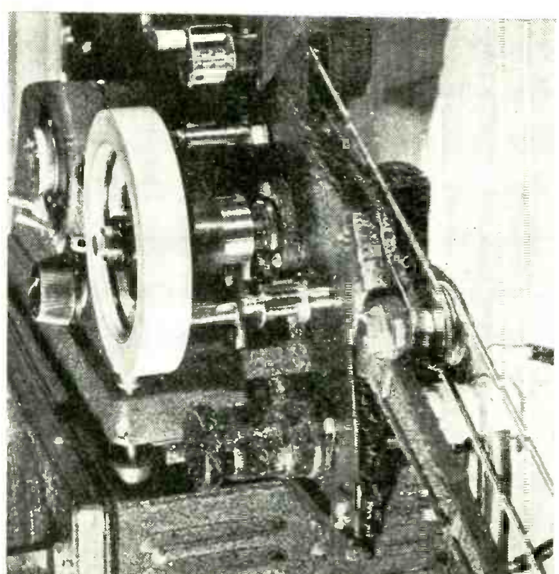
B.S.R.A. Annual Convention

HELD on May 18th-20th, the 1951 convention of the British Sound Recording Association again provided an enjoyable and informative week-end for provincial as well as London members of the Association. As in previous years, the exhibition, which this year was at the Waldorf Hotel, London, W.C.2, was open all day on Sunday as well as Saturday, and was well attended on both days. Details of some of the technical highlights of the exhibition are given elsewhere in this issue. The demonstrations of manufacturers' equipment which were such a successful feature of last year's convention were again given in a series of 20-minute sessions in the Ballroom to full audiences.

The convention opened with a musical evening at the Decca Studios, West Hampstead, when some fine examples of recent microgroove recording were heard under ideal conditions. During the evening a recording was made by Campoli of a violin solo and the audience were able to compare the "live" performance with an immediate playback.

The exhibition was opened by Sir Ian Fraser, who spoke of "talking books" and the debt which blind people owed to sound recording, particularly those who went blind in later years and could not acquire the requisite skill to read fluently by touch. The National Institute for the Blind and St. Dunstan's first issued books in 1936 and Sir Ian paid tribute to the ready technical and material help which the industry had afforded in launching this venture. To-day this library had over 3,000 reader-listeners, and 623 titles were available, with the addition, on the average, of one book per week. The system of recording was on 12in discs, running at either 24 or 33⅓ r.p.m., which thus anticipated the general issue of long-playing records. An experimental tape recorder for talking books which would enable a whole book to be issued in one unit had reached the stage when field trials could be initiated. Using 1,000ft of special ½in tape with 24 tracks spaced only 0.02in

C. G. H. Chalker receives the President's Cup from Cecil E. Watts assisted by the Hon. Sec., R. W. Lowden. A detail of the prizewinning exhibit, a photomultiplier sound head for a 16mm film projector, is shown below.



centre-to-centre, the tracking mechanism is enclosed in a plastic cassette which is reversed on the driving mechanism and the tape rewound after shifting the pickup head to the next track. The total recording time is of the order of 15 hours. Sir Ian emphasized that it would be some time before the new system could be put into service as very thorough trials must be completed before the capital expenditure involved, something like £100,000, could be authorized.

The annual dinner was made the occasion for the presentation of the President's Cup for the best exhibit in the amateur constructors' competition. The equipment shown in this section was of a very high standard and covered a wide range of amplifiers and components, some of very simple and ingenious design, as well as complete disc, tape and film recorders. The premier award went to Mr. C. G. H. Chalker, of Weymouth, for a sound-reproducing attachment, incorporating an electron multiplier photocell, for a 16mm film projector. The conversion was notable not only for the compactness of design, but for the high standard of workmanship and finish. The Committee Prize for the runner-up was awarded to the Rev. Cyril Butler for a sound-on-film recorder (variable density) which included a very well-made electromagnetic ribbon light valve.

Royal Society Conversazione

AMONG the scientific exhibits at the Royal Society Conversazione on 24th May were several of radio, electronic and acoustic interest.

B. H. Briggs and G. J. Phillips of the Cavendish Laboratory demonstrated a supersonic model showing reflection of radio waves from small irregularities and clouds in the ionosphere. Using triangulated receiving stations and comparing their continuous records on a time basis it has been deduced that the velocity of the pattern of irregularity over the ground is equivalent to winds approaching 200 m.p.h. in the upper atmosphere.

Recent striking developments in the quality of quartz crystals grown by hydrothermal synthesis were shown by C. S. Brown, R. C. Kell and L. A. Thomas (G.E.C.) and Drs. W. A. and Nora Wooster of the Brooklyn Crystallographic Laboratory, Cambridge, who also showed the technique of recovering electrically twinned crystals by applying a combination of mechanical and thermal strains.

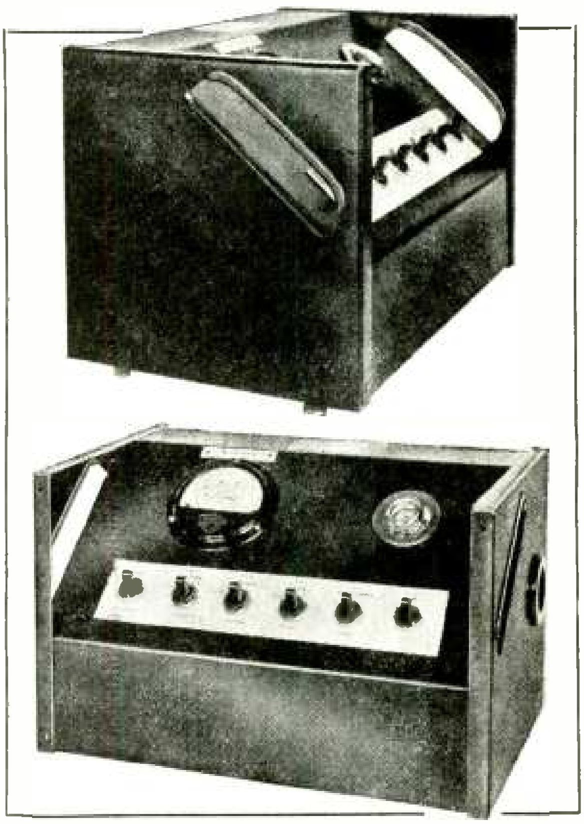
Factors governing the efficiency of speech transmission systems were demonstrated by P. Denes and Dr. D. B. Fry of the Phonetics Department, University College, London. Records on magnetic tape were used to show that when peak limitation must be employed, a rising gain/frequency characteristic before "clipping" followed by a falling correction characteristic gives better intelligibility than the converse, though both circuits give a nominally flat overall response.

Even more striking was a speech recording, distorted to a point well below intelligibility, which through the influence of psychological factors became easily intelligible when played back after the listener had been given a précis of the information contained in the conversation.

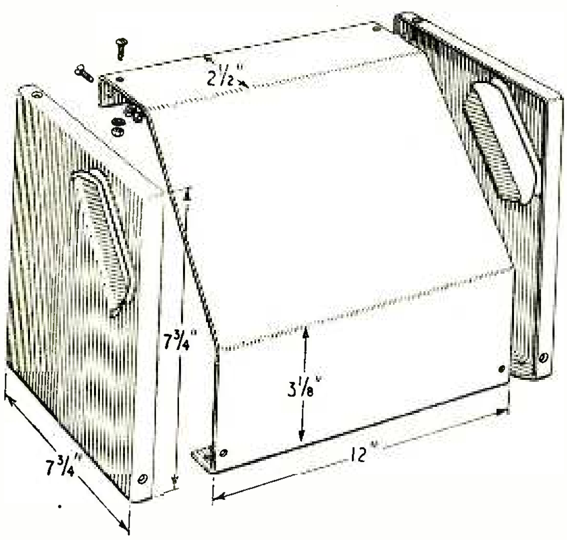
Standardized Chassis

Versatile B.B.C. Design for Housing Permanent or Temporary Equipment

DURING a recent visit to the B.B.C. Engineering Training Department's establishment at Wood Norton, *Wireless World* was attracted by the neat and effective design of a chassis that has apparently been standardized for demonstration apparatus. The chassis is also used for measuring gear and experimental apparatus of a semi-permanent nature, and would appear to have many other applications. Although components and wiring are visible and readily accessible, they are adequately protected in all positions; there are no projections to be broken, and the chassis stands firmly when upside down, on its face, on its back or even on the ends. The layout



Front outside views of a chassis housing a unit to demonstrate the time constant of a CR circuit ; note rubber feet.



Sketch showing construction (with leading dimensions) of the B.B.C. standardized chassis. The sloping panel is supported at the sides by two flanges bent in from the cut-away slots that form the hand grips.

has obvious advantages for instructional purposes, and a number of chassis may be stacked on top of each other. The "expendable" part, in which holes will normally be drilled, can be replaced without wasting the end plates.

As the illustrations here show, the general form taken by the chassis is that of a skeleton cabinet having a sloping front, solid end-plates and an open back and base. For a permanent job the back and base could be covered in. Each end-plate has a slot cut out at a "natural angle" for lifting and carrying, so there is accordingly a left- and right-hand end-plate. The top sloping edge of the hand grip is made more comfortable to handle by pressing a strip of metal, formed into a narrow channel, over the upper edge. The chassis illustrated is made of heavy-gauge (about No. 20) tin plate, cellulose sprayed, but any metal or finish can obviously be used.

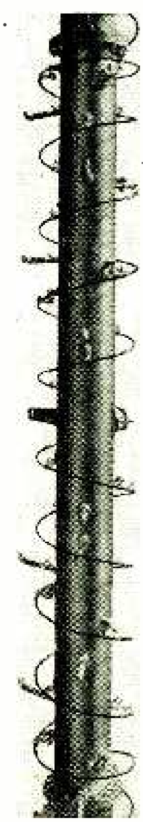
Dimensions are obviously elastic, but those of the specimen illustrated are given on the accompanying sketch. For some applications it may be convenient to standardize the size of the end-plates, but to use front panels of varying widths.

An angle-piece fixed along the lower back edge imparts rigidity, and may form a convenient mounting for components, as well as providing an anchorage for connecting wires.

HELICAL AERIAL

New High-gain Radiator for 500-Mc/s Television

AN aerial of unusual design and possessing the advantage of simplicity of construction and feed has been developed by General Electric of America. It is intended primarily as the radiator for a high-power television station operating on about 500 Mc/s and in the form shown in the illustration radiates an omni-directional wave horizontally polarized and having a very narrow vertical angle. The form of radiation can be described as a thin disc with its axis vertical.



By suitably proportioning the helix the disc of radiation can be given an upward or downward tilt, a very useful feature when the aerial is mounted very high and a local service is required. This feature, and the absence of any appreciable high-angle radiation, should go a long way towards eliminating fading in fringe areas due to reflections and scattering from the upper atmosphere.

This aerial functions on the travelling wave principle and the currents at like points in each turn of the helix must be in phase. This condition will be satisfied when each turn is an integral number of wavelengths in helical circumference, as measured at the velocity of propagation along the helix. All the conditions governing the size of the helix cannot be gone into here, so it must suffice to say that in the aerial shown each turn is two wavelengths in circumference at about 500 Mc/s. The diameter of the metal supporting pole is also important as the amount of energy it absorbs from the aerial governs its performance. It must absorb some, but not too much.

Although the main radiation is in the horizontal plane, some vertical radiation would normally be present in a plain helix. By using two helices connected end-to-end, one having a right- and the other a left-hand pitch, all, or most, of the vertical radiation is cancelled and the horizontal radiation is reinforced. The feed point of this combination is the centre, or junction, of the two helices which form a single unit in the system. As a unit it has a power gain of five compared with a plain dipole, but it is an all-round radiator whereas the dipole gives a figure-of-eight pattern only. Additional units, or bays, can be connected end-to-end to increase the overall gain, a four-bay array giving a power gain of 20. The illustration shows a single bay of the aerial, the right- and left-hand helices being easily identified with the feed point in the centre.

A coaxial cable can be used to feed the helix and when several bays are involved the mast itself can form the main transmission line. The mast would act as the outer conductor and the inner could be tubular also and used to pass up light and power cables for mast-head lighting at night and de-icing in winter. Individual bays drew power from the main feeder by means of "probes" inserted into the mast, the coupling to the centre conductor being adjusted to equalize the power supplied to each bay.

LETTERS TO THE EDITOR

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

The Industry and "E.H.F."

IF the industry is keeping quiet, I hope I shall not be considered to be giving away secrets if I suggest some of the factors which (from inside experience a few years ago) I believe to be on its mind.

Everyone agrees that a.m. cannot give better service than f.m., but the economic comparison is not so easy. A reasonably good f.m. receiver costs a little more (even 20 per cent more?) than a typical a.m. receiver. But an a.m. receiver specially designed with noise-suppression, etc., so as to give performance near that of the "standard" f.m. receiver would also be more expensive. So for high-fidelity, noise-free reception there is a strong case for f.m. and not much against it. On the other hand, high fidelity has never been a commercial proposition, and a fierce top cut (euphemistically called "tone-control") is the cheapest form of interference suppressor. If f.m. receivers are likely to be so cheapened by cutting i.f. gain and limiting that they do not behave like f.m. receivers in terms of noise, why bother to put on f.m. in the first place?

But, do not forget, expensive television sets have sold pretty well. Is this because television is so much more drastic a novelty, or is there enough money about nowadays to sell semi-luxury f.m. sets as well? But from the 1951 viewpoint (civilian production likely to be swept aside by military requirements), is there any point in studying the immediate market? Shall we not soon be back to the "austerity" receiver, trying to maintain some broadcast reception as a public service?

Leaving this gloomiest view, let us look at television. In your Editorial you give a visible shudder at the thought of mixed f.m. and a.m., and question the jurisdiction of the Television Advisory Committee. But since, under pressure from the industry, the television service was hastily restored in its exact pre-war form, and a promise given to maintain transmissions acceptable to current-production receivers for a number of years, how could we go all-f.m.? I and others suggested at the time that television sound should be put on f.m., or at least that provision should be made for dual sound channels for f.m. *and* a.m., say one above and one below the vision channel; but nothing was done, and I doubt whether second sound channels could now be fitted into the television frequency allocation. If the Television Advisory Committee insists on retaining a.m. for television sound (which in present circumstances would be reasonable) we could only choose between all-a.m. and mixed systems.

I think, however, that the only hope is for the B.B.C. to aim high, to refuse to be trammelled by the inconveniences which may arise from past errors of policy, and if they believe f.m. is better, let us go ahead with it. If high fidelity is not commercial, let the mass-production merchants make their cheap sets for this band as they do for the m.w. band, but let us have the transmissions available for the benefit of those prepared to pay for high fidelity, and to maintain British prestige in the art of radio transmission.

D. A. BELL.

Birmingham, 11.

YOUR last two editorials have invited comment on the B.B.C. proposal to adopt f.m. for sound broadcasting. I have no doubt when those most interested have seen and have had time to study the B.B.C. reasons for their recommendations, there will be no shortage of that commodity.

It is possible, however, to comment now upon the B.B.C.'s erection of two horizontally polarized aerials for this purpose. One has been erected at Wrotham, one at Sutton Coldfield, and others are under way. Now the television service uses vertical polarization, and one would therefore expect some very sound reasons for departing from the established practice.

I am indeed curious to know how the B.B.C. arrived at their decision. Did they consider that they might be closing the door on v.h.f. car radio? Did they carry out cost studies to make sure that horizontal aerials were not going to be dearer than vertical aerials? Did they realize that if this were the case by say ten shillings per aerial, that the total extra cost to the public could run into millions of pounds? Did they realize that in committing the v.h.f. listener to horizontal polarization they would make reception of different programmes from more than one direction more difficult? This last point would have special importance if independent local v.h.f. stations were set up using sites other than the B.B.C.

It could be that a limited consideration of the cost and convenience of the transmitting aerial, or other factors, led the B.B.C. to their decision in this matter, and it would be reassuring to know that this was not the case.

In Mr. Gillam's article on the design of the Wrotham aerial I am astonished to read that it was designed to accept either three f.m. transmissions or one f.m. and one a.m. transmission, but apparently not three a.m. transmissions. It would seem from this that the B.B.C. knew what conclusions were going to be drawn from the Wrotham experiments before the aerial mast was erected.

J. R. BRINKLEY.

Pye, Limited,
Cambridge.

B.B.C./G.P.O. Standards

IN any monopoly it is a truism to say that only the very highest standards must prevail so that when an organization claims that it is giving "the highest grade of technical service economically possible"[1] it is as well to examine that statement.

There are several amplifiers commercially available having a distortion content guaranteed less than 0.1 per cent with a bandwidth of at least 30–16,000 c/s; many feeder units are available which would not increase the distortion factor by more than 0.02 per cent and "quality" loudspeakers are legion. How many there are in use of these combined receivers it is difficult to estimate, but judging by the continuous advertising there must be a goodly company. Compare this specification then with the latest B.B.C. effort, the "high quality" Wrotham f.m./a.m. station. F.M., 60–15,000 c/s, distortion *not more than* 1 per cent; a.m., 60–10,000 c/s, distortion *not more than* 3 per cent.[2] The B.B.C. is, at best, ten times more distorted, with no greater bandwidth, in its latest transmitter, than the latest commercial receiving equipment. Add to this the distortion represented by the statement "although two high-quality (!) circuits are available from London, even these introduce considerably more distortion than occurs at the transmitter"[3], and a truly deplorable *projected* technical service is presented.

Just what technical or economic barrier prevents the G.P.O. from providing landlines to all provincial transmitters and studios with a bandwidth of 30—9,000 c/s with a distortion factor of not more than 0.1 per cent? Just what prevents the modification of B.B.C. transmitters to the same standard? Better by far to put the cost of the projected f.m. stations, £200,000 each, into new landlines and modulators than to spend an astro-

[1] F. A. Peachy, M.I.E.E. G. Stannard, B.Sc., and C. Gunn-Russell, M.A., Design Department, B.B.C. *Electronic Engineering*, May, 1951

[2] and [3] J. P. Hawker, *R.S.G.B. Bulletin*, March, 1951.

nomical sum covering the country with f.m. only to find that the landlines put us as you were!

Or is it that the B.B.C. has a different standard for the provinces than that for London? Judging by the frequency at which we hear "the discontinuity in the characteristic caused by the operation of the B.B.C. modulator in Class B" (D. T. N. Williamson in *Wireless World* on his amplifier) it may be so, for in several visits to the London area this "discontinuity" was not heard.

In all this I am concerned with "static" distortion as opposed to "controlled" distortion. To explain what I mean may I conclude with a story. Some two years ago I looked forward to a broadcast of a piano recital which I knew was to originate in Manchester. It began at 10.30 p.m.; by 10.40 the harmonic distortion (mostly seventh!) was such that I was constrained to telephone to Manchester. The engineer I spoke to was a long time coming back to the telephone after I had explained matters; during the period he was away the volume of sound from my receiver decreased approximately 6db and for the remaining fifteen minutes the pianist gave me much pleasure. My receiver is non-A.V.C. and no turning down of my volume control could have reduced the distortion. C. R. WHITE.

Bradford, Yorkshire.

Festival Demonstrations

THERE is so much that is worth publicizing in our British achievements in the fields of radio, television and radar that I am sure most *Wireless World* readers will be as disappointed as I was at the miserable show we have been given at our one and only Telekinema. By its name I had thought we were to see television at its very best on both closed circuits and live transmissions, and that stereoscopic film and so-called stereophonic sound were to be thrown in as additional attractions.

Instead, we have a quarter of an hour of short-line transmission from the foyer of the theatre with, until now, only two O.B.s from the B.B.C.—fifteen short minutes entirely swamped by about forty minutes of stereoscopic film. To confine television to constricted interviews in the foyer and give so much of the film programme to synthetic art is literally throwing away the substance for the shadow.

It would surely be more to our advantage nationally to demonstrate what British engineers can do in the way of transmission and reception and I rather think the public expects it. The fact that by means of the marvellous television receiver and amplifier at the theatre we can see the B.B.C. transmissions at almost full cinema size is bound to impress everyone, particularly those overseas critics of our 405-line transmission. The Telekinema can show more clearly than anything else the very high standard of our broadcast transmissions. It would be better to show this in preference to the "phoney" part of the stereo films. W. MacLANACHAN.

London, W.8.

"*Bass Without Big Baffles*"

THE ideal, expressed by your correspondent L. E. A. Bourn in the June issue, of trying to render to the ear a sound as near to the natural as possible is certainly a good one, providing that it is reasonably attainable in practice. Whilst the musical analogies, which he was able to quote with considerable authority, may be taken for or against the possible usefulness of a simulated bass, I should like to say that my amplifier was designed more from the point of view of the evidence afforded by physiological facts. The harmonic constitution of the various instrumental tones is capable of considerable alteration by passage through the mechanism of the ear.

Space would not permit a discourse into the causes of non-linearity in the ear and it will suffice to say that, at low frequencies where amplitudes are of necessity large, distortion by aural harmonics (in terms of sensation levels) is considerable when judged by the usual electrical standards. Admittedly, organ builders may employ mainly the 2nd and 3rd harmonics of a fundamental, but, in the case of the ear, subjective harmonics up to the 8th or 9th order can be detected by special methods. The characteristic curve of the ear resembles that of the grid voltage/anode current curve of a triode valve, and the ear is accustomed to being driven beyond the linear part of its curve at low frequencies with sound levels above the threshold of audibility. I am sure that your correspondent would find the results of electrical distortion at *low* frequencies surprisingly deceptive to the ear.

Dissonance between modulation products in the amplifier and other notes in the tempered musical scale would not differ materially from that occurring in the ear receiving *pure* tones, and is inevitable.

Much of the information quoted can be found in "Hearing," 1938, S. S. Stevens and H. Davis, published by Chapman & Hall. K. A. EXLEY.

Leeds, 6.

THE article by K. A. Exley in your April issue brings a most interesting and thought-provoking fresh approach to the old problem of obtaining the effect of bass without the use of a large cabinet. I would like to make one or two comments on his suggestions.

The method used by organ builders of producing the effect of a single large pedal pipe from a number of smaller pipes sounding certain harmonics is not very satisfactory when the tone to be simulated contains a large proportion of fundamental. Nor are the best results obtained unless the building is of considerable size with a fair amount of reverberation. The second and third harmonics are the most important; the higher harmonics do not add appreciably to the fundamental tone and are only necessary for the synthesis of certain well-defined tone "colours."

No steps are taken in the amplifier circuit put forward by Dr. Exley to reduce higher-order harmonics produced by V3. A simple RC filter between this valve and the point of entry to the amplifier might improve the smoothness of the synthetic bass. As this is only required below about 100 cycles, reduction of output could begin at 250 cycles or so. Also the output from V3 is fed into the amplifier at a point within the feedback chain, so that this input will be subject to degeneration just as would any spurious signal, such as hum, produced within the amplifier.

A further point is that the valve V3 is at a point following the volume control. While the input to this valve is considerable, having been subject to amplification in V1, it is likely that as the volume control setting is moved towards minimum the proportion of harmonic bass to signal will fall, and a point will be reached at which distortion in V3 is very small.

Might it be more satisfactory if the input (from pick-up or tuner) is taken first to a splitter, the anode of which feeds the harmonic generator valve, the output from this and the signal from the cathode of the splitter then being combined and fed to the main volume control? Output from the harmonic generator valve could first be passed through an RC filter to remove higher harmonics, and a volume control potentiometer preceding the junction with the main signal path would allow the proportion of harmonic bass to be varied to suit individual taste. Some amplification of signal prior to feeding to the distorting valve could be obtained by having the anode resistor of the splitter greater than the cathode load resistor. An advantage of this method would be that the entire harmonic bass circuit could be constructed around a single double-triode valve, such as 6SL7, and could be applied to any normal amplifier, thus avoiding the need for much extra constructional work on existing equipment.

Tunbridge Wells, Kent. F. D. C. BAKER.

DEVELOPMENTS IN

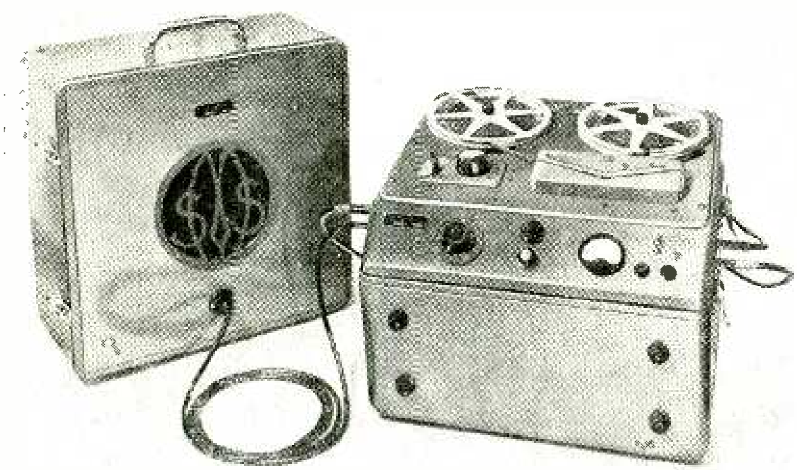
Sound Reproduction

Equipment Shown at the Recent B.S.R.A. and A.P.A.E. Exhibitions

Recording.—The new E.M.I. portable magnetic recorder, Type TR50, which weighs 59 lb and measures $17\frac{1}{2} \times 16 \times 12\frac{1}{4}$ in, is available for tape speeds of either 15 and $7\frac{1}{2}$ in/sec or $7\frac{1}{2}$ and $3\frac{3}{4}$ in/sec. The frequency response is 50 c/s to 12,000 c/s within ±2 db of the response at 1 kc/s at 15 in/sec, 8,000 c/s at $7\frac{1}{2}$ in/sec and 4,000 c/s at $3\frac{3}{4}$ in/sec. It is claimed that speed variations are less than 0.2 per cent at 15 and 7 in/sec and less than 0.3 per cent at $3\frac{3}{4}$ in/sec. Equalizer networks appropriate to the conditions are automatically brought into circuit by the speed selector control.

M.S.S. have now entered the tape recording field with a portable machine (Type PMR/1) using standard 1,200-ft reels of tape and designed to give a response of 50 to 9,000 c/s ± 2 db. The interesting feature of this machine is that, in addition to a 7-watt output for a 15-ohm loudspeaker, there is a second output designed to match the impedance of the M.S.S. disc-recording cutter head, so that direct dubbing from tape to disc can be carried out without additional amplifiers.

A push-pull output stage giving sufficient power for classroom work or use in small halls is provided in the new Model 1A tape recorder made by Simon Sound Service. Tape speeds of $3\frac{3}{4}$ and $7\frac{1}{2}$ in/sec are available and a single control lever working in a gate, rather on the lines of a car gear-change, gives foolproof choice of recording, playback and fast forward or rewind speeds. Attention has been given



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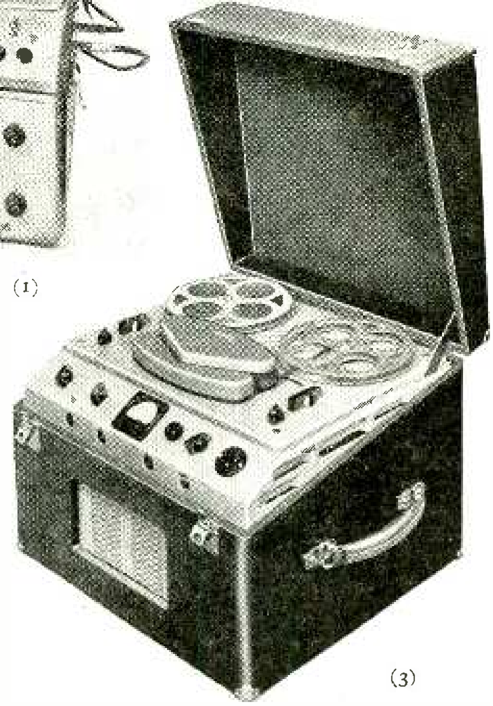

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New tape recorders. (1) M.S.S. Type PMR 1. (2) Detachable head assembly in the Leevers-Rich Type "C." (3) E.M.I. Type TR50.

to speedy acceleration and deceleration of the tape to facilitate transcription work.

The special tape recorder designed by Leevers, Rich & Company for professional use runs entirely from a 12-volt battery and provides "studio" quality in transportable form. It is particularly suitable for sound recording in film production. The specification is designed to meet wide variations in climate and the equipment has already been used "on location" in Norway and Africa. Everything has been done to ensure continuity of service in the field; the head assembly, for instance, is provided with plug-in connections and is instantly replaceable. A pulse synchronizing system developed for use with this recorder uses a separate track on the magnetic tape which records pulses at picture frame speed generated by the camera. A common a.c. power supply is unnecessary and both camera and recorder can thus be operated by separate batteries if necessary.

A magnetic tape recorder designed for synchronizing sound to silent film projectors was shown by Excel Sound Services (49, Bradford Road, Shipley) working in conjunction with a 16-mm projector. A capstan speed of 120 r.p.m. is chosen to work with the top sprocket of a cine projector and a 10-in diameter flywheel weighing 9 lb is incorporated to ensure smooth operation. The sound reproducer controls the projector motor speed through an electro-mechanical compensating relay.

British Ferrograph, were showing a new closed-loop tape deck (Model 67) for advertising and other applications where short-period repetitive reproduction is required.

A wider choice of tape is now available than last year. Durex Abrasives are in full production with their MC1-111 medium-coercivity tape, for which full magnetic data are available.

In addition to the original Type 65 "Emitape," Electrical and Musical Industries are now making a high-coercivity grade (Type H60) for use at the lower tape speeds.

Low-impedance recording, playback and erase heads have been added to the range of components made by Audigraph, who have also introduced a new series (Type 200) of self-aligning twin-track heads with tape guides formed in the moulded body.

Amplifiers.—Developments in quality amplifiers have been mainly in their auxiliary equipment. The Acoustical Manufacturing Company have produced, for use with their Q.U.A.D. amplifier, a new radio tuner unit which makes use of two stages of r.f. amplification feeding a high-level diode detector. To obtain low detector distortion, equal loading is provided for the signal and d.c. component and a low output (10-20 mV) at low impedance (5,000 ohms) is accepted. This is coupled to the main amplifier via a screened cable. A five-position switch gives the choice of four pre-set stations or gramophone and indicator lamps show the programme selected.

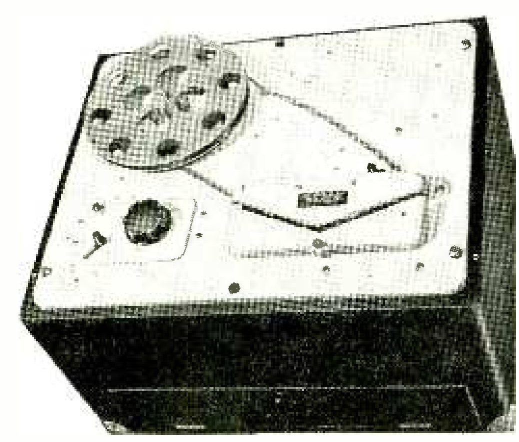
Goodsell were showing a range of "Williamson-type" amplifiers with output ratings from 6 to 15 watts. One version, for export, incorporates the new Partridge CFB output transformer assembled on the latest "C"-type core.

H. J. Leak & Company have developed a new remote control pre-amplifier (Type RC/PA/U) for use with their TL/12 power amplifier. It has switch selection of equalization characteristics for all current British and American disc recording characteristics as well as independent bass, treble and volume controls. A microphone input requires only 3 mV for 10 watts output from the main amplifier. This firm was also showing the new B.B.C. monitoring loudspeaker unit for which the TL/12 amplifier has been specified.

A new 50-watt power amplifier for sound distribution (Model 501) has been added to the Grampian range. It has provision for mixing inputs from four microphones and a gramophone pickup. Separate

(1) Goodsell amplifier with "C"-core output transformer. (2) British Ferrograph Model 67 continuous tape recorder. (3) Acoustical Manufacturing Company's radio tuner unit.

(1)



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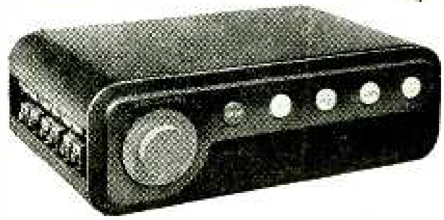


(3)

bass and treble tone controls and a bass boost for high-quality pickups are incorporated, and a switched meter provides a check on all valve emissions. The screen supply to the output valves is neon-stabilized.

Loudspeakers.—A new loudspeaker unit for the reproduction of frequencies above 3,000 c/s has been developed by Wharfedale. This is the "Super 5" which is a direct radiator with a 3½-in aperture using a cloth surround for the diaphragm and an aluminium-wound speech coil. A massive Alcomax III magnet with 1-in centre pole provides a flux density of 13,000 gauss.

Vitavox have made available the S2 pressure unit and CN157 horn which forms the middle- and high-frequency unit in the "Klipschorn" loudspeaker. It is designed for a frequency range of 200 c/s to 20,000 c/s and the pressure unit, although intended primarily to form part of studio and theatre installations, is suitable for domestic applications with the wider distribution provided by the cellular construction of the throat of the CN157 horn.

Designed for high-powered sound distribution systems, electronic organs, etc., the new Goodmans "Axiom 18" has a peak power-handling capacity of 50 watts. The 18-in diaphragm assembly is detachable for servicing and incorporates a dustproof linen spider suspension. The coil impedance is 6 ohms, and the magnet provides a flux density of 14,500 gauss.

A new lightweight pickup (P100) has been produced by the M.S.S. Recording Company. It functions with a downward pressure of only 5-10 gm and is available with interchangeable heads for standard or microgroove records. The moving-iron armature works in generous air gaps and the output is given as −34 db referred to IV r.m.s. from a 1 cm/sec + 10 db direct recording, when used with coupling transformer and equalizer.

Sound Distribution.—An interesting communication system for hospitals has been developed by Ardente for use in conjunction with the normal broadcast sound distribution system. The patients' pillowphones are of the moving-coil type and are provided with a switch at the side which converts them to microphones and also calls the duty nurse, who can enquire the patients' needs without having to traverse the length of the ward. Also shown by Ardente was a schools receiver installation which, in addition to normal B.B.C. programmes, provides automatic class-changing signals from a synchronous clock, and incorporates an oscillator for a fire alarm signal tone and microphone priority in emergency.

The Magneta Time Company were showing a comprehensive sectional amplifier assembly (Model S11) in which up to four units for radio, gramophone, speech, fire and time signals can be stacked on a basic 50-watt power amplifier to make a neat cabinet assembly when capped by a rounded top section.

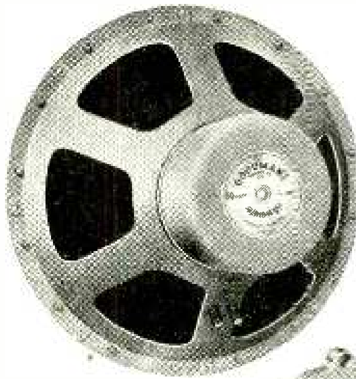
Remote control of sound distribution equipment over P.O. lines was demonstrated by G.E.C., who were showing examples of their rack-mounted Main Station and Out Station installations, as well as a wide range of smaller sound-amplifying equipment and components.

A new hand microphone (Type DP3) has been produced by Grampian. It is of the moving-coil type with metal diaphragm and its characteristics have been designed to give smooth response over the range of speech frequencies, with the minimum of extraneous pickup. A press-to-talk switch with heavy nickel-silver blades incorporates a third contact for relay operation.

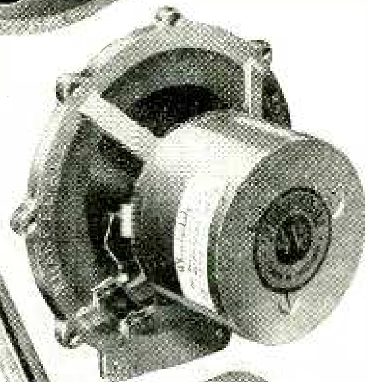
Vitavox have produced an alternative version of their B50 hand microphone with a built-in transformer to give either 500-600, 10,000 or 100,000 ohms output impedance. A desk cradle for these microphones is also available.

To the already comprehensive range of Truvox loudspeakers for sound distribution has been added a new lightweight 10-watt pressure driving unit, without transformer (Type SD47) to meet the demand for simplified installation and servicing adjustment.

An interesting device for sound distribution systems employing long lines was shown by the Antone Company of Epsom. It is known as the "Modulite" and consists of an Aldis-type signal lamp fixed to the loudspeaker standard and relay operated by speech currents. The narrow beam, which is focused on the operating or microphone position, gives clear indication that remote speakers are functioning.

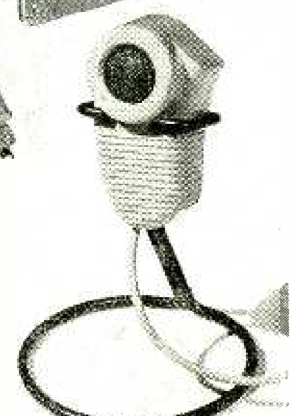


Goodmans "Axiom 18" loudspeaker.



Below: Wharfedale "Super 5" h.f. unit.

Grampian Type DP3 hand microphone.



Right: Vitavox Type B52 microphone, with built-in transformer, on desk stand.

WORLD OF WIRELESS

New Home Service Stations ✦ Instruments and Electronic Shows ✦ Radio Convention ✦ Birthday Honours ✦ Notes and News

B.B.C. Reception

TWELVE new low-power stations are to be brought into use by the B.B.C. to improve reception of the Home Service in certain areas. This was announced by the Postmaster-General in reply to a question in the House of Commons.

He stated that to mitigate as far as possible the deterioration caused mainly by foreign station interference on wavelengths allocated to the United Kingdom under the Copenhagen Plan, low-power medium-wave transmitters are to be erected in the vicinities of the following places:

	kc/s	Service
Barnstaple	1052	W. of England
Barrow	1484	N. of England
Bexhill	1457	W. of England
Brighton	1457	W. of England
Cromer	908	London
Dumfries	809	Scottish
Folkestone	1457	W. of England
Montrose	1484	Scottish
Pwllheli	881	Welsh
Ramsgate	1484	London
Scarborough	1151	N. Ireland
Whitehaven	692	N. of England

The P.M.G. stated that selection of wavelengths to provide a satisfactory service to the maximum number of listeners in these localities without spoiling reception elsewhere presented considerable difficulty, and it restricted the choice of the particular Regional Programmes which could be provided.

The B.B.C. hopes that eight of the new stations will be operating before next winter.

Instruments Exhibition

THE first exhibition to be devoted exclusively to the British instrument industry opens for ten days at Olympia, London, on July 4th.

Of the 140-odd exhibitors, nearly forty will be showing instruments and equipment of radio and electronic interest.

The exhibition, which will be in the National Hall, will be open daily from 11 a.m. to 8 p.m. except on July 14th when it closes at 6 p.m. Admission is 2s 6d. The organizers are F. W. Bridges & Sons, Ltd., Grand Buildings, Trafalgar Square, London, W.C.2.

Solder Film

THE not-inappropriate title of "The Vital Link" has been chosen for a well-produced educational film made for H. J. Enthoven & Sons, manufacturers of "Superspeed" cored solder. Though solder in itself may be a humble commodity, difficult to glamourize, the soundness or otherwise of connections made by its help in radio equipment is truly a vital matter. The film, which deals with both manufacture and use, may be borrowed by societies, study groups, firms and similar bodies.

Brit. I.R.E. Convention

THE third and fourth sessions of the Radio Convention sponsored by the British Institution of Radio Engineers will be held at University College, Southampton, from July 24th-27th.

"Radiocommunication and Broadcasting" is the theme of the third session (24th and 25th) at which Paul Adorian (president of the Institution) will be chairman. The papers to be read include:—

"Switching Methods for V.H.F. Networks" by E. P. Fairbairn (G.E.C.)

"Broadcast Reception on Large Merchant Vessels" by R. Copsey (Redifon).

"Submarine Cable Communications" by E. W. Smith, Ph.D., B.Sc. (Eng.), (Submarine Cables).

"High-Frequency Broadcast Transmission with Vertical Radiation" by P. Adorian and A. H. Dickinson (Rediffusion).

"Recent Developments in Vibrators and Vibrator Power Packs" by J. H. Mitchell, B.Sc., Ph.D. (Ericsson).

"Some Problems Encountered in the Design of Marine Transmitters" by D. J. Spooner (Redifon).

"Plastic Insulated Land Communication Cables" by A. L. Meyers, B.Sc. (Eng.), (T.C.M.).

"Wireless Broadcasting and Rediffusion Systems for Colonial Territories" by A. Cross and F. R. Yardley (Rediffusion).

"Some Future Developments in Air Radio" by G. R. Scott-Farnie and M. I. Forsyth-Grant (International Aeradio).

"The Design of the Domestic A.M. Sound Receiver" by F. T. Lett (E.M.I.).

"The Design of a Comparator A.M./F.M. Receiver for Broadcast Reception" by F. H. Beaumont (Fitton).

The fourth session (26th and 27th) is devoted to "Radio Aids to Navigation"; the first day's papers being largely on marine aids and the second on aeronautical aids. The chairman at this session will be F. S. Barton (T.R.D.E.) and the opening address will be given by Sir Robert Watson Watt. Among the papers to be read are:—

"The Use of Radio in the Navigation and Operation of Civil Aircraft" by D. H. C. Scholes (Plessey).

"The Application of Telecommunications to Civil 'Airways'" by D. P. Taylor (M.C.A.).

"Harbour Radar" by Grp. Capt. E. Fennessy (Decca).

"Random Phase Variations of C.W. Signals in the 70-130-kc/s Band" by W. T. Sanderson (Decca).

"The Seaman's Requirements for Navigational Aids" by R. F. Hansford (Sperry) and Capt. F. J. Wylie, R.N. (Retd.).

"Search Radar for Aircraft" by P. Stride (E. K. Cole).

"Some Navigational and Air Traffic Control Problems of Civil Aviation and the Application of Radio to Their Solution" by G. W. Stalebrass (M.C.A.).

"Trader Year Book"

IN the 1951 edition of "The Wireless and Electrical Trader Year Book" considerable space is devoted to television data and includes condensed specifications (valves and c.r.t. used, i.f., e.h.t. supply and aerial input) of current television receivers. Valve and cathode-ray tube base connections, with over 200 valve base diagrams, and abridged specifications of current radio receivers are also included.

The directory sections, printed on distinctively tinted papers, include manufacturers' and wholesalers' addresses, proprietary names and a classified buyers' guide.

Published by the Trader Publishing Co., Ltd., Dorset House, Stamford Street, London, S.E.1, the 292-page Year Book costs 10s 6d, post free.

Electronics Exhibition

THE sixth annual exhibition of electronic devices organized by the North-Western Branch of the Institution of Electronics, will be held at the College of Technology, Manchester, on July 24th (from 2.30 to 9 p.m.) and on July 25th and 26th (from 10 a.m. to 9 p.m.).

In addition to the section devoted to manufacturers' products, a non-commercial section, composed of exhibits from the Universities and from scientific associations, will be included. Home-constructed television receivers will be demonstrated and an amateur station will operate throughout the exhibition.

Admission will be by ticket obtainable from W. Birtwistle, 17, Blackwater Street, Rochdale, Lancs.

PERSONALITIES

Sir Ian Fraser, C.B.E., M.P., the new president of the Radio Industries Club, has a strong link with the industry and broadcasting. He was a member of the Government Broadcasting Committee (1925-26) and was a Governor of the B.B.C. from 1937-39 and again from 1941-46.

Sir Ernest Fisk, deputy chairman and managing director of Electric and Musical Industries, Ltd., was unanimously re-elected president of the International Federation of the Phonographic Industry at a recent meeting attended by representatives of fourteen countries.

W. A. C. Maskell, B.Sc.(Eng.), M.I.E.E., has been appointed general manager of the General Electric Company's radio and television works at

Coventry, in succession to the late W. H. Peters. He joined the company in 1925 and during the war was chief engineer of the G.E.C. radio works in the Bradford area. When these works closed in 1946 he returned to the head office to become deputy manager of the radio department. He is succeeded as deputy manager by **R. G. E. Mayo,** who joined the G.E.C. in 1927.

W. A. C. MASKELL, B.Sc. (Eng.)

O. W. Humphreys, B.Sc., F.Inst.P., M.I.E.E., who has been manager of the G.E.C. Research Laboratories for the past two years, has been appointed director of the Laboratories. He has also been elected a member of the Board of the Institute of Physics.

Philip V. Hunter, C.B.E., deputy chairman of B.I. Callender's Cables & chairman of the Telegraph Condenser Co. and of B.I. Callender's Construction Co., has had conferred upon him an Honorary Membership of the I.E.E. for "his outstanding services to the electrical industry and to the Institution."

HONOURS

Among the recipients of Birthday Honours conferred by the King are:—**W. K. Brasher,** secretary of the Institution of Electrical Engineers since 1939, and **G. R. Parsons,** G.P.O., who was secretary to the Beveridge Broadcasting Committee, who become C.B.E.; **E. G. Chadder,** who was recently appointed senior superintendent engineer (sound), B.B.C., and **H. Noble,** senior principal scientific officer at the Admiralty Signal and Radar Establishment, Haslemere, who are made O.B.E.; **A. Davenport,** general works manager, Salford Electrical Instruments, **F. Mitchell,** Flight Radio Officer, B.O.A.C., **E. H. Niblett,** technical and works director, Wright & Weaire, Ltd., and **W. H. Ritch,** chief Radio Officer, s.s. *Mahronda*, who are made M.B.E.

IN BRIEF

Licences.—Of the 12,452,300 broadcast receiving licences current in the U.K. at the end of April, 825,600 were for television receivers. During the first four months of this year there has been an increase of 239,500 television licences and a decrease of 82,200 "sound" licences, giving an overall increase of 157,300.

India's first high-power medium-wave broadcasting station was recently opened in Calcutta. The 50-kW transmitter operates on 1,000 kc/s.

Radio-controlled model aircraft, ships and tanks will be a feature of *The Model Engineer* Exhibition, to be held at the New Royal Horticultural Hall, Westminster, from August 22nd to September 1st. The Society of Model Aeronautical Engineers has introduced a new competition limited to radio-controlled model aircraft for which entry forms and rules are obtainable from the Manager, *The Model Engineer*, Exhibition Offices, 23, Great Queen Street, London, W.C.2. The closing date for entries is July 16th.

B.B.C. Exhibition.—Burns' plea "O wad some power the giftie gie us, to see oursels as others see us!" is answered at the exhibition staged by the B.B.C. at 201, Piccadilly, London, W.1, where visitors can see themselves televised. Disc and tape recorders are demonstrated, and the cutting of sapphires for tipping both recording and reproducing needles is shown. Admission to the exhibition, which will be open daily, except Sundays, from 11 a.m. to 10 p.m. until September 30th, is 1s.

Plastics and Radio.—The part played by plastics in the radio industry—from the insulation of wire to the production of a console television cabinet—was shown at the recent Plastics Exhibition at Olympia, organized by our associate journal, *British Plastics*. Papers read at the Convention held in conjunction with the exhibition covered the development of plastics and their application to various industries.

Decca.—The North British chain of Decca Navigator stations, opened on June 7th, is planned to serve the north western approaches and has its master station at Kidsdale, Wigtown.

Dielectrics.—The University of Liverpool, in co-operation with the Institute of Physics and the British Electrical and Allied Industries Research Association, is holding a summer school on the Theory of Dielectrics at the University from July 19th to 21st. This will be followed by a conference on dielectrics from July 23rd to 25th. Particulars of both functions may be obtained from Dr. Szigeti, Department of Physics, The University, Liverpool, 7, or from the Deputy Secretary of the Institute of Physics, 47, Belgrave Square, London, S.W.1.

"Voices Under the Sea."—A documentary 30-minute film about the cableship services of Cable & Wireless, Ltd., is now being shown daily in the Telekinema at the South Bank Exhibition. "Voices Under the Sea," as it is called, tells the story of a repair by one of the Company's ships, c.s. *Norseman*, off Ascension Island. Copies of the film, both 16- and 35-mm, will be available for the use of clubs and similar organizations from the Company's Public Relations Office, Electra House, Victoria Embankment, London, W.C.2. Foreign language versions are also being prepared.

"Elettra II," the new Marconi Marine research yacht, which recently returned from a demonstration cruise to Dutch, Belgian and French ports, will be at Frederikshavn for the Danish Fishing Festival (July 10th-13th) and at Ostend for the Fourth International Congress of the Sea (July 20th-22nd).

House of Lords.—The recently completed restoration of the House of Lords afforded an opportunity for installing a new sound reinforcing system. Equipment similar to that installed in the new Chamber of the House of Commons (see *Wireless World*, November, 1950) has been provided by Tannoy.

Radio Industries Club.—It is recorded in the report of the committee of the Radio Industries Club for the year ended March 31st, 1951, that during the year under review the membership increased by 29 to 713. The new officers are: Sir Ian Fraser, president; A. J. Dew, vice-president; J. G. G. Noble, chairman; and Owen Pawsey, vice-chairman. W. E. Miller continues as honorary secretary.

R.O.U. Officers.—The new chairman of the Radio Officers' Union is Radio Officer H. Moore, who has been on the marine staff of the Marconi International Marine Communication Co. since 1920. The new vice-chairman is Signals Officer B. Pettman, who, after fourteen years' service at sea, became an Air Radio Officer in 1938. He is at present at the B.O.A.C., Brentford.

I.E.E.—The annual report of the I.E.E. presented at the 79th annual general meeting of the Institution shows that the membership at April 1st this year was 36,558. This figure is an increase of 1,010 on last year and a 100% increase on the 1938 figure.

Institute of Physics.—The annual report of the Institute records an increase of 201 in the membership during 1950. At the end of the year the total was 3,858.

Air Radio Licences.—Detailed information of all examinations for aircraft radio operators and maintenance staff held under the auspices of the Ministry of Civil Aviation, including syllabi and specimen papers, are given in the M.C.A. publication "Certification and Licensing of Aircraft Radio Personnel—MCAP 90" issued by H.M. Stationery Office, price 1s 6d. Particular attention is drawn by the M.C.A. to the revised syllabus for the R/T (General) examination.

Television Servicing.—E.M.I. Sales & Service, Ltd.—the distributing and servicing organization for "His Master's Voice" and Marconiphone products—has equipped premises at 109, Piccadilly, Manchester, for training television servicing technicians. Particulars of the courses are obtainable from E.M.I. Institutes, Ltd., 10, Pembridge Square, London, W.2, or the Training Division, E.M.I. Sales & Service, Ltd., Sheraton Works, Wadsworth Road, Greenford, Middx.

British Radio.—A 28-page booklet reviewing the activities of the various branches of the British radio industry has been produced by the Radio Industry Council for circulation overseas prior to the 18th National Radio Exhibition which opens at Earls Court, London, on August 28th.

All Mod. Con.—"WANTED.—Bungalow (preferably) or House . . . Within television range. . . ." (Advertisement in Sussex newspaper.)

Courses on the technology of synthetic resin adhesives for both the woodworking industry and the electrical manufacturing and engineering industry are planned by Aero Research, Ltd., for the summer school which they are organizing for September 23rd to 29th at Cambridge University. The mornings will be devoted to lectures and the afternoons to practical demonstrations at the Company's works at Duxford. The use of the synthetic dual-purpose resin "Aerolite K" in the production of receiver cabinets is described in "Aero Research Technical Notes, No. 99," which is issued by the Company's Technical Service Department.

Consol Charts.—In reply to a question in the House of Commons regarding the over-printing of charts of British coastal waters with Consol lines of bearing, the Parliamentary Secretary to the Admiralty stated that four Admiralty Charts were being prepared. The charts are on a small scale but over-printing on the larger scale charts is not being undertaken as it is not considered that the accuracy of the system permits its use for coastal navigation.

Amateur Radio.—Cardiff members of the R.S.G.B. are to have a stand at the Welsh Industries Fair to be held in the town from July 4th to 18th. A transmitter (GW3WIF) will be in operation each day. The Festival Land Travel Exhibition, which includes an amateur transmitting station, will visit Birmingham (August 4th-25th) when it leaves Leeds on July 14th.

Army Specialists.—Among the 130-odd trades and occupations listed by the War Office in the booklet giving details of the Army's reconstituted Supplementary Reserve are those of Radio Mechanics and Tele-mechanics in Royal Signals and Radio Engineers in R.E.M.E. The object of the Supplementary Reserve, which, it is pointed out, is not part of the Territorial Army, is to provide the technical and administrative units which the Army would need on mobilization. Details of recruitment, training and pay are given in the booklet "The Supplementary Reserve" issued by the War Office.

Patent Office Library, at 25, Southampton Buildings, Chancery Lane, London, W.C.2, has extended its hours of opening. From Mondays to Fridays inclusive, it now closes at 9.0 instead of 6.0. On Saturdays it will continue to close at 5.0. It opens daily at 10.0.

R.F. Heating.—The annual report of the British Electrical and Allied Manufacturers' Association records that a glossary of terms and a code of safety precautions for industrial high-frequency heating equipment has been prepared and will be issued by the Association in a few months' time.

Television Without Eyestrain.—A leaflet giving advice on how to enjoy television viewing without eyestrain has been issued by the Association of Optical Practitioners, 65, Brook Street, London, W.1. The opinion of the Association is that, provided a few simple rules are observed, television is not harmful to the eyes. The enthusiasm of children should, however, be curbed and they should not be allowed to view television for long periods without rest.

Exporting Television.—British television receivers operating on American standards—525 lines, 60 frames, negative picture modulation—are wanted by the Mexican firm of Cia. Mercantil Campbell S.A., Popocatepetl 131, Mexico, to whom quotations should be sent.

INDUSTRIAL NEWS

Spain has ordered from Marconi's complete equipment for two television stations to be installed at Madrid and Barcelona. The order comprises two 5-kW vision transmitters, two 3-kW f.m. sound transmitters, two complete radiating systems each including a combining unit, 3-tier turnstile aerial and transmission line; four complete e.h.f. radio links; studios in both cities, including telecine equipment; two mobile outside broadcasting units; production and commentators' equipments, communication systems, and studio lighting equipment.

U.N. Television.—Three Marconi Image Orthicon cameras and ancillary equipment have been ordered by the United Nations Organization for installation at its new headquarters in New York.

Sweden's broadcasting authority has ordered from Standard Telephones & Cables, Ltd., a new high-power broadcasting transmitter for erection in Stockholm. The company has recently installed new transmitters at Hörby, Sundsvall and Gothenburg.

Marconi radio equipment has been chosen as the standard for aircraft of the Royal New Zealand Air Force. Initially three standard types of R.N.Z.A.F. aircraft, Devons, Hastings and Freighters, are to be fitted. The equipment will include AD107 high-power communication transmitters, AD94 communication receivers, AD401 intercommunication systems and the Marconi automatic direction finder AD7092A. A lower-power transmitter-receiver (AD97/108) will provide a secondary h.f. communication station.

R.C.A. Patents.—Electric and Musical Industries, Ltd., have made arrangements whereby they are able to grant licences for broadcast sound and television receivers under all patents of the Radio Corporation of America, in Great Britain, Northern Ireland and Eire for inventions made on or after January 1st, 1945. Licences under patents of R.C.A. on inventions made prior to that date are included in a previous arrangement.

Pye, Ltd., supplied the mobile radio-telephone equipment by which the Austin A40 car (on a record-breaking trip round the world) can keep in touch with the aircraft which will be accompanying it carrying spares and supplies.

Starr British Products.—The first two words in the name of the manufacturer of Starr gramophone needles were inadvertently transposed in the advertisement which appeared on p. 92 of our last issue.

Marconi's staff magazine, *The Marconi Companies and Their People*, has been awarded the special prize for staff magazines in a competition organized by the British Direct Mail Advertising Association.

"The Elliott Journal." — Elliott Brothers (London), Ltd., have produced a house journal, which, published bi-annually, will give a periodic review of developments in engineering and physical science, with particular reference to the work of the company. In the first issue of 36 pages there are articles on magnetic amplifiers and a phase-front plotter for centimetre-wave aerials.

A. H. Hunt, Ltd., advise us that, in view of the uncertainty of obtaining adequate supplies of suitable carton material, they have withdrawn from their current catalogue Type L24 dry electrolytic capacitors in cardboard cartons. Whilst no new orders can be accepted for this capacitor, every effort will be made to meet existing commitments.

American Tape Recorders.—Arrangements have been made by Byer Industries Pty., Ltd., of 8, Dorcas Street, Melbourne, Australia, for the exclusive manufacture for the sterling area of the Magnecorder tape recorder made by Magnecord, Inc., of Chicago, Ill.

Standard Telephones & Cables, Ltd., announce that arrangements have been concluded whereby the long association between the company and Western Electric, Inc., in the whole field of telecommunications will be continued.

Multicore Solders, Ltd., are to occupy a factory being erected by the Government-sponsored Hemel Hempstead New Town Corporation. It will be the second to be opened in the new town and is stated to be the largest in the world constructed solely for the manufacture of cored solder.

Stella Radio and Television Co., Ltd., the recently formed Company for marketing and distributing radio and television receivers—the first of which will be a table and console model with 12in tubes—announce that Eric W. Brades has been appointed a director and sales manager. He was with Philips Electrical for 21 years. The company's address is Oxford House, 9-15, Oxford Street, London, W.1.

A. C. Cossor, Ltd., announce that L. L. Roberts, general manager of the Company, and director and general manager of Cossor Radar, Ltd., has resigned from these posts.

Sound Sales, Ltd., have appointed J. L. Matthews in succession to C. D. C. Gledhill as London Sales Manager at Lloyds Bank Chambers, 125, Oxford Street, W.1. (Tel.: Gerrard 8782.)

Painton & Co., Ltd., announce the appointment of J. R. Slatter, A.M.I.E.E., as works manager. He was, until recently, works manager of the Igranic Electric Co., Bedford. R. Steven, B.Sc., has been appointed sales manager.

Gregg Radio, Ltd., of Bond Street, Hull, advise us that their London office at 39, Hyde Park Square, W.2, can accept equipment for servicing and supply spare parts for their radio and electro-medical equipment.

Mullard, Ltd., is the new name adopted by Mullard Electronic Products, Ltd.

E. K. Cole, Ltd., have received a further order from the Derbyshire Education Committee for forty-six 10-watt school radio equipments.

Duke & Co., of 219, Ilford Lane, Ilford, Essex, have opened a branch at 621, Romford Road, London, E.12. (Tel.: Grangewood 6677.)

Radiocraft, Ltd., of 25, Beardell Street, Upper Norwood, S.E.19, announce that their telephone number is now Gipsy Hill 5585.

Stewart Transformers, Ltd., have moved to 75, Kilburn Lane, London, N.W.10.

Frequency Modulation

3.—The Receiver

By "CATHODE RAY"

THE only really essential difference between an f.m. and an a.m. receiver is the special kind of detector needed for converting r.f. frequency variations into a.f. amplitude variations. In fact, as I mentioned in the first instalment, any ordinary a.m. receiver can be adapted for f.m. by the simple dodge of mistuning it slightly so that the slope of the resonance curve is used instead of the peak—provided, of course, that the receiver can be tuned at all to the frequencies used by f.m. stations, which are normally in the v.h.f. band. But this method is unsatisfactory in almost every respect; its sensitivity is poor, its distortion is large, and it fails to take full advantage of the noise-subduing capabilities of f.m. Quite a number of special f.m. detectors have been devised, but the most important—and the only one I am going to describe—is the one employing the phase discriminator.

This is quite easy to understand on a basis of elementary circuit theory; in particular, the parallel resonant circuit (Fig. 1). It can be imagined as being used to tune the anode of the i.f. valve feeding the detector. The resistance of the tuning coil is represented by r, and the Q of the circuit is $2\pi f L/r$. At exactly the resonant frequency, the reactances of C and L are equal and opposite, so that they cancel one another out, and the whole circuit behaves as if it were a high resistance, equal to $2\pi f LQ$. So a given current through it develops a high voltage across it, and since the circuit is effectively a resistance the voltage is in phase with the current. We know, of course, that if the frequency is raised or lowered the voltage will fall off each side, in the usual resonance curve, and the higher the Q the sharper the resonance peak. But in this case we are not so much concerned with the changing magnitude of the voltage as with its phase relative to the current. At frequencies higher than resonance, the reactance of L is higher than that of C, so most of the current will go through the C branch, with the result that it will lead the voltage across the circuit; at frequencies below resonance most of the current will go through the L branch and lag the voltage. The sharper the resonance (due to high Q) the more rapid the phase shift as the frequency is altered. The phase shift reaches ±45° when the frequency shift from resonance is approximately ±1/2Q times the resonant frequency. For example, if the circuit is tuned to an i.f. of 10Mc/s and has a Q of 50, the 45° points are reached when the frequency has been shifted about 1/100 × 10 = 0.1Mc/s or 100kc/s. Fig. 2 shows the complete phase curve for such a tuning circuit. Note that I have plotted the phase of the voltage relative to current because the current is the constant thing in the anode circuit of a pentode.

Suppose now that this circuit is tuned to an f.m. station. When the carrier wave is unmodulated, the voltage developed across the circuit is in phase with the current through it, but if the carrier is modulated with a frequency swing of ±100kc/s the phase of the voltage will swing between + 45° and − 45° approximately. What we want is some means of translating these phase swings into voltage swings.

The alternating current through the coil sets up an alternating magnetic flux around it, in phase with itself. If another coil is coupled to it, the flux will generate a voltage in that, too, proportional to the rate of change of flux, and therefore (as explained in any book on a.c.) 90° out of phase with it. Whether this voltage is 90° behind or ahead of the current depends on which way round one takes the terminals of the secondary coil. If the winding is centre-tapped, then relative to the centre point the two terminals will provide voltages both leading and lagging (because the method of connection makes them opposite in

Right: Fig. 1. Parallel tuned circuit, the phase changes in which are the basis of the frequency discriminator which is the heart of an f.m. receiver. Here r represents the loss resistance of the circuit.

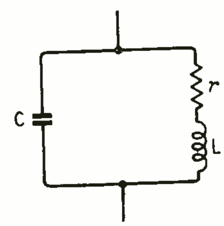
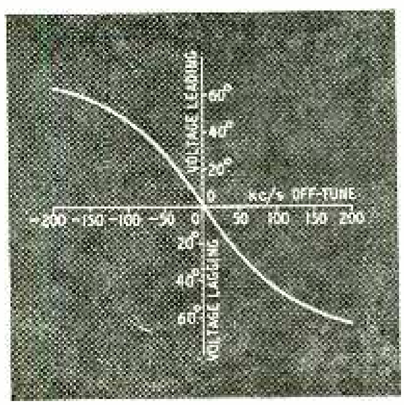


Fig. 2. Graph of phase difference between voltage and current in Fig. 1 when $r/L = 0.4\pi \times 10^6$. The useful range of a discriminator is usually ±45°.



Below: Fig. 3. Theoretical discriminator circuit, lettered to correspond with the vector diagrams, Fig. 4.

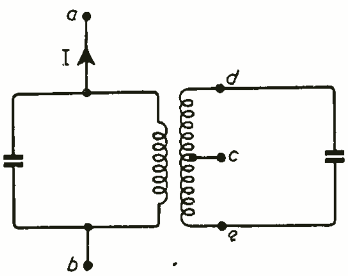
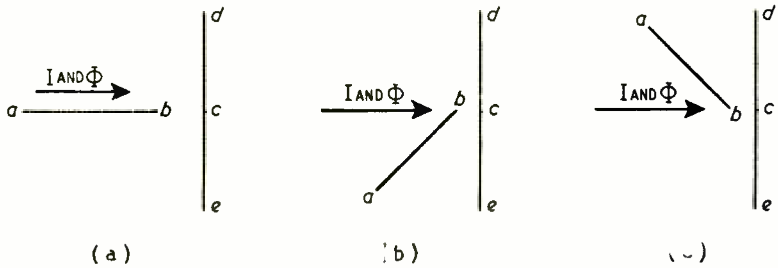


Fig. 4. Vector diagrams relating to Fig. 3 when the voltage V_{ab} is (a) in phase with, (b) leading, and (c) lagging the current I and consequently the alternating magnetic flux Φ, which generates V_{cd} and V_{ce}. If *b* were joined to *c*, to represent the discriminator connection, these diagrams would show how V_{ad} and V_{ae} vary in opposite ways with phase angle.



polarity, or 180° out of phase with one another).

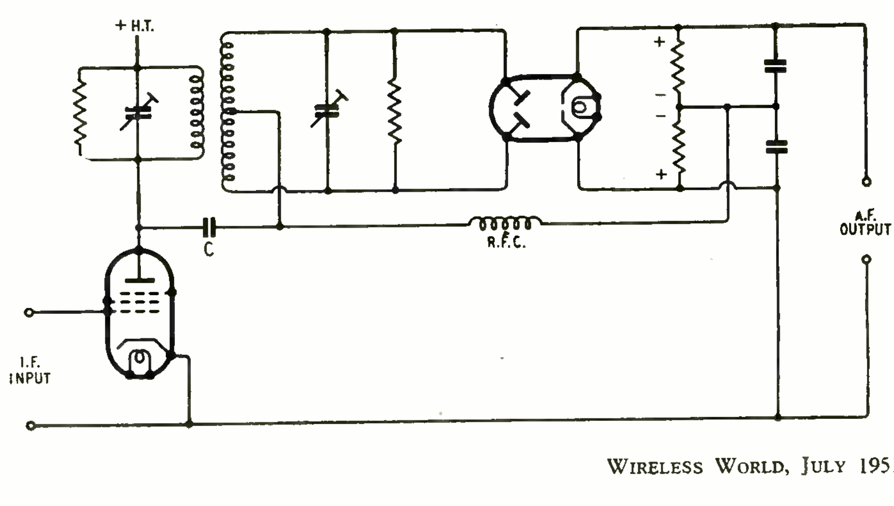
If we don't draw some sort of relative phase diagram pretty soon we shall lose track of the situation. We could, of course, draw a few sample cycles of the voltages and currents in their relative phase relationships, but in that form it is difficult to see the results of adding any two together; so let us draw a vector diagram. After all, I didn't spend three months explaining vector diagrams for no purpose! Fig. 3 is the circuit to date (the loss resistances being, as usual, taken as read), and Fig. 4(a) is the vector diagram when the coils are at resonance. The purpose of the secondary winding should now be coming into view: since the phases of the voltages produced by it are locked to the current in the primary, any phase shift between primary voltage and current (due, say, to f.m.) means a phase shift between primary and secondary voltages. The downward frequency swing makes V_{ab} lead I, as in Fig. 4(b), and the upward swing makes it lag, as at (c). By simply connecting the "live" terminal of the primary, *b*, to the centre tap of the secondary, *c*, one gets two alternating voltages, V_{ad} and V_{ae}, that vary in *magnitude* as the signal *frequency* swings. This could be seen more clearly by redrawing the Fig. 4 vector diagrams, with *b* and *c* coinciding. These i.f. voltages can be rectified by the usual detector diodes, giving two voltages that vary relative to one another at the frequency of modulation. At resonance they are equal and opposite, so cancel one another out. When the frequency swings below resonance, V_{ad} exceeds V_{ae}, and if its rectified output is connected so as to be positive the resultant is positive. When the frequency is higher than resonance V_{ae} exceeds V_{ad} and the resultant is negative. One gets a curve rather like Fig. 2 but with output voltage as the vertical scale instead of phase shift. You will probably see that $V_{ad} - V_{ae}$ is not going to be exactly proportional to phase shift, so the curve will not be exactly the same, but it will be something like it.

Now it would not be worth while setting up an f.m. system, with a nice quiet background, if the reproduction were bound to be horribly distorted. In fact, we expect really high-class results. So this matter of the precise shape of the curve is very important. If the detector output voltage did follow Fig. 2 exactly, there would be a considerable amount of third-harmonic distortion, unless the phase-shift were confined to a few degrees each side of centre, and then the quality of the output would be at the expense of quantity.

But before discussing this in detail perhaps we had better descend from all this rather abstract theory to take a look at a practical discriminator circuit, Fig. 5. It should be easy to identify the Fig. 3 transformer, with its primary in the anode circuit of the last i.f. valve, and the two halves of the secondary feeding diode rectifiers, the outputs of which are connected in opposite polarity to yield the required a.f. voltage. If point *c* in Fig. 3 were connected directly to *b* it would bring the whole secondary and rectifier outfit to practically + h.t. voltage, which would be inconvenient. So a blocking capacitor C is used, of sufficient capacitance to offer negligible i.f. impedance. The d.c. connection for the rectifiers is made, without short-circuiting the i.f., by the choke RFC. The capacitors across the diode load resistors are the beginning of a filter for removing frequencies above the audio limit and also providing de-emphasis of the upper audio frequencies. Note that resistors are used across primary and secondary windings for adjusting the Q of the tuned circuits to give the best results with the standard frequency deviation. If the tuning were too sharp, the slope of the Fig. 2 curve would be very steep at first and would quickly flatten out, causing both positive and negative peaks of large-amplitude a.f. waveforms to be flattened. As it is, some compensation for the curvature shown in Fig. 2 will clearly be necessary.

And here we must realize that the foregoing simple account of how the discriminator works has ignored a number of complications. For one thing, we have

Fig. 5. Essentials of a practical discriminator circuit. The connection between the primary and secondary coils is made via C to block the steady h.t. voltage.



been assuming that the primary current and the voltages remain constant all over the working frequency deviation. Since the primary has a resonance peak as well as a phase shift curve, this assumption is rather rash. Then we have taken no account of the secondary current, which generates a magnetic flux that will inevitably affect the primary. The extent to which it does so depends on the closeness of coupling. These two effects tend to offset one another, because if the coupling is closer than "critical" the secondary current will raise double humps on the primary resonance curve. Another thing that affects the relationship between phase shift and output voltage difference is the transformer ratio. This, at least, can be fairly easily studied, by drawing the vector diagram for various values of *de* : *ab* and in each case plotting *ad*—*ae* against phase angle. But choosing the best combination of all three parameters—transformer ratio, coupling, and Q—to produce a voltage-difference/phase-angle curve that exactly compensates for the curvature of Fig. 2, so that the voltage-difference/frequency-swing graph is as nearly as possible a straight line, is rather too complicated to go into here. Sufficient to note that it can be done very successfully (Fig. 6 is an example), but that it is quite a tricky business, and if one fails to hit on the right combination the result is likely to be considerable harmonic distortion. Set builders please note!

Even when all is well with the discriminator, its merits will be wasted if the transmission is not accurately tuned in. There are actually two reasons for this, one of which will appear when we consider impulsive noise, but in the meantime there is the very obvious one that if the carrier frequency is appreciably off the centre of the Fig. 6 curve the range of linear operation is reduced and there is a risk of the frequency swing going beyond one of the sharp bends, with dire effects on the louder parts of the programme. This condition sets in before mistuning is sufficient to make a noticeable difference to volume, nor is there the same tone change as with a.m., so listeners who are not very sensitive to distortion (and how many of them there are!) may have difficulty in getting spot-on unless automatic frequency control is used. Fortunately this is not too difficult to arrange, because we already have a large part of an a.f.c. system present —the frequency discriminator. When a station is properly tuned in, there should be no net d.c. output from the diodes—only a.f. a.c. Mistuning causes a d.c. component, and if this is used to control a reactance valve in parallel with the oscillator tuning, the oscillator frequency is shifted until the tuning is close to centre.

Removing Amplitude Variations

The receiver must be a superhet, of course, to change the incoming v.h.f. to a frequency at which the signal can be amplified effectively. An i.f. in the region of 10Mc/s is likely. And even if there is a.f.c. it is wise to pay special attention to the frequency-stability of the oscillator. If the incoming signal is 100Mc/s, a drift of only 0.1% is 100kc/s—more than the full frequency deviation of the transmitter! With ordinary tuning components, the warming-up drift might get even beyond the control of a.f.c. Another thing: great care must be taken to avoid any frequency modulation of the oscillator, especially by the power-supply a.c., since a frequency swing as little as 0.001% would be enough to cause hum.

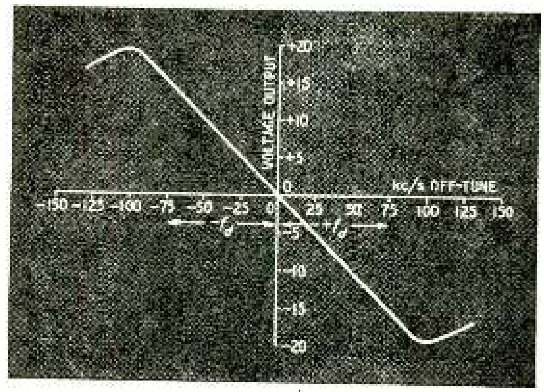


Fig. 6. When the best circuit values and adjustments are in use, the curvature of Fig. 2 is almost completely neutralized in the overall characteristic. As shown here, the characteristic is suitable for f.m. with a deviation f_d of ±75kc/s.

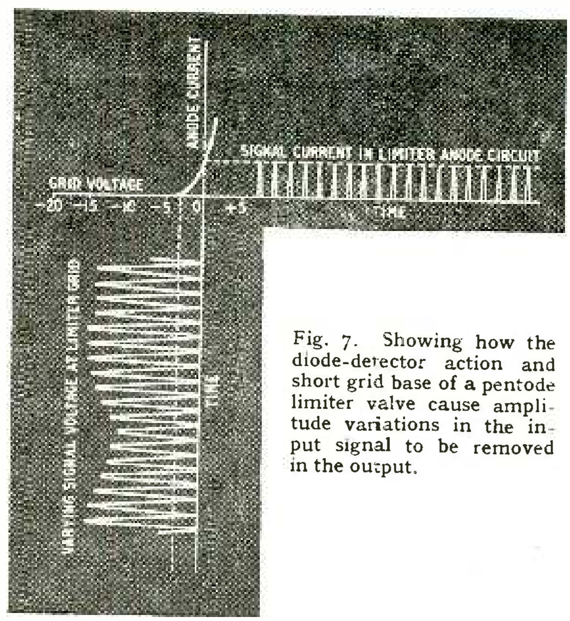


Fig. 7. Showing how the diode-detector action and short grid base of a pentode limiter valve cause amplitude variations in the input signal to be removed in the output.

You will recall that the noise-reducing capabilities of f.m. depend largely on amplitude variations in the signal supplied to the detector being eliminated. This is usually done in the last i.f. valve, a favourite method being to feed that valve with an abnormally low screen voltage. The result is to give it a very small grid base—only a volt or two. The grid is connected as a diode detector, so that the greater the signal amplitude reaching it the greater the negative bias generated by rectification, and the more the signal voltage is pushed down below cut-off. This action is shown in Fig. 7. Provided that the peak-to-peak signal voltage at the grid is never less than the grid base, then, the amplitude of the anode signal current is practically unaffected by input variations, either in the signal itself or as a result of noise or interference.

Seeing that the main idea of f.m. is to provide good reception of signals so weak that in an a.m. system

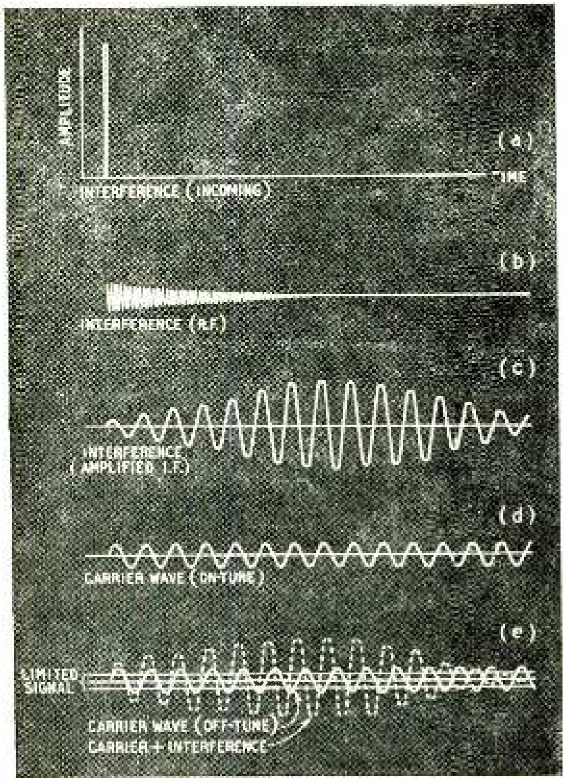


Fig. 8. This sequence shows (though not exactly to scale) how the character of ignition interference changes as it progresses through the receiver, from its original very brief form (a) to a damped r.f. oscillation (b) and an i.f. wave train (c). If the receiver is tuned to the carrier frequency (d) it synchronizes with the interference, which can be removed by the limiter. But if the carrier is mistuned (e), the interference introduces phase (and hence frequency) shifts, which get past the limiter, as shown.

they would be disturbed by noise, there must obviously be a considerable amount of i.f. amplification to ensure that even the weakest signals overload the last i.f. valve in the thoroughgoing manner just described. And at the same time the tuning must not be too sharp —we want it to be flat over about 200kc/s. So it looks as if several i.f. stages will be needed.

Altogether then, by the time an f.m. receiver has been provided with a frequency-stabilized oscillator, several i.f. stages, limiter, carefully designed and adjusted discriminator, de-emphasis circuit, a.f. amplifier and loudspeaker worthy of the wide a.f. band, and probably a tuning indicator and a.f.c, it does not seem likely to come into one of the lowest price classes. But then " ideal " designs never do. If one is content with a reasonably good performance, an f.m. receiver need not differ very much in complication or cost from the corresponding a.m. set.

There is just one other thing I promised to say something about—the effect on f.m. reception of the so-called impulsive noise, which in practice means chiefly motor-car sparking-plug interference. This subject was crowded out of the last instalment and in any case will probably be easier to appreciate now that the f.m. receiver has been reviewed.

The interference from ignition arrives in the form of intense pulses each lasting only a very small fraction of a microsecond (Fig. 8(a)). It cannot get very far through the receiver in this form, because it includes all frequencies from very low up to hundreds of Mc/s, and the receiver is tuned to accept a band only about 0.2Mc/s wide. What happens is that each pulse shock-excites the r.f. tuning circuit into a damped oscillation consisting of quite a large number of cycles. Fig. 8(b) is only a suggestion of this, not drawn to scale. The frequency is reduced by the frequency changer to i.f., which then stirs up the i.f. circuits and is amplified (c). Note that there is no possibility of tuning the interference out, because it takes on the frequency to which the set is tuned. The duration of each train of oscillations, when presented to the limiter and discriminator, is roughly equal to the reciprocal of the overall bandwidth. That may sound rather complicated, but it just means that if the bandwidth is, say, 0.2Mc/s, each pulse train lasts for about $1/0.2 = 5$ microseconds. This is very interesting, because if you have an a.m. receiver and decide that you will take advantage of the much narrower bandwidth of the programme to tune the receiver more sharply, restricting the bandwidth to say 30kc/s (= 0.03Mc/s) with the praiseworthy intention of reducing interference, you find that the pulse trains last $1/0.03 =$ about 30 microseconds. Which is not so good. Moreover, if the a.m. receiver has no limiter, the interference is likely to be greater in amplitude, too. Even if you use one of the very cunning limiters that manage to cut off the peaks of noise without distorting the peaks of programme, each spark in the engine messes up the programme for 30μsec. instead of 5μsec. That explains the apparently upside-down policy of the designers who make v.h.f. a.m. receivers much less selective than they need be, in order to reduce interference (assuming of course that the interference is of the untuned type).

But to get back to our f.m. We have seen that the noise pulse trains are arriving bang in the middle of the waveband to which the receiver is tuned. (By " waveband " I mean the band of frequencies accepted by the receiver at any one setting of the tuning control —not the range of wavelengths or frequencies over which it can be tuned by turning the control). If the set is accurately tuned, so that the wanted carrier wave (Fig. 8(d)) is also bang on, the two synchronize, and after the limiter has done its stuff one would hardly know that the interference was coming in. In this way any well-designed and well-tuned f.m. receiver should give considerable protection against ignition. Just as the Egyptian court magicians were able to imitate some of the marvels wrought by Moses, however, a.m. receivers can be produced that will do this particular trick almost if not quite as well.

Now consider what happens if the f.m. receiver is *not* accurately tuned to the programme. The noise trains still come in at the centre of the waveband, but as the carrier wave is now off-centre (Fig. 8(e)) there will be a frequency difference between them. The resulting phase modulation (which of course is a sign of the presence of f.m.) can be plainly seen. So interference is duly accepted by the discriminator and passed on to the loudspeaker. Considered in another way, the noise is equivalent to a powerful side-frequency, which must make itself felt, regardless of the limiter. And that is why I said there were *two* good reasons for making sure that an f.m. receiver was always kept accurately tuned.

Fig. 1. Radio telescope at Cambridge, using two spaced paraboloids to establish a multi-lobed interference pattern.

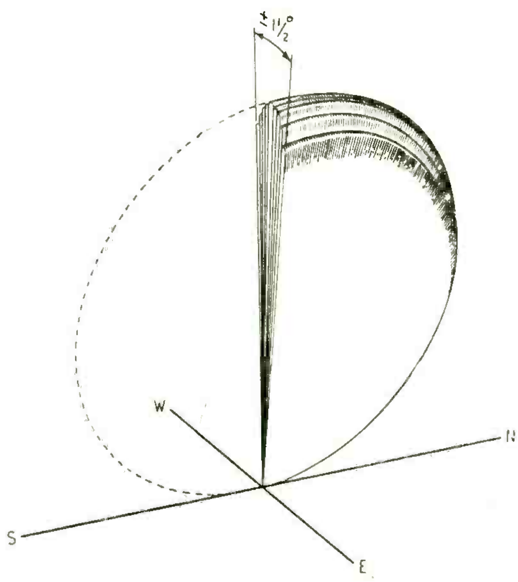
Radio Astronomy

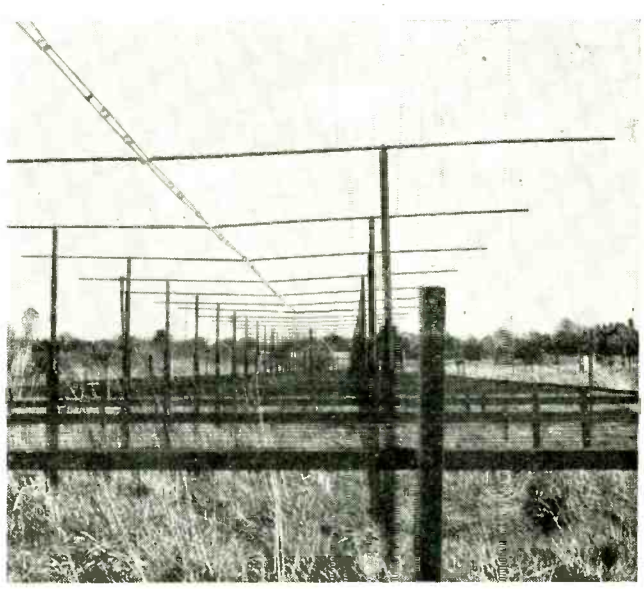
Studying the Cosmos by Radio Methods

HIGH above the South Bank Exhibition, London, on the now famous Shot-tower, is mounted a device that radio engineers will know as a paraboloid and others as a radio telescope, and it symbolizes a comparatively new application of radio in which Britain is at present taking a leading part. This new science of radio astronomy covers a wide range of different activities, makes use of both radar and direction-finding techniques and, as an aid to visual astronomy, has been responsible for a number of remarkable astrophysical discoveries. Most of the important advances have been made in the post-war years with largely ex-Service equipment, so the science owes a great deal to the tremendous improvements wrought by wartime development.

Perhaps one of the most spectacular events in the history of radio astronomy has been the discovery of radio stars. As long ago as 1932 it was known that radio emanations in the form of noise were arriving on this planet from somewhere in space; but no great importance was attached to these findings, even when, later on, aerial systems of improved directivity showed that the signals were stronger coming from some directions than others. Then, in 1948, almost simultaneously from Australia and Britain, came the announcement that a number of very localized sources of emission had been detected, and these have since become known as radio stars.

One great problem in this kind of direction finding is picking out the radio star from the general background of radiations on similar noise frequencies coming from the rest of the galaxy. Obviously a highly directional aerial system is required and, so far, two methods have been tried. One of them uses a large paraboloid to produce a pencil-beam radiation pattern that can be made to sweep the sky like a searchlight, but perhaps the most technically interest-





Left: Fig. 2. Cross-section of a multi-lobed interference pattern set up by the spaced aerial system in Fig. 3.
Right: Fig. 3. Array of stacked dipoles, constituting *one* of the two spaced aerials in an interferometric radio telescope.

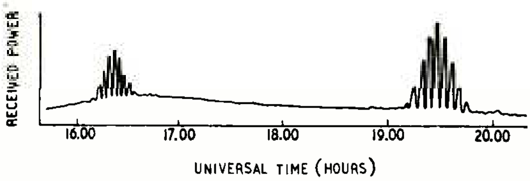
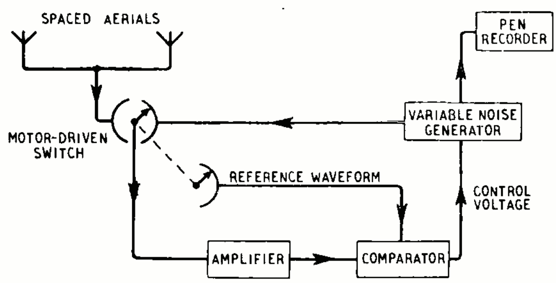


Fig. 4. Part of a record obtained with an interferometric radio telescope, showing two radio stars (in Cygnus and Cassiopeia respectively).

Fig. 5. Block diagram of receiving system used with radio telescopes for measuring small noise powers.



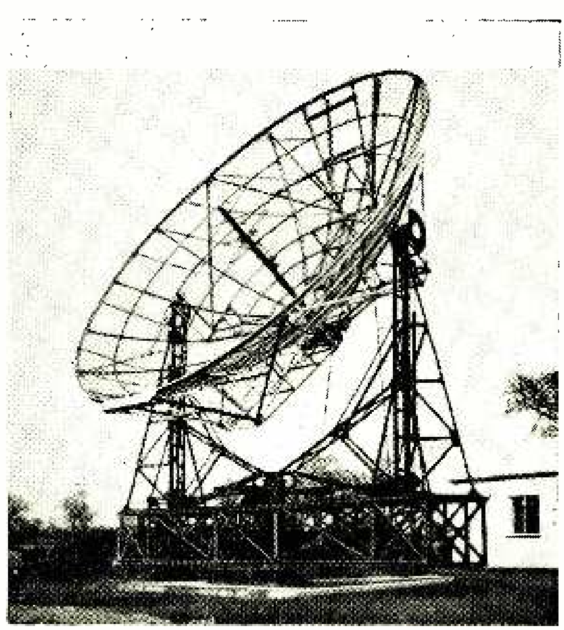
ing is the interferometer type of radio telescope with which most of the original discoveries were made. The British version was built at Cambridge by a team of Cavendish Laboratory workers under the direction of M. Ryle. It consists of two aerials spaced 110 wavelengths apart on a line running East-West (λ is 3.7m), and these, by virtue of the phase differences caused by the two different path lengths, set up between them a multi-lobed interference pattern as shown in Fig. 2. In the North-South direction this beam extends almost from the North Pole to the equator, but its total width is only about $\pm 1\frac{1}{2}$ degrees and this comprises a group of extremely narrow lobes with sharp minima in between.

Thus, as the earth rotates, the beam is swept flatwise across practically the whole of the Northern hemisphere. In the absence of any localized sources of emission—or when the angular diameter of the source is large compared with the lobe separation—the output remains constant or gives only slow variations, but when the envelope is swept across a radio source of sufficiently small diameter the output shows a periodic variation corresponding exactly to the maxima and minima of the interference pattern. A typical record of two such intense sources plotted against time is shown in Fig. 4. It will be seen that the central peak, corresponding to the central lobe of the interference pattern, indicates with great accuracy at what time the centre of the radio star was passed, and from this the right ascension of the star (or "longitude" in the celestial sphere) can be found. The declination (or "latitude") of the star is obtained from the rate of change of path difference to the two aerials. With radio stars near the Pole Star this is slow and tends to spread out the maxima and minima on Fig. 4, whereas with radio stars low down near the equator it is fast and tends to bunch them up together. The declination of the star can therefore be calculated from the time interval between two successive minima on the chart.

Another interesting measurement is the angle subtended by the radio star—from which its diameter can afterwards be calculated. This is obtained from the ratio of the minima to the maxima in Fig. 4, for the "depth" of the minima is really a measure of the smallness of the source. (A large source, subtending an angle greater than about half a degree, will be received by more than one lobe, and will show no maxima and minima.)

Detecting and measuring the signals from radio stars is no easy matter, for they are infinitesimally small. Even with high-gain parabolic or stacked aerials as in Figs. 1 and 3, they are still only about one-thousandth of the noise level of the receiving apparatus! On the face of it the task would seem to be impossible. The method adopted, however, avoids the necessity for taking absolute measurements from the output of the receiver. A local noise generator is continuously and automatically adjusted so that its power output is always equal to that of the aerial, and it is from this that the measurements are made. The arrangement is shown in Fig. 5. One advantage of such a system lies in the nature of the noise generator itself, which consists of a temperature-limited diode working into a resistance load. Since the noise power produced by this arrangement is in direct proportion to the current flowing through the diode, it is only necessary to measure this current with a conventional pen recorder and the result (e.g., Fig. 4) will be a record of the noise power in the aerial. For keeping the noise generator in equilibrium with the aerial, a motor-driven switch samples each in turn and feeds the result into an amplifier; then, if the powers are not equal, the output of the amplifier will contain a waveform at the sampling frequency whose amplitude is a measure of the unbalance. This is selected by a filter and compared with a reference waveform (generated by the switch-motor shaft), and the resulting "error signal" is used to control the noise generator towards equality. It will be noted that the system is independent of the gain and frequency response of

Steerable paraboloid used as a radio telescope at Jodrell Bank Experimental Station. The dipoles at the focus can be changed for working at different frequencies.



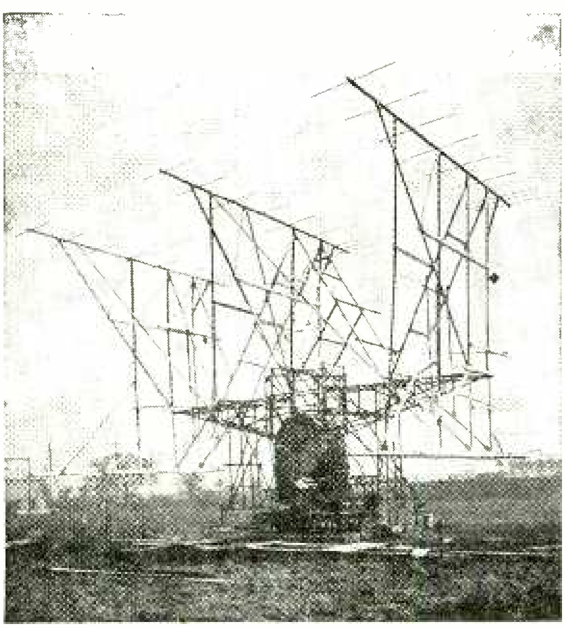
the amplifier, and the sampling frequency is sufficiently fast to prevent fluctuations in gain from upsetting the comparison.

Using such methods, the Cambridge workers have discovered and plotted about 50 radio stars in the Northern hemisphere, while the Australians have accounted for a similar number in the Southern hemisphere. It seems likely that these hundred or so are the most intense of a large number of radio stars distributed throughout the galaxy in a similar manner to the distribution of visual stars. So radio astronomy may well provide a further means of studying the actual structure of the galaxy, especially those parts which are for ever obscured from view by large clouds of interstellar dust. Nobody knows what radio stars are, but the most probable suggestion is that they are normal stars in the process of formation, and that this is responsible for the generation of electromagnetic waves. At the Jodrell Bank Experimental Station of the University of Manchester, workers are using the pencil-beam technique with a huge 218-ft paraboloid, and one of their principal discoveries has been a radio source in Andromeda—a galaxy outside our own and 750,000 light-years away!

Similar techniques are being applied to the study of the sun and sunspots, and to finding the polarization of the received waves. Another interesting subject is the "twinkling" of the radio stars. Since the effect is caused partly by refractive disturbances in the ionosphere (as well as by fluctuations at the source), radio astronomy is providing a valuable means of studying this region—and it has the advantage over radar that the waves are coming right through instead of being merely reflected from the bottom surface.

Another interesting branch of radio astronomy is the study of meteors, or shooting stars, and here radar comes into the picture as a means of determining such factors as range, velocity and direction. To an outsider this work may seem of little practical value, but in the world of astronomy the radar observations

Fig. 6. Radar aerial array mounted on a searchlight, for meteor observations at Jodrell Bank. Each radiator is a folded dipole with six directors and a reflector.



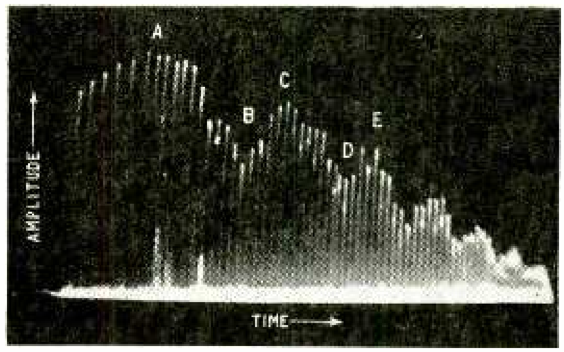
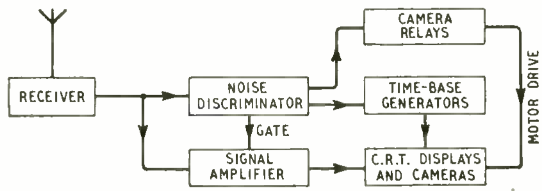


Fig. 7. Successive radar pulses returned from the meteor trail as it crosses the radar beam. Transmitter p.r.f.=1,000 per sec; time-base=0.1 sec; meteor velocity=34 km/sec.

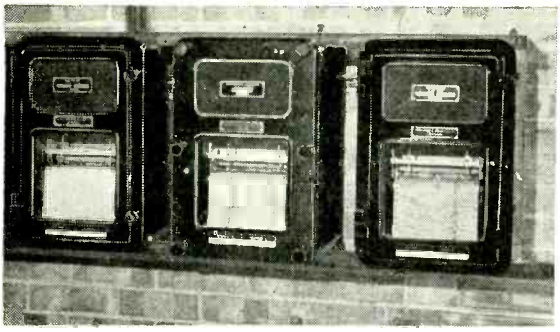
Fig. 8. Block diagram of automatic meteor recorder.



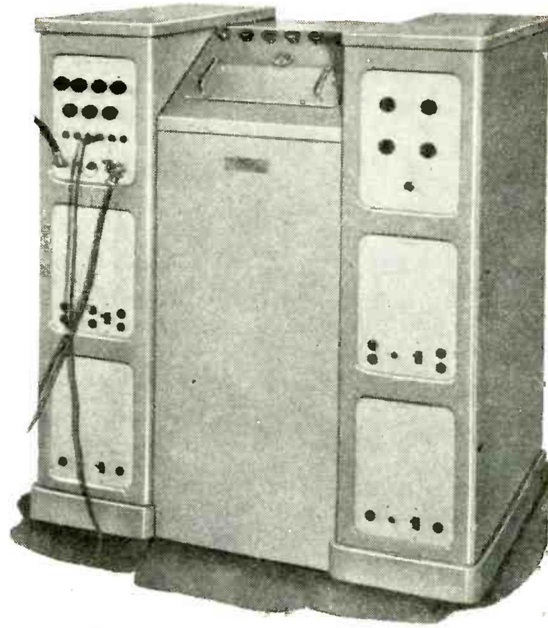
have already provided much valuable information that could never be obtained visually, and have settled at least one age-old controversy. Briefly, there have been two hotly opposed schools of thought on the origin of the meteors, one saying that they are confined to orbits in the solar system and the other that they are visitors from interstellar space. The vital information required to clinch this argument is a knowledge of the meteor velocities, and various attempts have been made to measure them optically—not, however, with very much success.

Although the meteors are actually about the size of a pin-head and enter our atmosphere at somewhere in the region of 100,000 m.p.h., their rapid burning-up leaves behind an ionized trail of up to six miles in length, and this makes a very effective reflector of radio waves. J. S. Hey, a pioneer in all branches of radio astronomy, first used radar in 1946, and his method was to take two spaced observations on a meteor, measure the time interval and so calculate the velocity, but this did not lead to very conclusive results. In 1948, however, a new and interesting method was brought forward by workers at the Jodrell Bank Experimental Station, under the direction of A. C. B. Lovell, and this has led to the construction of a recording apparatus which is automatically triggered by the meteors themselves, whenever they arrive, and leaves all the data necessary for velocity calculations recorded on films.

An essential of this new method is that the meteor trails shall form across the radar beam at right angles, and for this reason the Yagi aerials are generally "aimed" horizontally (Fig. 6) to encounter meteors falling vertically. With the aid of a slow single-stroke time-base the first fifty or sixty echoes from the trail are displayed in a line and the result is as shown in Fig. 7. Now the periodic variation in amplitude here is caused by phase changes resulting from different echo-path lengths as the meteor extends its trail across the radar beam. As the meteor passes the normal of the radar beam, the echoes rise to a maximum A,



Above: Group of pen recorders measuring various radio sources at Cambridge.



Right: Automatic meteor recorder for making a continuous photographic record of two c.r.t. displays. The camera is underneath the sloping panel and can be lifted out.

but it comes next to a point where the echoes from its trail will be returning down a path that is *one half wavelength longer* than the right-angled path or normal. The new echoes will therefore be 180 deg out of phase and will tend to cancel the previous ones, thereby producing a minimum at B. Similarly at C, D and E, so that the time intervals measured between AB, BC, etc., have only to be associated with the corresponding distance intervals (between the "half-wave path difference" points) to give the velocity of the meteor. These distances are obtained by continuously measuring the range on another c.r.t. time-base and, with a knowledge of the wavelength, forming triangular problems in which they are the unknown side. In practice, a fairly simple formula gives the velocity direct from the measured data.

The automatic recording apparatus, therefore, contains two time-base displays fitted with cameras: a single-stroke one (0.1 sec)—triggered by the meteor echoes themselves—for producing records as in Fig. 7, and a faster one (7 millisec)—showing the first few echoes in relation to the transmitter pulse—for recording ranges. Fig. 8 shows the essentials of the equipment. Echo pulses from the receiver (a conventional superhet) pass into a discriminator which separates genuine echoes from random noise impulses by virtue of the fact that the latter are generally of much shorter duration than the 8-16μsec radar pulses. It therefore works as a "gate" on the signal amplifier, and only allows the genuine echoes through to the c.r.t. display—where they are immediately photographed. In addition, the discriminator serves to trigger the time-bases of the displays upon arrival of a meteor—and to actuate a relay system which starts the camera motor and blanks out the c.r.t. trace until the next film frame is in position. There is also a suppression system, of course, to render the receiving equipment inoperative during a transmitter pulse.

With the aid of such apparatus, the Jodrell Bank workers have made a number of remarkable discoveries. First of all, they have settled the astronomical argument in favour of those who believe that the meteors originate in the solar system. Then they have found that the sporadic shooting stars seen at night are not the only ones, but that vast showers occur in the day-time—when, of course, radar is the only means of observation. In fact, they estimate that some 8,000 million meteors enter our atmosphere every day. As to the origin of the meteors, the observations seem to indicate that the night-time showers are caused by this earth passing through the trails of comets, and this was strikingly demonstrated in 1946 when the Giacobini-Zinner comet passed within 15 days of us (a very close shave, astronomically speaking!) and the recorded meteoric activity went up about 5,000 times. The day-time showers, however, do not appear to be associated with comets, and it is possible that they are actually debris produced by disintegration of some of the minor planets.

South Bank Radio Telescope

The radio telescope at the South Bank Exhibition is being used to detect both solar and galactic noise and this, after amplification, is presented to the public in visual and aural form in the Dome of Discovery. The aerial on the Shot-tower (a wide-band folded dipole with a 30-ft paraboloid) is swept across the sources of emission by means of a remotely controlled gun mounting and, at the same time, the resultant variations of signal level are shown on a pen recorder and reproduced on a loudspeaker.

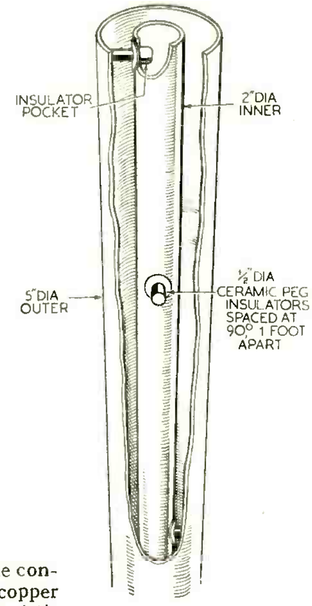
At the bottom of the Shot-tower and connected to the aerial by coaxial cable is the receiving equipment. This, however, does not utilize the kind of system shown in Fig. 5—merely a 120-Mc/s superhet of high sensitivity and stability and low noise level (makers, Leland Instruments). An important part of it is the low-noise pre-amplifier, which has a 6AK5, triode-connected and neutralized, coupled in cascode to a single earthed-grid section of an ECC91 double triode, the third stage being another earthed-grid ECC91 section (see *Proc. I.R.E.*, June, 1948, page 700). From here the signals are fed to the receiver proper, the output of which divides into two channels, the first passing via a filter to a d.c. amplifier and the pen recorder and the second going through an a.f. amplifier to the loudspeaker. Stabilized h.t. supplies are used, while the valve heaters are supplied by a battery of secondary cells which are charged at the same rate as the current is being consumed.

Wrotham Aerial System

(Concluded from page 214 of the previous issue)

2.—The Main Transmission Line and the A.M./F.M. Combining Filter

By C. GILLAM *



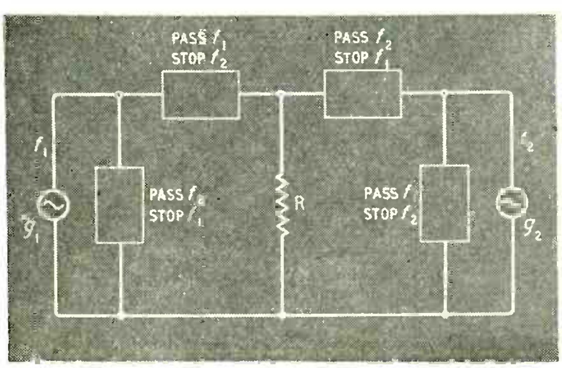
The main transmission line consists of two concentric copper tubes with a characteristic impedance of 51.5 ohms. The spacers are ½-in dia Frequentite rods.

It was explained in the first part of this article how a slot radiates and how a number of slots can be arranged to produce a high gain omni-directional radiator; also, the problems involved in distributing r.f. power to a multiple-slot radiator were discussed. In this part, the transmission line which conveys r.f. power to the distribution system is described and an explanation is given of the method adopted at Wrotham to enable an f.m. and an a.m. transmission to be radiated simultaneously from the single aerial system

THE main transmission line is of the same general design as that used at Sutton Coldfield. It has an outer conductor of copper tube with an internal diameter of 5in and an inner conductor of copper tube with an external diameter of 2.128in, giving a characteristic impedance of about 51.5 ohms. The spacers are ½-in diameter Frequentite rods inserted radially in pockets let into the inner conductor; there is one such rod every foot of length, successive rods being shifted relatively 90 deg around the inner conductor. Because of the rather high frequency, very great care was needed to match out all impedance discontinuities at angles, expansion joints, etc., but eventually the standing-wave ratio due to reflections in the line itself when terminated in its characteristic impedance was less than 1.03 over the whole band from 87.5 Mc/s to 95 Mc/s. The measured attenuation of the line is 0.65 db at a frequency of 95 Mc/s. Due to site exigencies, the main transmission line has to follow a rather circuitous route on the ground, so that although the height to the centre of the slot system is only 405ft the total length of the line is about 727ft. The measured attenuation thus corresponds to an average attenuation factor of 0.09 db per 100ft of line including all angles, expansion joints, etc., which is very close to the theoretical figure for a plain copper line with no insulation losses.

The standing-wave ratio measured at the input end of the main transmission line when terminated by the complete distribution feeder system and slot radiator was less than 1.1 over each of the two ranges. This result is interesting, since apparently the standing-wave ratio of the distribution feeder system and radiator is not degraded by the interposition of the transmission line. In fact this is not so, and the effect is accounted for by the attenuation in the main transmission line; see Appendix II for a further explanation.

Fig. 6. Principle of the combining filter, rectangles represent the lumped reactance structures.



The object of this filter is to enable two separate transmitters, working on different frequencies, to deliver their power into the common load which consists of the main transmission line terminated by the slot radiator. It is necessary that each transmitter should " see " a resistive load of the correct value, and that to avoid cross-modulation a negligible proportion of the output power of either transmitter should reach the output terminals of the other. The problem is rather similar to the " diplexing " of vision and sound transmissions at Sutton Coldfield, but the solution adopted there, involving a relatively simple balanced bridge " diplexer," also required two transmission lines from the transmitter hall as well as a load divisible into two equal parts and susceptible to feeding in parallel or push-pull.

At Wrotham the load cannot be divided in this way, but fortunately the band-width required for each transmission is comparatively narrow, and it is possible to use a " notch " type filter. The principle of operation of such a filter is shown in Fig. 6, where

* Marconi's Wireless Telegraph Company

g_1 and g_2 are generators and the rectangles represent lumped reactance structures with the impedance characteristics indicated. If these reactances were absolutely lossless, they could be made to exhibit an infinite impedance in the " stop " band, and a zero impedance in the " pass " band. In that case, it would have been sufficient to employ series elements only. However, practical components are such that in the " stop " band the impedance is not great enough to prevent a current flowing which would be large enough to cause appreciable interference. Accordingly a shunt element is used which has characteristics opposite to those of the series element. The effect is rather similar to that of an ordinary smoothing circuit at the output of a rectifier, where series high reactances and shunt low reactances are used alternately in order to prevent alternating currents reaching the d.c. circuits. Figure 7 shows a practical realization of the filter, again using lumped reactance components. Here the L_1C_1 circuits anti-resonate at frequency f_2, and the L_2C_3 circuits anti-resonate at frequency f_1, where f_2 is the higher frequency. At f_1 the L_1C_1 combination is off tune, and appears as an inductive reactance, which resonates with C_2, the whole appearing as a very low resistance. Similarly at f_2 the L_2C_3 combination is off tune, but since f_2 is above the anti-resonant frequency it appears as a capacitive reactance which resonates with the inductance L_4. Figs. 8 and 9 explain the action of the filter at the two frequencies separately.

The reason for describing a circuit of this type as a notch filter is clear from Fig. 10, which shows how the current in R varies when generator g_1 is replaced by a variable frequency generator of constant e.m.f. with some internal impedance. As the frequency increases from zero, the current rises to a peak at f_1 the " pass " frequency, falls in a sharp " notch " at the " stop " frequency f_2, and then slowly climbs again towards the maximum value. If the same characteristic were measured on the g_2 side, the result would be rather similar, except that the current would be large at low frequencies, and would tend to zero at frequencies above the " stop " and " pass " values.

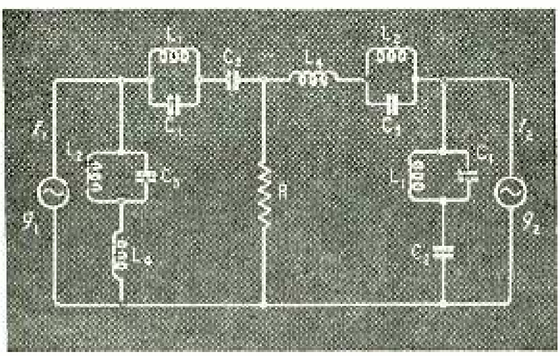


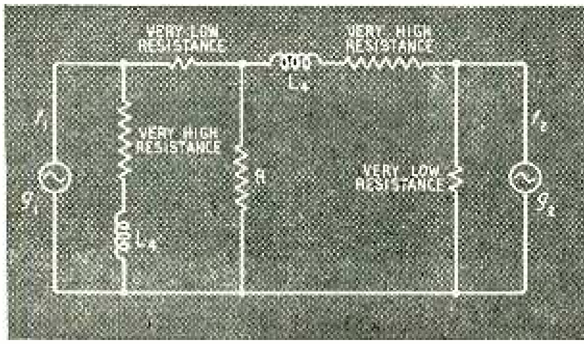
Fig. 7. Practical form of a combining filter including series and shunt elements and using lumped reactance components.

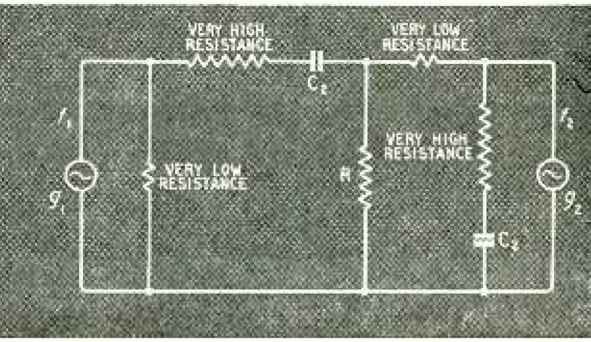
Below Left : Fig. 8. Combining filter as shown in Fig. 7 as it appears to transmitting frequency f_1. Below Right : Fig. 9. The filter of Fig. 7 as it appears to the alternative frequency f_2.

Transmission Line Filter

It is readily possible to construct a filter which operates in a very similar manner, but in which transmission line elements are used in place of inductors and capacitors and the Wrotham combining filter is of this type. Consider Fig. 11 where AB is a twin-wire transmission line. Two stubs, a short-circuited one CD and an open-circuited one CE are shunted across the line at C. CD is half a wavelength long at f_1, and consequently its input impedance is equal to its termination impedance, namely zero. That is to say, at f_1 CD behaves as if there were a short-circuit across the line at C, and hence any energy at frequency f_1 reaching the junction C is completely reflected towards its source. Frequency f_2 is a little higher than f_1, so that at f_2 CD is greater than a half wavelength long. The shorter stub CE makes the total length DCE three-quarters of a wavelength at f_2. Under these circumstances CD looks like an inductive reactance and CE like a capacitive reactance of exactly equal magnitude. The two stubs therefore resonate as a whole and appear at C as a high-resistance shunt. Thus energy at frequency f_2 is not impeded, but a small proportion is abstracted to make good losses in the stubs.

In Fig. 12 there is a similar situation, the thick line AB representing the inner conductor of a co-axial transmission line. CD and CE are co-axial stubs, and the convention is used here and in subsequent diagrams of a short bar at the end of the stub to indicate a short-circuit, and a small o to indicate an open-circuit. The thin line parallel to AB represents the r.m.s. voltage on the line at frequency f_2, for which the source is somewhere beyond B. Since the line is assumed to be correctly terminated at some point beyond A there is no standing wave on it. At C this voltage is applied to the two stubs, and it sets up on them the voltage standing wave shown. It is to be noted that the maximum amplitude of this standing wave is greater than the r.m.s. main line voltage. Fig. 13 shows what happens to transmission f_1,





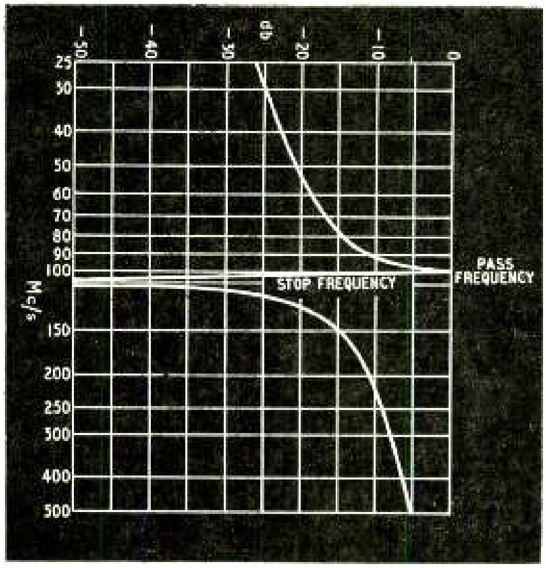
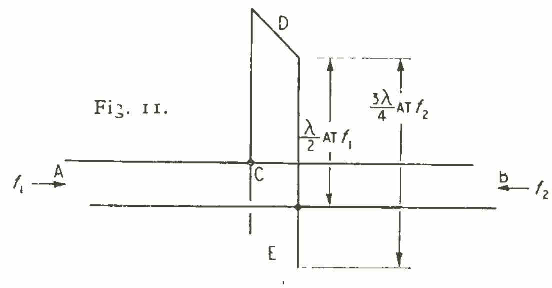
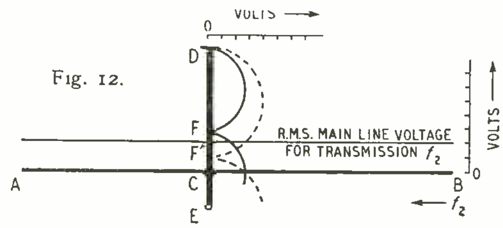
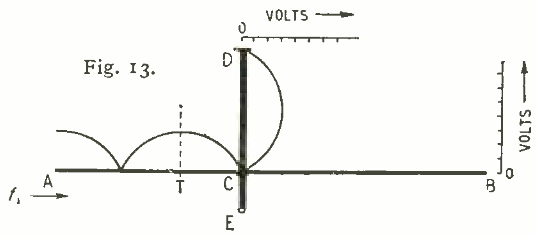


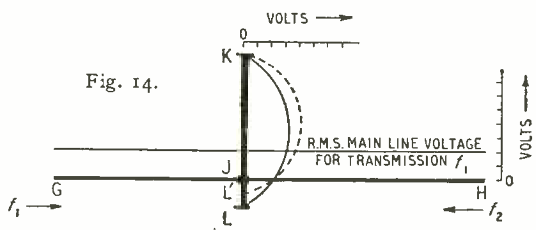
Fig. 10. Curves showing the insertion loss of the combining, or "notch," filter.

Fig. 11. Twin-wire transmission line with one open-circuit and one short-circuit stub. Fig. 12. Similar arrangement as shown in Fig. 11, but for co-axial transmission line and stubs. Fig. 13. The line and stubs of Fig. 12 as it appears to frequency f_1 for which the stub DC$=\lambda/2$. Fig. 14. Two short-circuited co-axial stubs to block f_2, for which KJ$=\lambda/2$ and to pass f_1, for which KL$=\lambda/2$.







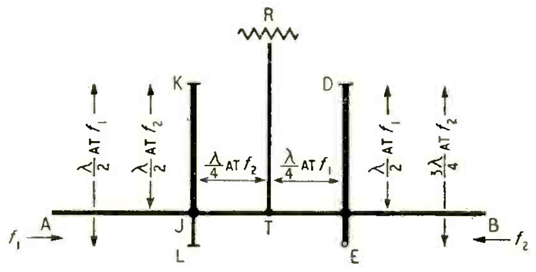


arriving from the direction of A; the "virtual" short-circuit at C sets up a standing wave on the main line, which is a continuation of that on the stub CD, with voltage nodes every half wavelength back from C. In Fig. 14 there is shown another section of line GH with two short-circuited stubs, JK and JL shunted across it at J. JK is an exact half-wavelength at frequency f_2, and it behaves for that frequency exactly as does CD in Fig. 13 for f_1. At the latter frequency JK is less than a half wavelength long, and it is built out to a half wavelength by the short stub JL. The thin line parallel to GH on Fig. 14 now represents the r.m.s. voltage at the frequency f_1 from a source to the left of G, the line being assumed correctly terminated to the right of H. An exact half-wave standing wave is set up on LJK and again the maximum value is greater than the r.m.s. main line voltage. As in the previous case for f_2, the f_1 transmission is now unimpeded but there is a small energy loss in the stubs.

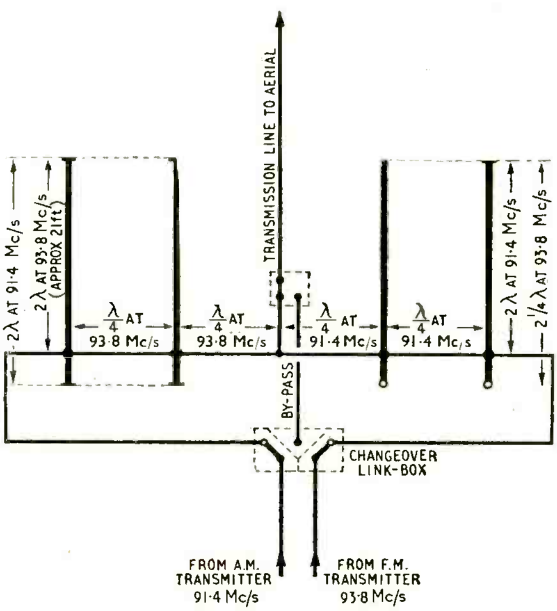
Before leaving Figs. 12 and 14 it is necessary to consider the effect of the amount of the frequency difference between f_1 and f_2. In Fig. 12 the half wavelength at frequency f_2 extends on DC from D to F, while there is a quarter wavelength from F through C to E. If f_2 had been closer to f_1, F would have been nearer to C at F′ so that F′C would have been a smaller part of the wavelength. The voltage at C would still have been the same, but the standing wave would have had a greater amplitude, as indicated by the broken curve. This greater amplitude would have involved a greater power loss in the stubs. In Fig. 14 the situation would have been rather similar, since for a smaller frequency difference JL would have been shorter, say JL′ and again the standing wave would have had a greater amplitude. Circumstances may be such that a stub designed on these lines is impracticable, either because of the high voltage of the standing wave, or because the stub abstracts too much power from the transmission, or just because the losses in the stub are so great that the resultant heat is an embarrassment. All of these difficulties are eased by making the short-circuited stub two, three or even more half wavelengths long at the "stop" frequency, instead of only one half wavelength as in Fig. 13. The effect of doing this is to multiply the length FC in Fig. 12 or JL in Fig. 14 by the same factor, so that the standing-wave amplitude is equal to the line voltage at a point nearer its maximum, and in consequence the maximum itself is less. There is, unfortunately, a concomitant disadvantage, since at the "stop" frequency, the virtual short-circuit on the main line is not so good as before, and a small proportion of the energy gets past it.

On Fig. 13, T is a point on the main line one quarter wavelength at f_1 back towards the f_1 generator from the stubs CD and CE, and it is therefore at a maximum of the f_1 voltage standing wave. If we were to cut the line at T and measure the impedance looking

Fig. 15. Combining filter with co-axial elements for two transmissions, f_1 and f_2, built up with the stubs of Figs. 12 and 13.



Below : Fig. 16. The complete combining filter as used at Wrotham constructed from co-axial transmission line elements.



toward C at the frequency f_1, its value would be very high. The virtual short-circuit at C appears at T as a virtual open-circuit. A branch line can be connected at T and if it has a correct termination, practically all the energy at frequency f_1 arriving at T will pass into this branch line, and only a very small proportion will be transmitted towards C. It is clear that we now have a transmission line system which behaves in an analogous manner to the lumped reactance networks of Fig. 7. A complete filter on these lines is shown in Fig. 15, which makes use of one pair of stubs from Fig. 12 and one pair from Fig. 14. This form of filter would be quite satisfactory provided that f_1 and f_2 were not too close together.

At Wrotham, the two transmissions have frequencies which differ by only about two and a half per cent, the a.m. transmission being at 91.4Mc/s, and the f.m. transmission at 93.8 Mc/s. In order to reduce the voltages and the losses in the stubs to an acceptable value at the "pass" transmission frequency, it has been necessary to make them two wavelengths long at the "stop" frequency. Then, in order to ensure the specified degree of separation between the two transmissions, a further set of stubs has been put on each line at points a quarter of a wavelength nearer to the transmitters (Fig. 16). These additional stubs also have the effect of compensating for the impedance discontinuity introduced by the first stubs, so that in the pass-band the filter presents only a very low standing-wave ratio to the two transmitters. In fact the measured standing-wave ratio on the a.m. branch is better than 1.03, and on the f.m. branch it is indistinguishable from unity. The insertion loss of the complete filter measured from one transmitter branch to the other with the output transmission line connected is considerably in excess of 60 db, this being the limit which could be measured with the available apparatus. This means that of the 25 kW of the f.m. transmission, considerably less than 25 milliwatts reach the a.m. transmitter. For both transmissions the insertion loss in the pass-band is of the order of 0.25 db, which corresponds to a loss of about 1,400 watts from the f.m. transmission, and a little less from the a.m. transmission. This power appears as heat in the stubs, and in order to keep their temperature to a reasonable value, air is continuously blown through them.

The filter is built up entirely from standard 5-in transmission line tubes and junction boxes. Because of the very high voltages on the stubs the inner conductors of these are supported only at points very near to the voltage nodes, and these supports are large conical Frequelex insulators fitted in special cast boxes. A by-pass with link boxes is installed, so that the transmission line from either transmitter can be connected directly to the aerial transmission line with the combining filter out of circuit.

Editorial Note

With reference to the footnote on page 211 in the June issue, it should be noted that the general design of the slotted cylindrical aerial and the development of the wide-band folded slots resulted from original work by the B.B.C. Research Department. The slot feed and reactance compensation system is the subject of a B.B.C. patent application No. 677/49.

APPENDIX II

Effect of Line Attenuation on Standing-wave Ratio

Saying that a particular load produces a standing wave on a transmission line means that it causes a proportion of the forward wave reaching the load to be reflected back towards its source. Now the forward wave in travelling from the source experiences attenuation, that is, its amplitude is greater at the input end of the line than at the load. The reflected wave, travelling backward, has a greater amplitude at the load (which behaves as its source) than at the input end of the line. So the ratio of reflected wave to forward wave is smaller at the input end than at the load, and the standing-wave ratio is correspondingly reduced. The reduction is readily calculated, as follows.

Let the line attenuation be α db, then the corresponding voltage amplitude ratio is $m = 1/\text{antilog}_{10}\frac{\alpha}{20}$ (where $m<1$).

If the standing-wave ratio at the load is S_t, ($S_t>1$), then the reflection factor at the load is $r_t = (S_t - 1)/(S_t + 1)$. That is, S_t is accounted for by a forward wave of unity amplitude, and a backward wave of amplitude r_t.

Because of the line attenuation, the forward wave must have an amplitude greater than unity at its input, actually $1/m$. Similarly the backward wave is attenuated and its amplitude becomes mr_t. Finally, the input standing-wave ratio is :—

$$S_i = \frac{1/m + mr_t}{1/m - mr_t} = \frac{S_t(1+m^2)+1-m^2}{S_t(1-m^2)+1+m^2}$$

Recording on Tape

Some of the More Prevalent Causes of Indifferent Results

By R. W. LOWDEN *

THE general theory and technique of magnetic recording have already been covered in this journal[1], and it is proposed in this article to give some further practical hints which may save the experimenter a few headaches and disappointments.

The layout of a tape recording machine will depend essentially on three factors: performance, size and cost. The desired performance puts immediately a lower limit to the size of the machine and its cost. If a frequency response of up to 7,000 c/s is required it will be found necessary to run the tape at a speed of at least 7½ inches per second. If, however, the tape is run at 15 inches per second it will be found to be much easier to achieve a flat response up to 7,000 c/s with a substantially good response up to at least 10,000 or 12,000 c/s, but both the cost and volume of the recording medium used will be immediately doubled.

One of the most important things when contemplating the design of a tape recorder is to have a clear idea of the performance required in terms of the importance to be given to the three vital factors of frequency response, signal-to-noise ratio, and distortion. These are all very closely interdependent.

All too often a wide frequency response is made the prime aim, and in spite of its achievement the results are found to be very disappointing. It is generally better to restrict the range at the upper end and give more weight to the other two factors.

Experimenters in this fascinating branch of sound recording fall into three classes: first, those who will wish to make the whole recorder from start to finish and have a good knowledge of mechanics and electronics; second, those who have not the facilities or skill for mechanical construction but can cope with the electronics; and third, those who will purchase a complete commercial machine and confine their experiments to the actual art of recording.

To the first class, it is suggested that a careful study of the mechanical principles involved is just as important as a thorough understanding of the electronic requirements; indeed, the two are interdependent, and time spent in really knowledgeable planning will pay handsome dividends in the overall results achieved. The main decisions to be made at this stage are the maximum continuous playing time and the tape speed or speeds, as both these affect the spool size, motor and final capstan speeds and capstan diameter, as well as the general layout and overall size of the tape deck. Consideration must also be given to such things as braking, location of heads, pressure pads and capstan jockey wheel actuating mechanisms, and also any interlocking devices which may be thought necessary. Remember also that the tape speed will affect not only the frequency response but also the equalization required for correct playback.

Hum

At the low-frequency end of the scale hum is the biggest problem, since, assuming the conventional constant-current recording characteristic, the signal output from the tape is of a comparatively low order. Great care is therefore necessary if a signal-to-hum ratio of better than, say, 45db is to be achieved. It is of great assistance to use a transformer between the head and the first valve of the playback amplifier, in order to lift the signal well above the amplifier hum and noise. This arrangement will, of course, give no improvement in the hum induced into the head, but this is a matter of careful screening and correct positioning of components.

It must be remembered that the transformer has to match an inductance and not a resistance, and in deciding on the optimum ratio one must take into account the fact that the impedance from which it is working varies with frequency.

To assist in the reduction of hum it is helpful if the hum-producing and hum-sensitive components can be orientated so that their windings are in the most favourable position for low hum pick-up. In this connection the magnetic hum pick-up in the first valve cannot be ignored.

If it is desired to work the first valve's heater from a.c. supply a type with a bifilar heater should be chosen, such as the EF37A or the EF40, the latter being particularly good for this position. A clear distinction should be made, however, between orientating components for minimum hum pick-up or generation, and orientation to pick up such a value of hum as to be in anti-phase with that induced in other parts of the circuit, i.e., "hum bucking."

Whilst this "hum bucking" may be a satisfactory solution from the amateur's point of view when a single model only is being constructed, it must be avoided in any large-scale production, as its effect is by no means constant and, moreover, it is usually only possible to balance out the fundamental, leaving the much more objectional harmonics still present.

Motors can also be a source of large hum generation due to leakage from the field. Normally a special lamination and winding arrangement is necessary to

* Hon. Sec., The British Sound Recording Association.

[1] "Magnetic Recording," G. L. Ashman, August 1944.
"The German Magnetophon," R. A. Power, June 1946.
"Magnetic Recording Technique," D. Roe, October 1949.
"Magnetic Recording Tape," H. G. M. Spratt, March and April 1951.

cut this down. Again, with squirrel-cage asynchronous motors, rotor ripple may be objectionable if the head screening is insufficient. Because of the slip frequency in the rotor this sometimes causes a hunting note as it is obviously not exactly in phase with the supply mains.

"Wow and Flutter"

In the actual construction of the whole tape transport system it cannot be too emphatically stressed that only the best possible standard of workmanship will suffice. Anything short of this will produce "wow" and "flutter" to a marked degree. It is not a simple matter to transport a tape *at a constant linear speed* across the recording and reproducing heads, and however good may be the "electronics" they will not make up for poor workmanship in this direction.

On the question of tape drive, "wow" is the great enemy, and getting it down to very small proportions is an extremely difficult task. Here again there is a choice between several evils. Low-speed, large-diameter flywheels are good from the "flutter" point of view, but are inclined to have cyclic "wows" at flywheel speed, i.e., low frequency. High-speed, small-diameter drive systems overcome this fault, but are liable to "flutter" symptoms at around 25 c/s unless they are very accurately made.

Normally it is necessary, before assembly, to grind all essential peripheries on their own spindles and bearing assemblies. It must also be remembered that the tape transport mechanism has, first, to provide a constant linear speed drive for the recording and reproducing functions and, second, to provide a high-speed drive in both the forward and rewind direction for ease in editing the tape. The first function requires adequate flywheel effect and mechanical filtering to overcome the irregularities in the motor torque caused by "cogging," etc., whilst in the second requirement the flywheel effect should be kept to a minimum to cater for the very rapid change of speed.

On the electronic side, by far the simplest approach is to have two separate channels for the record and playback operations, feeding into separate heads, with a third head fed from an oscillator for purposes of erasing. This method will avoid the complicated switching circuits which must be used with a combined record-reproduce head, and will ease the design from the point of view of screening and general layout of component parts. Another great advantage of the three-head system is that, as reproduction is possible immediately following recording, it is easy to make alterations in the recording characteristic and note the results without the necessity of having to rewind before reproducing. This facility alone is well worth the slight extra expense needed for the second channel. Even when the final characteristic has been decided upon it is valuable to be able to monitor the actual programme without having to rely on the modulation meter as the sole indication of a successful recording, only to find that there is nothing on the tape!

Head design is almost a science in itself. Generally speaking, recording and playback heads should be made from high-permeability nickel-alloy laminations of the thinnest possible cross-section to reduce eddy current losses, and as much work as possible must be done on them before they are heat treated. Then they must be handled with care and finished by only the lightest grinding and polishing.

In order to arrive at a very narrow effective magnetic gap, approaching that of the physical gap, it is necessary to grind and polish the faces very carefully. When one gets down to the order of 0.00025 in physical, an effective gap of 0.00033 in can usually be obtained by hand honing of the butting faces. The depth of the butting faces to be left can be approximately 0.04 in, which will allow a good running life before serious change of the characteristics of the head sets in.

With narrow gaps of this order, however, intimate contact must be maintained between the tape and the head. Pressure pads materially assist here, although the pressure must not be too great or wear will be unduly heavy.

In order to cut down the hum introduced into the head, copious screening with Mumetal is desirable, leaving only the smallest possible slit for the entry of the tape. In one well-known make of recorder a Mumetal wing is placed over this gap after the tape has been inserted, to distort the field in this vicinity so as further to reduce hum pick-up.

Heads can be wound of any reasonable impedance, provided that the oscillator and feed arrangements are matched to them. The oscillator itself must have a pure and symmetrical waveform, particularly in respect of second harmonic, as this has the same effect as a direct-current polarizing field, which will give a high background noise. Direct-current components must be eliminated from the head while recording, and where connection is made from the anode of a valve, the isolating capacitor must be of a very high quality.

On the question of the oscillator for erasure; the usual frequency is approximately 45 kc/s and is often obtained by the use of a single 6V6 valve. With care this is quite a satisfactory arrangement, but there is no doubt whatever that a much better waveform can be obtained by the use of a small oscillator valve feeding a small power valve, both valves working well within their particular limits. If the waveform of the self-excited 6V6 valve is not pure, and it very rarely is, then the tape will leave the erase head with a small amount of background noise, as mentioned above. The use of a power valve with a degree of control of output will ensure a really clean erasure and a more flexible control which will be found useful when experimenting with tapes requiring a higher erasing current.

Recording Characteristic

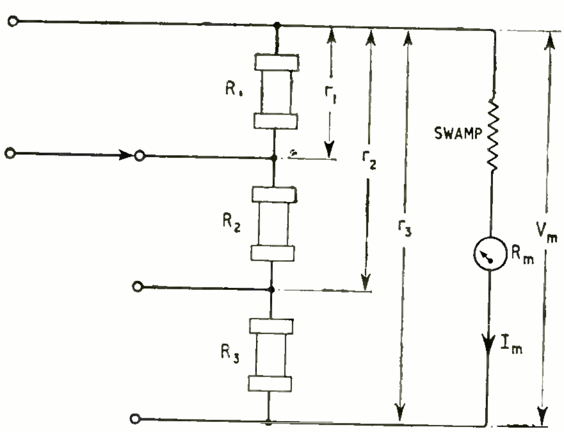
Regarding recording characteristic, here again the end use of the equipment determines largely what can be done. Where only speech is to be used advantage can be taken of a weighted frequency response, e.g., the high frequency end can be given some pre-emphasis before recording. This is, however, not always possible in cases where the recorder is to be used for noise analysis, where the same spectrum distribution does not hold good. In the former case, however, a 6 db pre-emphasis at 10,000 c/s, based on 1,000 c/s, can be safely adopted, as some of this will be employed in overcoming the head losses, which increase with frequency. It is generally preferable to adopt a constant-current characteristic, with sufficient pre-emphasis to overcome head losses in the recording chain, and to arrange for any bass- and treble-tilting circuits to appear in the reproducing amplifier, where they can be usefully employed in compensating for room acoustics, personal preference, etc.

During the past six months the constructor has been better looked after than previously as regards availability of suitable tape for recording at the lower speeds of $7\frac{1}{2}$ and $3\frac{3}{4}$ inches per second. At least three makes of high-coercivity taps are available in this country at around 35s per reel of 1,200 ft. It is necessary to warn the user that he should look carefully for any tape which has a number of pieces joined together to make up the usual 1,200 ft reel. In some cases, where faulty tape has escaped the notice of inspection departments, the difference in response obtained on the various pieces in one reel have varied by as much as 3 db and the user should make sure that he is not being led astray in his experiments by the use of such tapes.

In conclusion the author acknowledges gratefully the collaboration of E. H. Niblett, E. B. Angold and J. W. Clarke in the preparation of this article.

Universal Meter Shunt

Avoiding Switch Contact Errors in Multi-range Instruments



Connections of a universal shunt.

THE common form of high-resistance universal shunt is very useful with a high-resistance galvanometer, but for permanent use with a low-resistance and low-range milliammeter to extend its range the universal shunt has to be designed to suit the resistance of the individual instrument. The great advantage of the universal shunt in this application is in the avoidance of switch or other contact errors. In this circuit the shunts are permanently connected, preferably by soldered joints, and the external connections made either by terminals or a switch in which any variation in contact resistance makes a small difference to the circuit resistance but none in the instrument circuit.

To eliminate temperature error it is essential for the movement to have a swamp of Eureka or other low-temperature-coefficient wire in series with it. If the milliammeter has no internal shunt it may not have a swamp and this should be added externally: the swamp resistance should be about three times that of the movement.

The calculations are given for a typical case of three ranges, I_1, I_2 and I_3, but the method can be extended as required. I_3 is the lowest range, and it must exceed the range of the instrument, preferably by a factor of not less than 1.5. Thus an instrument of 1 mA range would have its lowest of three ranges 1.5 mA. All the shunts are connected in series and directly across the movement and swamp; thus when the I_1 or highest range is in use the other two shunts act as extra series resistance in the movement circuit. This means that if the terminal volt drop is the standard 0.075-volt (75 mV) the drop across R_1, the shunt corresponding to the range I_1, will exceed this amount. The resistance of the movement and swamp is called R_m, and the current through the movement at full-scale deflection I_m, with V_m as the voltage drop across the movement, R_m. V_m then equals $I_m \times R_m$.

In order to calculate R_1, R_2 and R_3, other subsidiary terms are necessary, r_1, r_2 and r_3, where, as seen in the Figure, $R_1 = r_1$, $R_2 = r_2 - r_1$ and $R_3 = r_3 - r_2$. r_1, r_2 and r_3 are now found from the three expressions—

$$r_1 = \frac{(r_3 + R_m)I_m}{I_1}$$

$$r_2 = \frac{(r_2 + R_m)I_m}{I_2}$$

$$r_3 = \frac{V_m}{I_3 - I_m}$$

The terminal resistances differ from the individual shunt resistances and are :—

$$\text{Range 1, } \frac{R_1(R_2 + R_3 + R_m)}{r_3 + R_m}$$

$$\text{Range 2, } \frac{r_2(R_3 + R_m)}{r_2 + R_3 + R_m}$$

$$\text{Range 3, } \frac{r_3 \times R_m}{r_3 + R_m}$$

The relation between the ranges may be anything required, but in practice it is better to limit the ranges to common factors, such as multiples of 10, for ease of scale reading, or factors of 2 and 5.

E. H. W. B.

"**Radiolocation**" is the title of a booklet issued by the Marconi International Marine Communication Co. to assist navigators in assessing and interpreting radar responses. The major part of the 16-page booklet is devoted to notes on target recognition and explains possible misinterpretations due to land contours, vegetation and beam and pulse distortion. The booklet is obtainable from the Technical Information and Publicity Division, M.I.M.C. Co., Marconi House, Chelmsford, Essex, price 2s 6d.

FURTHER NOTES ON THE

Wireless World Television Receiver

WITH the opening of the Holme Moss television station some changes are needed to the signal- and oscillator-frequency circuits of the *Wireless World* Television Receiver in order to permit its reception. Of the two receiver units described—the straight t.r.f. and the superheterodyne—only the latter is suitable for stations other than London. The reason is, of course, that only the superheterodyne was designed for vestigial-sideband reception.

This superheterodyne was described in *Wireless World* for February and March 1949, and the modifications needed for Sutton Coldfield appeared in August 1949. These modifications comprised mainly a change in the number of turns on the two signal-frequency coils and the oscillator coil. In addition, however, the r.f. intervalve coupling was altered from the double-wound transformer used for London to a single-winding because the former was found unsuitable at the higher frequency of Birmingham. This single-wound coupling is now retained for all new channels.

The circuit diagram of the signal circuits thus still takes the form given in Fig. 1 of the article in the August 1949 issue. The coil windings for the different channels are given in Table 1, in which the previously published details for London and Birmingham are repeated for ready reference.

The formers used are, of course, the same as in the original design and are prepared from ⅜-in paxolin tube. In the case of the oscillator coil polystyrene tube is preferred but this is difficult to obtain and paxolin is a satisfactory alternative. The winding lengths are specified in Table I as well as the turns since the inductance depends on both. No. 36 d.s.c. wire is used for the signal-frequency coils and No. 20 enamelled for the oscillator; in all cases the oscillator coils are close wound.

The aerial coil has for each channel 1½ turns of No. 36 interwound at the earthy end for the aerial coupling and the entry 9 + 9 turns for the London intervalve coil signifies that this is a double-wound transformer, as previously described.

There is one possibility of difficulty arising in the case of Channel 2, Holme Moss, and this is through i.f. harmonic feedback. The usual method of avoiding this is to pick the intermediate frequency so that it does not occur.

It is not possible to find any frequency which avoids the possibility of the effect on all television channels unless the frequency is unusually high. In this receiver the frequency was chosen to avoid the effect on as many channels as possible with a moderately low frequency and the precaution was taken of including very thorough screening in order to prevent the feedback at its source. As a result there should be no trouble; in fact, no trace of it has been evident in tests with a signal generator.

However, if the screening is less perfect than in the original model, or any defects of construction are present which permit feedback to occur, then an interference pattern of diagonal bars may appear on the screen on Channel 2. If such a pattern is found the proper course is to remove the coupling between the input and output circuits which is responsible for it. An alternative is to increase the intermediate frequency by 1 Mc/s. To do this all i.f. coils, both sound and vision, should have 7.5% less turns and all i.f. alignment frequencies should be increased by 1 Mc/s.

Apart altogether from changes for new television channels, experience with the set has indicated a few minor alterations which generally improve the performance and which can, with advantage, be made by any user of the set no matter what station he receives.

It has been found desirable to add a linearity control to the frame time base. Originally, the curvature of the valve characteristic was relied upon to correct for the distortion introduced by the time constant of the output circuit. It has become evident in recent months that this is not completely successful. This may be because of minor changes in the valve characteristic or it may be that more people are using similar, but not identical, alternative valves.

Whatever the precise cause, there is no doubt that compensation by the valve characteristic is now failing increasingly to be sufficient. Fortunately, a very simple remedy exists, and requires the addition of only one extra resistor and capacitor. The relevant

Table I

Channel	Station	Aerial Coil			Intervalve Coil			Oscillator Coil	
		Turns	Length (mm)	Alignment Frequency (Mc/s)	Turns	Length (mm)	Alignment Frequency (Mc/s)	Turns	Frequency
1	Alexandra Palace	12	7.5	45	9+9	7.5	43	15	32
2	Holme Moss	11	7.5	51.5	8	7.5	49	10	38.75
3	—	10	10	57	7	7.5	54	9	43.75
4	Sutton Coldfield	10	13	61.5	6	10	59	8	48.75
5	—	9	13	66.5	5	7.5	64	6	53.75

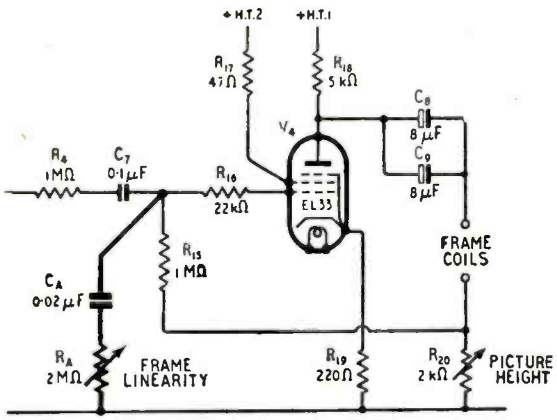


Fig. 1. Output stage of frame time base modified to include an adjustable linearity control. The new components are R_A and C_A.

portion of the frame time-base circuit is shown in Fig. 1 with the original circuit references. The linearity control comprises a 2-MΩ variable resistor R_A in series with a 0.02-μF capacitor C_A.

The adjustment of R_A has a considerable effect on picture height and so it must be carried out in conjunction with the height control R_{20}. It is preferably carried out on a transmission of Test-card C; if it is done on the ordinary test signal preceding the programme the aim should be to adjust for a perfect circle. If R_A is made too low in the course of adjustment the top of the picture will become cramped and may fold over.

Some constructors have found difficulty in obtaining good horizontal linearity, their main trouble being in preventing a vertical white line from appearing towards the left-hand side of the picture. The trouble is mainly one of adjustment, for it is not always realized that the settings of the width and linearity controls are both critical and interdependent. In addition, some constructors do not seem to be aware of the modified damping circuit which appeared in *Wireless World* for April 1949, p. 128. This circuit is usually easier to adjust than the original one.

One possible cause of difficulty lies in resistor tolerances. The chain of damping resistors R_{19}–R_{21} (Fig. 1, July 1947) comprises four 1-kΩ resistors and the variable resistor R_{23} is also of 1 kΩ, the aim being to obtain a total resistance variable from 1 kΩ to 5 kΩ. However, because of resistor tolerances it is possible for small gaps to appear in the range. To avoid this, R_{19}, R_{20} and R_{21} should each be shunted by a resistor of 4.7 kΩ, 1-W rating. This makes each step nominally 0.825 kΩ instead of 1 kΩ and the total range is from 1 kΩ to 4.475 kΩ which is adequate and provides some overlap between steps.

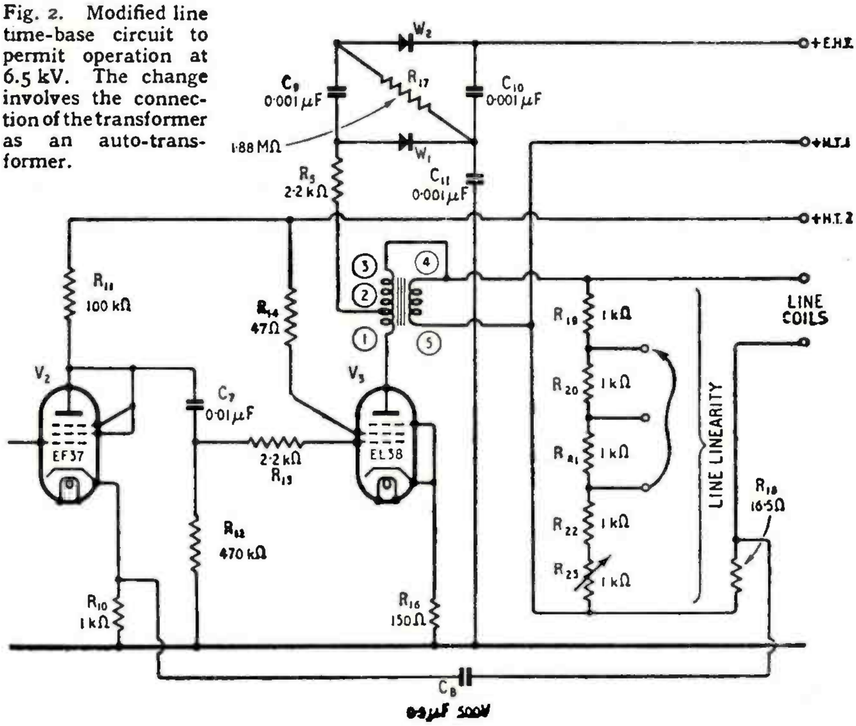
It should be pointed out that this change is desirable only if the optimum setting of the linearity control comes at one extreme end of its travel. If it comes within the range, so that one can pass through an optimum setting on R_{23}, it will not help.

A good many enquiries have been received about the use of this set with a 12-in tube. Such a tube can be used without any modification at all as long as it is of the normal type with a deflection angle of about 50°. However, the brightness obtained at the normal 5 kV existing in this set is below present-day standards. It is not possible to increase this voltage without also modifying the time base because a higher voltage requires an increase of scanning current.

However, a simple modification does permit operation at about 6.5 kV with full scan and the modified circuit is shown in Fig. 2. The change comprises essentially the connection of the output transformer as an auto-transformer so that the effective ratio becomes 5 : 1 instead of 4 : 1.

There is an increase of current in the deflector coil and due to this and to the higher ratio the e.h.t. voltage is increased to about 6.5 kV. Because of this the voltage ratings of C_9, C_{10}, C_{11}, W_1 and W_2 should be increased from 2.5 kV working to about 3.5 kV. The arrangement has actually been tried out with the original components without any trouble but their lives would almost certainly be reduced by such operation. Anyone who is using the normal arrangement and wishes to adopt the new one might well feel inclined to do so with the old components and to employ them until they fail, but anyone starting afresh should unquestionably use the proper ratings. The old parts might work for months or years under these

Fig. 2. Modified line time-base circuit to permit operation at 6.5 kV. The change involves the connection of the transformer as an auto-transformer.



over-run conditions or they might fail in a matter of days.

It is to be noted that the deflector coil and damping components are all at full h.t. potential, so it should be remembered that components which were previously at chassis potential are now 480 V above chassis. The feedback circuit has been modified because of this and now includes a 0.5-μF capacitor C_B.

The damping circuit is now virtually the modified one of April 1949, but the variable capacitor of that circuit is absent because with the higher transformer ratio the inherent circuit capacitance is more important and additional capacitance is not permissible. All adjustments are carried out exactly as in the original circuit.

This modification for operation at an increased e.h.t. voltage is put forward with some hesitation because it has been tried out on one set only and there is the possibility that through an accumulation of component tolerances in one direction the fly-back time may sometimes be rather slow, in which case the left-hand side of the picture will appear folded over. If this does occur there is little that can be done about it. The modification should, therefore, be regarded as experimental only.

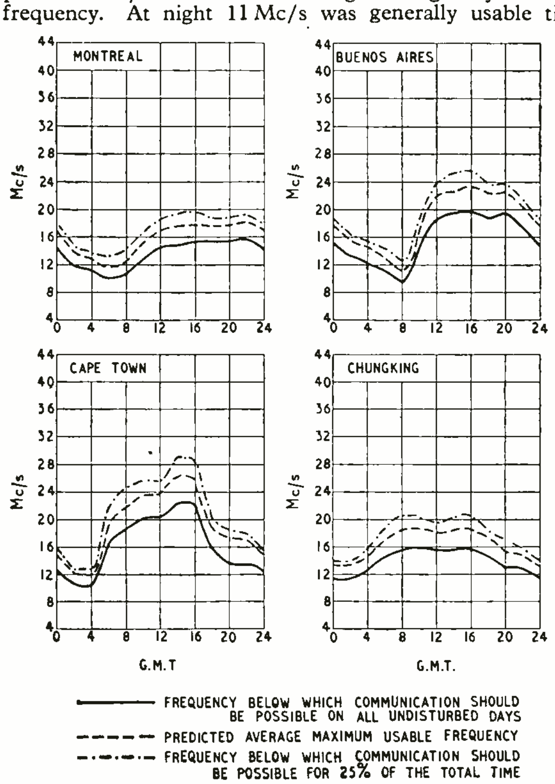
SHORT-WAVE CONDITIONS

May in Retrospect : Forecast for July

By T. W. BENNINGTON*

DURING May the average maximum usable frequencies for these latitudes decreased very slightly by day and increased considerably by night. These variations were in accordance with the normal seasonal trend, but both day and night m.u.fs were higher than had been expected, owing, it is thought, to the increased solar activity during the month.

Daytime working frequencies did not show much variation from the previous month, and were somewhat higher than had been expected. Even so, 17 Mc/s was about the most consistent frequency for east/west paths, though 21 Mc/s was sometimes usable. Frequencies above 21 Mc/s were hardly ever heard. On north/south paths 24 Mc/s was about the highest regularly usable frequency. At night 11 Mc/s was generally usable till midnight, and frequencies below 9 Mc/s were seldom really necessary.



As was expected, the rate of incidence of Sporadic E increased considerably during May, and often this became capable of propagating the higher frequencies over medium distances. Swedish and Danish f.m. stations on frequencies around 42 Mc/s were often audible in this country.

Sunspot activity was, on the average, higher than for many months past. The giant sunspot alluded to last month again crossed the sun's central meridian, on May 15th, and, during this passage across the sun's disc, attained proportions such as placed it amongst the four largest spots ever to be observed at Greenwich.

There was considerably less ionospheric storminess in May than for some time past. Disturbances did, however, occur during the periods 1st-4th, 10th-13th, 24th, and 27th-28th. The month was notable for the number of Dellinger fade-outs which occurred. Ten of these were reported, some of them of severe intensity, the worst occurring at the following times: 8th, 1515-1545; 10th, 1000-1030; 15th, 1128-1300; 18th, 1024-1255; and 23rd, 1140-1230.

Forecast.—During July there should be very little change in either daytime or night-time m.u.fs for these latitudes, as compared with those for June.

Working frequencies for long-distance communication should therefore remain relatively low by day and high by night. Over east/west circuits the highest regularly usable daytime frequency may be of the order of 15 Mc/s, and while 17 Mc/s may often be usable, it is unlikely that frequencies above 20 Mc/s ever will. On north/south paths 21 Mc/s should be a regularly usable daytime frequency, and those up to 28 Mc/s may occasionally become so. At night 11 Mc/s should be regularly usable until after midnight over most circuits, and 9 Mc/s should remain so the night through.

During July Sporadic E capable of propagating the higher frequencies should continue to be prevalent, and medium-distance communication by way of this medium should often be possible on metre waves and sometimes on longer wavelengths. Normal communication over medium distances will be controlled for several hours daily by the E or F_1 layers, and the usable frequencies for such communication should, during those hours, be relatively high.

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

* Engineering Division, B.B.C.

Approach to "High Fidelity"

Signposting Some Alternative Routes—And One or Two Blind Alleys

THIS article is addressed not so much to those who have "arrived" in electro-acoustics, or to those "hi-fi enthusiasts" whom nothing will deter from the joys of the chase after the unattainable, as to the many people who have sought advice on the ways and means of obtaining quality of reproduction from records and radio which is better than that offered by the ordinary run of commercial broadcast receivers.

Ignoring for the moment decibels, frequency characteristics and all such like trees, let us step back a little and take a look at the wood as a whole.

First, a matter of terminology. According to the dictionary fidelity means "exact correspondence to the original"; qualifying adjectives such as "high" or "low" are therefore either superfluous or inappropriate. Of more practical importance is the realization that fidelity of reproduction via the medium of a loudspeaker or speakers in an ordinary living room is impossible, for the simple reason that the acoustic characteristics of the room will be added to those of the hall in which the sound originated. Even if one went to the expense of fitting up a special enclosure with sound absorbing walls, floor and ceiling, or, more simply, agreed to tolerate the use of headphones in order to exclude air vibrations in the room, it would be of little use unless a two-channel system of transmission or recording were also available virtually to transport the listener's two ears in correct relative position to a point inside the hall or studio. Even then he must keep his head still[1] and will have to forgo those subconscious minor orientations which are an essential part of attentive binaural listening.

If fidelity of reproduction is impossible there is no denying that some very pleasant sounds are frequently to be heard coming from loudspeakers of all shapes and sizes. One outstanding performance in the writer's memory was of a solo voice, heard in a small living room through the medium of an "all-dry" portable with 3½-inch loudspeaker and a run-down battery limiting the output to about 50 milliwatts! Most people have had similar experiences of being "carried away" by performances in unpromising circumstances and on analysis it is generally found that the deviations from the orginal (one cannot call them distortions in this context) are not sufficiently incongruous to destroy the illusion of reality.

How Do We Hear?

Judgment of what constitutes good reproduction is thus shifted from the objective world of measurement to the subjective, relative and often arbitrary human reaction to sound stimulus. It is often said glibly that "the ear is the final criterion," but this is only a half truth. Much is known about the mechanism of the ear itself: that the electrical potentials generated in the cochlea faithfully reproduce the acoustic waveform, but that these potentials are applied to nerve fibres which constitute individual bottle-necks to the extent that can transmit only "spikes" or pulses of their own characteristic waveform at a repetition rate with a maximum probably no higher than 4,000 or 5,000 per second. Some help in recognizing high frequencies would seem to be conferred by the fact that the region of stimulus in the cochlea is dependent on frequency, but any orderly arrangement at this point is offset by the apparently random connection and mixing of the nerve fibres connecting the cochlea to the brain. How the brain sorts out this jumble of coded signals and finally conveys the consciousness of, say, a pure sine wave of 1,000c/s at a certain loudness level is still one of those mysteries which the physiologists have yet to solve, but there seems little doubt that the faculty of interpreting this pattern is one which we acquire as the result of a long sequence of experiences beginning at birth.

Conditional Judgments

When we speak of "the ear" we generally mean the whole process of auditory perception which includes the brain and one's past history of experience and training. It is important to recognize that quality which satisfies now may prove to be intolerable in five years' time; conversely, blemishes in reproduction which are noticed at a first hearing, if they are not corrected at once, may be assimilated into the background of experience and tolerated by habit. It is well known that people who have been brought up on cheap broadcast receiver quality dislike good quality reproduction at a first hearing; conductors who spend most of their time with real orchestras dislike "canned music" of any kind.

The ear, then, is not necessarily the final criterion; it is too easily conditioned to the familiar and becomes alert only to unaccustomed elements—true or false—in the sound.[2] Direct comparison with the original—a privilege of the few in broadcasting and recording organizations—is the only firm basis for the development of a critical faculty—unless one has the nerve to take a quality headphone portable to the concert-hall!

The point of this somewhat discouraging introduction is a practical one. In the long run it pays to buy or build an amplifier a little better than one which may now be regarded as adequate. Not so long ago the valve makers accepted non-linearity equivalent to 5 per cent harmonic distortion as the basis for calculating the output available from power valves, since there seemed little point in gilding the lily by working to lower limits. Later, 2 per cent was put forward as a standard of good practice for public address installations, and the criterion for monitoring

[1] M. G. Scroggie (Letter to the Editor, "*W.W.*," April, 1951).

[2] See also, report of I.E.E. discussion meeting "To What Extent Does Distortion Matter in the Transmission of Speech and Music," *Wireless World*, March, 1948, p. 97, and report of B.S.R.A. lecture "Some Physiological Factors in Quality Appreciation," by E. A. Vetter, *Wireless World*, February, 1949, p. 52.

work in studios and high-quality domestic reproducers is now a fraction of 1 per cent. Much higher non-linearity distortions are inherent in the mechanism of the ear (it is thought that they may be an essential part of the mechanism by which we appreciate loudness), but we have lived with them so long that we can accept them and yet notice the slightest additional distortion. The effects of separate non-linearities are cumulative; the distortion products multiply like weeds and methods of control are similar—they must be cut down before they have time to seed.

Wide frequency range is of secondary importance to low non-linearity distortion, but it is generally more than adequate in any amplifier with the quality of components and degree of negative feedback necessary for keeping distortion down to fractional percentages, and one can always throw too wide a response away with tone control circuits if it proves an embarrassment, which more often than not it is! Bass response below 70c/s is seldom required for the appreciation of the musical content of the majority of orchestra works and level responses down to 20 or 30c/s often bring in hum and motor rumbles when reproducing records. At the other extreme a sustained response at high frequencies will faithfully reproduce surface and background noise and the more virulent elements of non-linearity distortion in other parts of the equipment or in the original transmissions and recordings. As P. P. Eckersley has put it: "The wider you open the window, the more the dirt blows in." Too little top response will mar the pleasure of those who have an appreciation of orchestral tone colour. On some vintage modern discs we can safely go up to 15 or even 20kc/s (while the records are brand new!), but, on the average, a cut or "roll off" at 8 or 10kc/s is more pleasant, while many worthwhile pre-war records benefit by a cut to 5 or 6kc/s. So a well designed variable top-cut control and a compensating bass control are a *sine qua non*. In restricting frequency range, it is a matter of experience that the response should be trimmed at both ends symmetrically to preserve good balance. A useful rule of thumb is that the product of the highest and lowest frequencies should equal 500,000; thus, 50-10,000c/s, 100-5,000c/s, etc.

Pickups

Choice of a gramophone pickup does not present any great difficulty and good results are obtainable with either moving-iron, moving-coil or piezoelectric crystal movements. The smaller the mass of the moving parts (which include the stylus) the less likely is there to be record wear. If the voltage-generating element is heavy some sort of compliance between needle point and armature or cartridge is essential. With the older heavy magnetic pickups a fibre needle provided the buffer element—at the cost of high-frequency loss; in one modern crystal pickup a cantilever stylus mounting is designed to present a low needle-point impedance in the mechanical equivalent of a transmission line. Moving-coil pickups have lower outputs than the moving-iron types, but are easier to design for low harmonic distortion. Single-turn ribbon pickups have potentially the lightest movements of all, but as they are also the least sensitive experience is necessary in designing the coupling and pre-amplifier circuits for low hum; the makers usually provide guidance in these matters.

Diamond is the best stylus material, but it must be properly ground and polished (an expensive process). Sapphire is a good if variable material and tungsten carbide is gaining in favour because of its toughness. All the foregoing are suitable for use only with very low mechanical impedances at the needle point. At high frequencies accelerations up to 1,000 times that due to gravity may be experienced, and, with heavy moving parts large forces are involved and damage to the groove wall is inevitable. When in doubt use fibre and accept the h.f. loss; that is unless you can afford to throw records away after a few playings.

A simple r.f. amplifier and detector circuit is best for radio reception on a quality basis, but owing to the congested state of the ether one needs to be close to a main station to avoid background interference. The alternative, until an e.h.f. broadcasting system is established, is a broad-band superhet unit with two or more degrees of selectivity.

Loudspeakers

The choice of a loudspeaker is a purely personal matter, for this reason; the perfect loudspeaker has yet to be made and, whatever you buy, some inadequacy in one form or another will have to be accepted. What that inadequacy will be depends primarily on what type of programme material you are interested in, and to some extent on any blind spots which may exist in your faculty of hearing. People whose first interest is in the spoken word, or the solo singer or instrumentalist, need not be so critical of non-linearity distortion, which will, however, be of paramount importance if orchestral or concerted music of any kind is the main objective. Conversely, smooth deviations from a level frequency response may not seriously affect orchestral reproduction, but a bass resonance may have a disastrous effect on speech, and any prominence in the frequencies around 3,000-5,000c/s will draw undue attention to sibilants.

Another point to watch for is the general level at which a good balance of tone is produced. Some loudspeakers, which sound good at levels which annoy the neighbours, give an emaciated performance at reduced volume—this quite apart from the natural apparent loss of bass and top at low levels inherent in the characteristics of the human ear.

You will be very lucky if you hit first time on a loudspeaker with which you will be still pleased after living with it for 12 months; and don't turn down an otherwise good unit because it "has no bass response." In nine cases out of ten the first judgment on a really true bass response is that it is not there at all!

There is as yet no unanimity as to which principle of diaphragm construction gives best results, though the moving-coil drive is universally accepted. Single and twin-diaphragm, direct radiators, combined low-frequency direct radiators and concentric high-frequency horns—all are capable of first-class performance when handled by skilled (or lucky) designers. Opinion is equally divided on the question of the best method of mounting. Large baffles, holes in the wall, closed and vented cabinets all have their advocates. The vented cabinet is popular because it is reasonably compact and gives an extended bass response, but its resonance must not be too "live," or coloration will be evident on music as well as speech. There is general agreement that the loading of a horn offers many advantages, particularly in the matter of transient response.* The snag with horns is that their

* Discussed in detail in another article in this issue.—Ed.

physical size determines the cut-off at low frequencies, and to reproduce adequately below 100c/s they have to be built rather larger than the average room will accommodate. A combination of horn and bass resonator of either the pipe or the Helmholtz type affords a possible solution of this difficulty.

Realistic reproduction must take into account the apparent size of the source of sound. It is just as incongruous to hear a voice coming from a battery of loudspeakers spread over an area of several square feet as to listen to an orchestra from the "point source" represented by a single directional unit. In one commercial unit scattering by reflection from the corner walls of high-frequency sounds, and the natural diffusion of very low frequencies from a bass chamber, give the illusion of depth on orchestral music, while the residual directional properties of the forward radiation from the main cone occur in a band of frequencies which predominate in speech and help to reduce the apparent size of the source. An alternative solution, which should appeal to the experimenter, is to devise a portable screen made up of deflecting surfaces which can be placed in front of the loudspeaker on appropriate occasions.

At least one specific recommendation is permissible, and it applies to all types of loudspeaker employing a moving-coil drive; get one with the highest flux density in the magnet that you can afford, since this is the very foundation of good transient response and high electro-acoustic efficiency.—F. L. D.

New American Walkie-Talkie

Sixteen Valve Self-contained Set for Mobile or Stationary Use

AN outstanding example of modern miniaturization technique is the new walkie-talkie v.h.f. radiotelephone (Type AN/PRC-10) designed and made by the Radio Corporation of America for the United States Army Signal Corps. It is intended as a replacement for the SCR300 equipment used extensively by the American forces during the recent war, and is about half the size and half the weight, though giving about twice the operating range. The design allows for operation as a portable station with the set carried like an infantryman's pack, as a mobile station in a vehicle, as a fixed ground station or as an unattended relay.

New R.C.A. walkie-talkie designed for the United States Army Signal Corps. This illustration shows the equipment assembled as a pack set.

The AN/PRC-10 set is frequency modulated, contains 16 valves and some germanium diodes and is housed in two waterproof cases held together by spring clamps. The upper unit, comprising the transmitter and receiver, measures $9\frac{1}{2}$in × $10\frac{1}{2}$in × 3in and weighs 9 lb only. The complete equipment as a portable pack set, including transmitter-receiver, battery power unit, carrying harness, hand mic-telephone unit, aerials and spare parts, weighs about 25 lb.

Reduction in size and weight compared with the SCR300 is effected by the use of sub-miniature valves in all positions except the transmitter output stage, which is a miniature; by the use of very small sub-assembly units and by scaling down everything proportionally. For example, the tuning coils are under $\frac{1}{4}$ in in diameter yet give a "Q" of near 100; the five-gang tuning capacitor is only about half the length of the one used in the SCR300, which is not large by any standards of comparison, and the complete i.f. sub-assemblies measure $\frac{3}{4}$ in in diameter and 2 in long, or no larger than a miniature valve, and contain the whole of the stage components including the valve. They are in hermetically sealed metal cans with base pins and plug into the set. In the event of a failure of any unit due to valve or components, the whole unit is replaced by a spare, of which several are included in the equipment.

The receiver is a superhet with two r.f. stages, mixer and separate oscillator, five i.f. stages acting also as grid circuit limiters, discriminator using two germanium diodes and a single audio output stage. There is also a squelch valve for muting the set in the absence of a carrier and two crystal-controlled oscillators for checking the calibration. One on 1 Mc/s injects into the aerial coil, the other on 4.3 Mc/s into the i.f. amplifier and harmonics of the former produce calibration pips every 1 Mc/s throughout the tuning range. The receiver sensitivity is 0.5 μV for 2.5 mW output.

An electron-coupled master oscillator, with its tuning capacitor included in the ganged capacitor unit, is used in the transmitter. Send and receive frequencies are synchronized and the transmitter frequency is controlled by comparison to the receiver's local oscillator. A small portion of the output is fed into the receiver, *via* the aerial coil, which is common to both the transmitter and the receiver, there it is amplified, passed to the discriminator and the d.c. output used as the controlling voltage for an a.f.c. (automatic frequency control) circuit. The transmitter output is about 1 watt and the frequency deviation is 15 kc/s.

Two aerials are provided, one is a seven-section whip for stationary use and when maximum range is required, the other is a semi-rigid type made of strips of steel tape riveted together. It is about 3 ft long and can be folded into a small space.

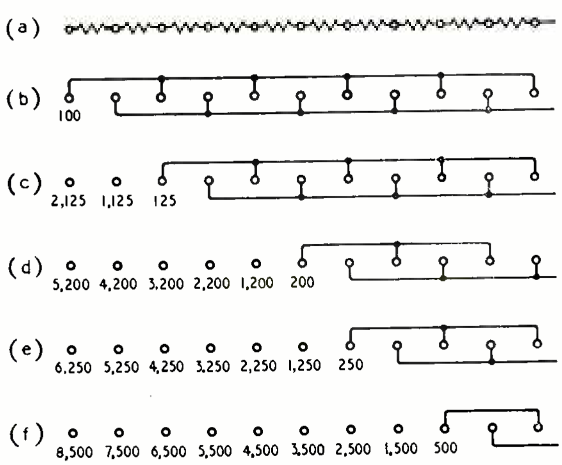
Multiple-Unit Resistors

Various Values by Series-Parallel Connections

If a number of similar resistors are available they may obviously be used in series for values up to *n* times the resistance of one, if *n* is the total number of units. Thus if ten similar units each of 1,000 ohms are available they may be used for any resistance from 1,000 to 10,000 in steps of 1,000 ohms. The same principle holds exactly for other values, such as 100,000-ohm units adding up to one megohm. This latter case is that obtained by using a standard sub-divided megohm. It is only necessary for the accuracy to be as high as that required for the measurements in view. Resistors having a tolerance of 5 or 10% will in general be useless for such work. 1% is often satisfactory, but 0.5 or 0.2% better.

In addition to the obvious 1, 2, 3, etc. times the unit resistance other combinations are possible by paralleling some or all of the units. Paralleling may be carried out even if all the units are permanently connected in series, as in the figure, and the sub-divided megohm is one example.

Different values obtainable from a tapped 10-kΩ resistor.



At (a) is shown the maximum resistance with all in series. Diagram (b) shows the minimum resistance with all paralleled. This is one-tenth of the resistance of one unit or one-hundredth of that of the total, using ten units. In diagram (c) two of the shorting straps are removed and the new resistance is now 125 ohms; by adding one or both of the remaining series units the values of 1,125 and 2,125 ohms result. Five sections paralleled produces 200 ohms, at (d); adding the remainder allows 1,200, 2,200, 3,200, 4,200 and 5,200 ohms, as before. In diagram (e) four sections are paralleled, giving 250 ohms, and by adding the remainder the values of 1,250, 2,250, 3,250, 4,250 and 5,250 ohms are obtained. With only one pair of units paralleled (f) the resistance of 500 ohms, or half that of one unit, is obtained, with totals available of 1,500 by steps of 1,000 to a maximum of 8,500 ohms.

For ease of use the resistances available are shown in the sketch. The paralleling of 3 or 6 units has been omitted as it introduces recurring decimals, and although these may be of use on occasion they are more difficult to deal with.

These arrangements are often of use in a laboratory where no real standards are available, such as a decade resistance or a Post Office bridge. Uses include series resistance for a voltmeter to change the range temporarily; they may also be used to check or calibrate a resistance tester assembled from a voltmeter and battery, requiring only the initial resistance units of known and good accuracy. E. H. W. B.

FESTIVAL COMPUTOR

Those who find computors difficult to understand should make sure of paying a visit to the Festival of Britain Exhibition at the Science Museum, Kensington, where Ferranti are demonstrating an electronic digital computor that has been specially designed to show the general principles of these machines. It is called "Nimrod" because it has been arranged to play the game of Nim with human opponents—and it generally wins. This game is basically a mathematical problem, and in solving it the machine shows the three essential characteristics of an automatic computor—it calculates, remembers, and makes decisions.

Nimrod uses voltage levels to represent numbers and is aperiodic. This makes it possible to display the "thought processes" step by step, and two explanatory diagrams are lit up as the machine progresses through the problem. As well as playing six variations of the game, it can also be arranged to play against itself—a spectacle full of poetic justice for the mere human who has just been outwitted.

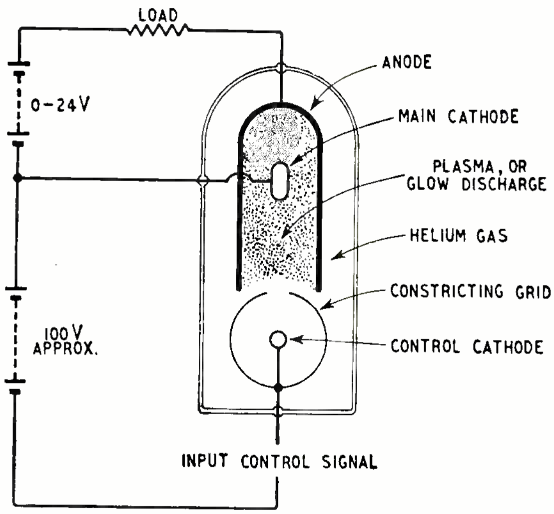
Altogether 480 valves are used, all Brimar 12AT7 double triodes, but since the majority of these 960 sections are only called upon to perform two simple functions for binary calculation—conduct and non-conduct—the operating conditions are not at all critical. This makes for good reliability, exceeding that of electromechanical relays according to the makers, and at the time of going to press Nimrod has not yet experienced a single failure.

Gas Discharge Tubes

New Principles for Control, Amplification and Stabilization

THE properties of electrical discharge through gas have been known for many years now and are utilized in such familiar devices as the thyratron, the neon stabilizer and the gasfilled rectifier. There does not seem to have been much further development in this field, however, until just recently, when something like a minor revolution has been started by the sudden blossoming of some quite new ideas.

One new tube, for instance, which may have considerable repercussions on the electronics industry, is a gasfilled type in which the flow of current is directly and continuously controlled by a third electrode as in an ordinary hard triode. This represents a considerable advance on the normal gasfilled relay or thyratron where the grid merely serves to fire the discharge and has no further control over the flow of current. It also represents an advance on the ordinary hard valve which, because of the inherent space-charge limitation of anode current, has a sometimes inconveniently high impedance. Thus, combining as it does features of both the gasfilled relay and the triode, the new tube can be used not only for progressive control operations (as distinct from simple switching), but for amplification as well, especially where low-impedance circuits are desirable.



Sketch of the "plasmatron" and external circuit. The purpose of the constricting grid round the control cathode is to increase the plasma density.

The important point about the functioning of this tube is that it does not produce a complete gas discharge between anode and cathode as in an ordinary thyratron. Instead, the extra control electrode establishes an independent glow discharge which permeates the space between the anode and cathode, neutralizes the space-charge, and serves as a conducting medium for the main flow of current. Now the density, and hence the conductivity, of this auxiliary discharge depends largely on the amount of current maintaining it, so that this current—in the control-electrode circuit—provides a direct means of controlling the main anode-cathode current. The relation between the two currents is, in fact, substantially linear, while the degree of amplification in terms of current can be of the order of 100:1. So long as the anode voltage is kept below a certain figure the control electrode continues to be effective, but above this point a complete discharge between anode and cathode takes place and the tube behaves like a straightforward thyratron.

An American version of the tube, called the "plasmatron" and described by E. O. Johnson in *Electronics* for May, 1951, has the main cathode enclosed within a U-shaped anode, at the open end of which is the control electrode—actually another cathode. Both cathodes are heated. Up to 24V can be applied between the anode and main cathode while the control cathode is kept at about 100V negative, the main current being of the order of half an amp. The I_a—E_a characteristics are very similar in form to those of a pentode and the plasmatron does, in fact, show the properties of a constant-current device. This enables it to be used, for example, as an a.f. output valve working direct into the loudspeaker speech coil, although the frequency response does fall off rather sharply at 10kc/s owing to the inability of the auxiliary discharge to change its density at such a rapid rate.

A new French tube having basically similar properties is described by Raoul Besson in the May 1951 issue of *Toute la Radio*. This, however, uses a cold main cathode, while the control electrode (also cold) is described as a grid. Another important difference is that the control electrode is held at a positive potential with respect to the cathode. Physically, the anode and cathode are at either end of the tube and the control electrode is in a small appendix in the side wall—midway between them, but not interposed in their path. The anode-cathode voltage is here of the order of 300V, and, with a standing main current of 3mA and a standing control current of 2μA, a change of 1μA at the control electrode produces a change of 200μA in the main current. Again, if the normal operating conditions are exceeded a complete anode-cathode discharge takes place and the tube behaves like an ordinary thyratron. The possible applications of this tube are, of course, somewhat different from those of the "plasmatron," but the author is principally concerned with its use as an amplifier for photo-cell currents.

In this country, we understand that Mullard are working along similar lines, but no details are available yet except that the firm is chiefly interested in the cold-cathode type.

Although the gas discharge phenomenon can also be utilized for voltage stabilization, its range of application in this field has been somewhat limited because practically the only type of stabilizer to appear on the market so far has been the familiar neon tube. This, of course, is restricted to working somewhere in the region of 100 volts (per section in the case of multiple types) with tube currents of the order of milliamps. Recently, however, a new kind of stabilizer has been introduced for working at much higher voltages with currents of only microamps required to maintain the discharge. The discharge is actually a corona formed between two coaxial electrodes in a gas filling, the anode being in most cases a single wire and the cathode a comparatively large-diameter cylinder enclosing it. When the tube is wired up with a series resistor it behaves in much the same way as a conventional neon tube and, generally speaking, gives a stabilization ratio of about one per cent.

Corona discharge tubes are now being made in this country by Nucleonic and Radiological Developments of Chelsea. A typical example from this firm uses a 10-MΩ series resistor (the tube resistance being about 100kΩ) and stabilizes at 450V with an initial current of about 10μA. Increasing the input voltage to, say, 800V produces only a 7-V rise in the stabilized voltage. Although this firm's range of tubes is at present restricted to 400-1,000 volts, the possible upper limits are actually very high and in America tubes have been produced for stabilization up to 40,000 volts. Up to 10,000V can be stabilized in a tube no larger than an ordinary receiving valve, and this order of working voltages, of course, makes the corona stabilizer very suitable for use in the e.h.t. supplies of Geiger-Muller, x-ray and television cathode-ray tubes.

R.I.C. Specifications

THREE new specifications covering the performance, requirements, production tests and schedule of types, values and sizes for capacitors have been issued by The Radio Industry Council. RIC/133 deals with ceramic dielectric fixed capacitors, RIC/134 with electrolytics and RIC/137 with metallized mica capacitors. With the exception of the electrolytics the recommended tolerances are ±2, ±5, ±10 and ±20 per cent and the capacitance values conform to the so-called "preferred" ranges for these tolerances. The ±2 per cent range of values are as for ±5 per cent.

In the case of the ceramic capacitors it is recommended that a colour code (defined in RIC/133) be used as an alternative to direct marking of capacitance, working voltage, group classification and temperature coefficient. This consists of five colours, the end one giving the temperature coefficient (+100 to −750) in parts per million per deg C, the following three the capacitance in picofarads and the fourth the tolerance.

Sections 1 and 2 covering performance requirements and production tests respectively are issued in respect of RIC/133 and 134, but section 3, schedule of types values and sizes (dimensions), etc., is included in RIC/137 as well as sections 1 and 2.

Sections 3 for RIC/112 and 113, grade 1 and 2 respectively fixed composition resistors, for RIC/132, stacked foil mica dielectric fixed capacitors, and for RIC/136, metallized paper tubular capacitors, are now available. Sections 1 and 2 were issued some time ago.

Sections 1 and 2 of RIC/133 and 134 can be obtained from The Radio Industry Council, 59, Russell Square, London, W.C.1, at 5s each. Specification RIC/137 complete with all three sections costs 7s. No charge will be made for section 3 in the case of previously purchased specifications RIC/112, 113 and 132, but for additional sections a charge of 1s 6d is made for RIC/112 and 2s for each for the other two. The complete specification RIC/136 now costs 6s 6d. All prices include postage.

There is an R.I.C. specification available now dealing with colour coding for connections in radio and electronic equipment, other than domestic radios. It is RIC/1000/C, was issued in April last, and costs 1s 6d by post.

NEW BOOK

A.C./D.C. Test Meters. By W. H. Cazaly and Thomas Roddam. Pp. 180+viii with 112 illustrations. Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price 18s.

THIS book deals only with moving-coil indicating instruments and their use with resistances, metal rectifiers and transformers for a.c. and d.c. voltage and current measurement. As a corollary, ohmmeter methods of resistance and capacitance measurement are covered.

In the first chapter the basic meter movement is described. In the second, the use of shunts for extending current ranges and their calculation are treated, as well as voltmeter ranges and the ohmmeter. The 36 pages of this chapter cover all the d.c. applications and nearly two-thirds of them are devoted to the ohmmeter.

A chapter on metal rectifiers follows and there is then one on "A.C. Voltage Ranges." Current transformers are quite well treated and their use for extending both current and voltage ranges is dealt with. There is a chapter on accuracy and another dealing with the construction of a multi-range test instrument.

The book concludes with a chapter on Power and Capacitance Ranges and there is an Appendix in which the latter are analysed.

The treatment is straightforward and fairly elementary, and practical aspects are kept well to the fore. Generally speaking, the book will prove of great utility to those interested in test instruments and it is one which can confidently be recommended to them.

Few errors were noticed, but there are some. On p. 51 it is stated:—"Commercial rectifiers are normally marked by colours to show polarity; a red spot indicates which end of the rectifier would be connected to the positive pole of a source for current to pass easily. . . ." This is incorrect; in British practice the red spot or plus sign indicates the end which delivers current in a rectifier circuit; it is the end which is equivalent to the cathode of a diode valve. Some years ago germanium rectifiers were marked in accordance with American practice and in agreement with the statement in this book, but they have now been brought into line with the normal convention for copper-oxide and selenium rectifiers.

Another minor error is on p. 9, where an exaggerated example is given to illustrate the effect of meter resistance on current. It is unfortunate that the authors should have chosen the measurement of filament current of valves as their example because anyone performing the experiment will not obtain the result which they give. They have overlooked the fact that the resistance of a valve filament changes greatly with its temperature and, hence, with the current flowing. Had they chosen a simple resistor for their example all would have been well.

These are but minor points in a good little book and they detract very little from its value. W. T. C.

Temperature Fuses

Operated by Heat Generated in Mains Transformers

THE idea of using a fuse in a radio, or television, receiver, which operated if the temperature of a given item exceeded a pre-determined figure, was discussed at length by F. C. Connelly in the article "Safety Precautions" which appeared in the January issue of *Wireless World.* While the risk of fire due to a breakdown in insulation, or the failure of a component, is admittedly slight, if simple and effective means can be taken to lessen the hazard it deserves all the encouragement it can be given.

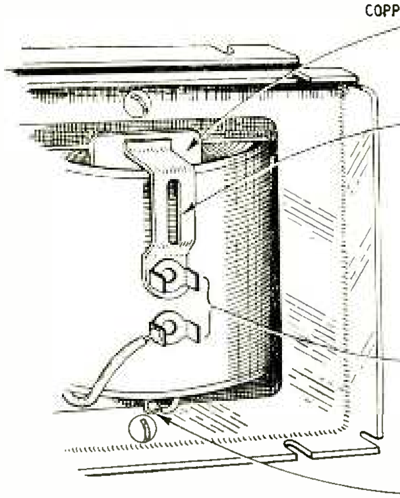
One method of fitting a temperature fuse was illustrated; another was described in a recent issue of *Murphy News.* From an article by L. Driscoll it appears that a fuse of this kind has been fitted to certain Murphy receivers for some time past.

The temperature fuse used in these sets is embodied in the mains transformer and consists of a well-insulated copper strip, (A) in the accompanying sketch, inserted between the heater and h.t. windings. This strip projects beyond the coil at both ends, at one end it is fashioned into a small lug to which is secured one end of the primary winding. The other is "soldered" by means of a special low-temperature fusible alloy, to a spring (B). The other end of this spring forms one connection for the mains supply.

If the temperature in the transformer rises abnormally, heat is conducted along the copper strip to the fusible alloy, which melts and allows the spring (B) to part company with (A) and so breaks the primary circuit of the mains transformer.

The fusible metal consists of bismuth, tin and lead proportioned to produce an alloy having a sharply defined melting temperature without an undesirable plastic range. A circuit breaker of this kind is proof against short-period surges, such as may occur at switching on. In the case of this Murphy fuse its position and composition are arranged so that the temperature rise at the hottest part of the transformer will not exceed 135 deg C when measured two minutes after the fuse has melted. It thus complies with a draft specification, British Standards B.S.415, which lays down certain safety requirements for *inter alia,* mains-operated radio apparatus. It is stated that, on test, the fuse opened $1\frac{3}{4}$ min after the inner portion of the transformer h.t. secondary winding had been deliberately short-circuited.

A feature of this type of fuse is, of course, that it can be rejointed after being blown—simply by applying heat.



Details of the temperature fuse incorporated in the mains transformer fitted to certain Murphy radio sets.

Research YOU Pay For

ALL commercial firms will tell you that research has to be paid for—some even that it should pay for itself—and although this may be considered a deplorably mundane attitude, it is quite understandable in organizations whose main purpose is, after all, to make money. With Government research we have a different state of affairs. Here is work which does not have to show immediate returns but can be directed towards the general advancement of science and industry—and however useless it may seem at the time, it does bring rewards in the end. But even this has to be paid for—and, of course, the honour falls upon us, the reluctant taxpayers.

Exactly how is our money spent? In the radio field some idea can be gathered from the annual reports of the Radio Research Board which, under the Department of Scientific and Industrial Research, is responsible for work done at various establishments, chief among them being its own station at Slough. The 1949 Report, for example (now available from H.M.S.O. at 1s 9d or 1s 11d by post), shows that the year's research was mainly devoted to propagation, including the study of ground waves, the troposphere and the ionosphere. Other aspects reviewed are the effect of weather and the forecasting of ionospheric conditions. In addition, there is information on radio noise, materials of special interest, measuring techniques at v.h.f., and on the generation of centimetre and millimetre waves.

Recently we had an opportunity to see some more recent work when the N.P.L. held its 1951 Open Days at Teddington. Amongst the new exhibits were a microwave interferometer that can be used either for determining the velocity of radio waves or for measuring distances of several metres, and the pilot model of the N.P.L. electronic digital computor with some associated apparatus. Not so new, but still interesting, were an experimental system for finding the distances of thunderstorms by analysing the received waveforms of the lightning flashes, and a demonstration of the overtone resonances of coils at frequencies higher than that of the normal self resonance. Electronic devices figured prominently as means to ends in many of the other research exhibits.

Manufacturers' Products

New Equipment and Accessories for Radio and Electronics

Coated Screen for Cabinets

AN interesting method of screening television receivers to prevent them from radiating interference is to paint a conducting coating on the inside of the cabinet. A graphite material known as "dag" Dispersion 479 has recently been introduced for this purpose by Acheson Colloids Ltd., of 18 Pall Mall, London, S.W.1, who tell us that tests show that radiation from the e.h.t. and line time-base generator is attenuated by 20-30 db, a typical case being a reduction in measured field strength from 200μV/m at 21ft to 31.5μV/m at 9ft with a 210-kc/s signal. The efficiency of the screening is comparable at 120 kc/s with that of copper mesh having 36 strands to the inch, and although the coating is not so good at higher frequencies it is still of the order of 60 per cent efficient at 210kc/s

Miniature Hearing Aid

A HIGH degree of amplification without distortion is claimed for the new K30 miniature hearing aid by Amplivox, of 2 Bentinck Street, London, W.1. It has a flat-response microphone and is used in conjunction with the Amplivox E3 miniature magnetic earphone, which is claimed to have a frequency response remarkably free from peaks and resonances. The maximum gain is 57db, but this can be increased by a further 7db by using another type of earphone. Plug-in valves are used for easy replacement and the chassis is housed in an aluminium-alloy case finished in either coral pink or silver grey lacquer. The batteries can be easily removed from a compartment fitted with a hinged spring cover; they are Ever Ready types, B.123 (30V) for the h.t. and D.12 (1.5V) for the l.t.

Miniature Ball Race

INSTRUMENT makers will be interested in the recent importation from Switzerland of a miniature ball race measuring only 1.5mm (diameter) × 0.93mm. This is the type C1.5, available from Miniature Bearings Ltd., 192 Sloane Street, London, S.W.1, who act as sole British distributors for Roulements à Billes Miniatures of Bienne, Switzerland. Designed as a pivot bearing, it consists of a pressed steel cup, a dust cover, a ball cage and three chrome steel balls. The manufacturing tolerances, 1.2 and 1.6 thousandths of an inch for the depth and diameter respectively, are fairly large because pressed steel races of this type suffer slight distortion during heat treatment. A heavier grade of the C1.5 is available with an overall diameter of 1.65mm.

Television Pattern Generator

FOR checking and adjusting television receivers in the absence of a transmission, a synchronized test-pattern generator has been produced by Radar Radio & Television, Ltd., of 26 Oakleigh Road, New Southgate, London, N.11. It comprises a signal generator for feeding simultaneous sound and vision signals into the aerial socket of a receiver, with provision for switching off the sound signal when required. A video waveform with sync. is also available for injection into the video stage. The pattern modulating the vision signal (approx. 10mV output) consists of a number of vertical bars divided into horizontal sections, each section being graded from black (30 per cent modulation) to full white (100 per cent modulation). Provision is made for removing the pattern modulation and leaving a blank unsynchronized raster, and for unlocking the frame synchronizing frequency from the mains so that hum can be seen.

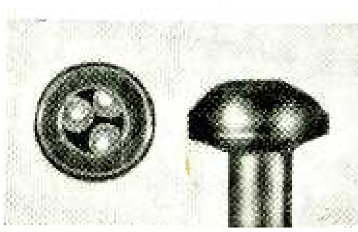
The generator is a portable instru-

(1) Television pattern generator, by Radar Radio & Television. (2) Pre-heated soldering iron by Grafton, Kersten & Co. (3) Amplivox hearing aid. (4) Miniature ball-race, by Miniature Bearings Ltd., shown against a pin-head. (5) Tubular capacitance trimmer by Erie, with spring-clip fixing.

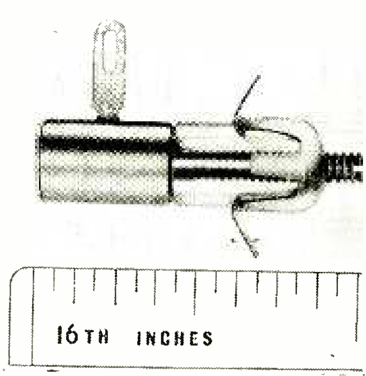
(1)

(2)

(3)



(4)



(5)

ment, weighing 15½lb, for use on a.c. mains. Two versions are available, Model L for the London vision and sound frequencies, and Model B for the Sutton Coldfield frequencies.

C.R. Tubes for Television

Two new 12-inch television c.r. tubes with aluminized screens have been announced by the General Electric Company. Type 6705A has a 6.3-V heater and type 6706A has a 10.8-V heater; both have white screens and can be used at e.h.t. voltages up to 10kv.

New Trimmers

THREE new trimming capacitors have recently been announced by Erie Resistor, Ltd., of Millora Works, Beevor Road, South Denes, Great Yarmouth. Type 531 is a compact tubular trimmer designed for low minimum capacitance and a high maximum-to-minimum ratio, the ranges available being 0.5-5pF and 1-8pF. To vary the capacitance an adjusting screw moves a plunger up and down inside the dielectric tube, and in the 1-8pF range this takes 18 complete turns to go from minimum to maximum.

Silvered ceramic is used for the rotor and stator in the type 557, which is available at the moment with a negative temperature co-efficient of 750 parts/million/°C in the ranges 5-30pF and 8-50pF. It has a slot for screwdriver adjustment in the ½-in diameter rotor. Finally, the type 135 is claimed to be the first trimmer produced in this country that is fully sealed (effective against vacuum and a pressure of two atmospheres) and fully tropicalized (temperature range −50°C to +100°C). It is available in two ranges: 1-12pF (with positive temp. coeff.) and 3-50pF (with neg. temp. coeff). The depth and diameter are both approximately ½in and adjustment is made by screwdriver.

Pre-Heated Soldering Iron

ONE disadvantage of the small pencil-bit type of iron used in fine soldering work is that the bit tends to get too hot for the solder and to burn away rapidly when not in use. This is obviated in the new "Neoflec" soldering iron, produced by Grafton, Kersten & Co., Ltd., which is kept just below the melting point of solder when not in use, but can be brought up to the required soldering temperature almost instantaneously by pressing a button on the handle. The 24-volt element is inside the nickel-plated bit so that the transfer of heat to the work is very rapid, and in this way a very fine bit is made possible because there is no necessity for an accumulation of heat.

A transformer giving 2 amps at 24V is required to operate the iron, although it will also work at 25-26V and can be run from a battery; the consumption is 19W in the pre-heat condition and 43W at full heat.

At the moment, the iron can only be supplied to manufacturers, radio servicing technicians and for export. The address of the firm is 77 South Audley Street, London, W.1.

MANUFACTURERS' LITERATURE

Dry Battery Manufacture described and illustrated in a well-produced booklet marking the fiftieth year of The Ever Ready Company (Great Britain) Ltd., of Hercules Place, Holloway, London, N.7.

Mobile Radiotelephone: specification and description of the "Reporter" in a leaflet from Pye Telecommunications Ltd., Newmarket Road, Cambridge.

Export Catalogue of Ediswan valves from the Edison Swan Electric Co. Ltd., 155 Charing Cross Road, London, W.C.2.

Steel C.R. Tube, type T901, described in a leaflet from The English Electric Co. Ltd., Queens House, Kingsway, London, W.C.2.

Quartz Crystal Units (G.E.C.) catalogued in a booklet from Salford Electrical Instruments Ltd., Peel Works, Silk Street, Salford, 3.

Miniature Standard Cell (Weston); specification in a bulletin from Muirhead & Co., Ltd., Beckenham, Kent.

Central Aerial Systems for flats (radio and television) described in a booklet from E.M.I. Sales & Service Ltd., Wadsworth Road, Greenford, Middlesex.

Pocket Valve Data book containing abridged data from Mullard Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Television Feeder Cables catalogued in a folder from W. T. Henley's Telegraph Works Co. Ltd., 95 Aldwych, London, W.C.2.

Components Catalogue (1951) from M. Watts & Co., 8 Baker Street, Weybridge, Surrey.

Switch Catalogue from Arcolectric (Switches) Ltd., Central Avenue, West Molesey, Surrey.

Wave Analyser (tunable filter type) described in a bulletin from Muirhead & Co., Ltd., Beckenham, Kent.

Enclosed Racks and parts catalogued in a leaflet from Alfred Imhof Ltd., 112-116 New Oxford Street, London, W.C.1.

RANDOM RADIATIONS

By "DIALLIST"

Good Show

BY THE TIME that you read this the Joint Engineering Conference will have taken place. It was a splendid plan and both those who first thought of it and those who did the vast amount of hard work involved in organizing it and carrying it out deserve warm thanks and congratulations. The idea of the whole thing was this. The branches of engineering covered by the three senior institutions—the I.C.E., the I.Mech.E. and the I.E.E.—are becoming more and more closely inter-connected: you can't build a railway without civil engineers to lay the track, make the tunnels and build the bridges; mechanical engineers to design the rolling stock and other machinery; and electrical engineers to see to power supplies, signal systems and so forth. Each branch makes its own contribution to shipping, telecommunications, broadcasting . . . the list is endless. And the work of each branch must dovetail in with the others. Very well then; what could be more useful than a joint conference of the three institutions, arranged specially to bring home to engineers of any of these kinds how their work must fit in with that of the other two branches, and that of each of those branches with theirs? It was an excellent idea to devote the mornings to papers and discussions and the afternoons to visits to factories and so on, providing first-rate practical examples of the co-ordination of these three sorts of engineering.

The Unattended Radio Transmitter

AM I RIGHT in believing that this country pioneered the development of the unattended radio transmitting station and, in particular, that used as a broadcast relay? I think so; but doubtless readers will correct me if I'm not. Whether or not we were first in the field, we have gone right ahead in the practical application of the idea, for no other country can point to anything approaching the Third Programme transmitter at Daventry—to say nothing of the numerous smaller stations which go on quite happily relaying this programme or that, working all on their own and with no human attention save what comes into the category of routine maintenance. Two basic inventions, both British to the best of my knowledge, are responsible for making the unattended wireless transmitter something more than a beautiful dream. The first of these concerns the operation of two or more transmitters in parallel at one site: a station could not work unattended satisfactorily if a fault, such as the "blowing up" of a valve, would put it completely out of action; with two or more transmitters running in parallel such a technical hitch (to use the B.B.C.'s official term) means to the listener that the signal is still there, though its strength is reduced for the time being. The second important invention is automatic monitoring, which enables a relay transmitter to call attention to its own shortcomings.

Supplying the World

Whether or not we originated the idea, we seem to be recognized now by the rest of the world as *the* producers of reliable unattended transmitting apparatus. The Marconi Company, for instance, are now engaged in making no fewer than seventeen of these equipments, ten for Italy and seven for Sweden. As both of these countries have long been amongst the most progressive in the matter of developments in wireless, this is indeed a compliment to our radio industry. In these transmitters the parallel principle is given the fullest play; each, in fact, consists either of three 660-watt or four 500-watt units working in phase to provide a 2-kilowatt output. Should a fault occur in any unit, the transmitter automatically switches itself off. Within from two to five seconds the faulty unit is isolated and cut out — still automatically — and the others are switched on again. A fault thus means a barely noticeable interruption of the service, followed by a comparatively small temporary falling-off in signal strength.

Wave-Change Switches

THOUGH THE BROADCAST RECEIVING SET is now approaching its thirtieth year as a piece of domestic equipment, some of its original weak points still remain. Two in particular come to mind: the volume control and the wave-change switch. The commonest types of these both contain sliding contacts and these are a frequent source of bother, particularly in the switches. Surfaces corrode in time; fine dust finds its way on to them and, absorbing moisture from the air, forms a thin cement-like coating. The set becomes more and more noisy and something has to be done about it. One effective way of cleaning up dirty contacts is to make use of that very fine abrasive paper —far finer than the finest grade of emery cloth—the technical name of which I can't for the life of me recall, though I've no doubt some kind reader will step into the breach. I still have a little left from a supply I bought long ago. Cut a narrow strip of this paper and fold it lengthwise so that there is an abrasive surface on both sides. Manœuvre it into each contact of the switch in turn, working the knob to and fro as you do so. You must not leave the contacts dry for, as an article in *W.W.* some time ago showed, they'll wear very quickly if you do. A good lubricant can be made by mixing two drops of mineral oil into a teaspoonful of lighter fluid. Apply a minute amount with a small *clean* feather. The lighter fluid evaporates and leaves a thin lubricant film.

Sets and Shocks

That the wireless set is one of the safest of all articles of domestic electric equipment is shown by the very small number of accidents for which it is responsible, despite its daily use by millions of folk who know nothing whatever about electricity. The same goes for television sets. The recent fatal accident to a boy, due to a faulty televisor, was given a good deal of publicity in the lay press as the "first television fatality." As a matter of fact, it was the "sound" portion of the receiver which was concerned and not the purely vision part at all. This sad business was caused by a chance defect that might equally well have arisen in a "universal" sound-broadcast set.

Interference Problems

THE WORK DONE by the I.E.E. Committee on Radio Interference and that still in progress covers a multiplicity of the wireless reception problems of to-day. It has, for instance, already prepared jointly with the B.S.I. codes of practice for the abatement of interference from motor ignition systems (CP1001) and from medical and industrial h.f. apparatus (CP1002). Others dealing with fluorescent lamps and with interference suppression in general are on their way. The advice of the I.E.E. Committee is always available to the P.M.G.'s Advisory Committee on Interference—if they ask for it. One only hopes that they do!

Does Quality Matter?

WHEN I READ or listen to dissertations on the quality of wireless transmissions I often find myself wondering whether the matter is of any importance at all to the big majority of listeners. I do not mean that they don't appreciate high-fidelity reproduction when they hear it; what I am suggesting is that they do not hanker after good quality if it does not come their way. A wild statement? There's no proof that any such thing occurs? I accept the challenge. Have you ever heard anyone complain that the sound accompanying the television transmissions from Sutton Coldfield is inferior in quality to that radiated from the Alexandra Palace? No? Nor me neether, as they say in Yorkshire. Yet here are the cold, hard facts. A.P. deals faithfully with a band of audio frequencies extending up to about 12,000 c/s; the sound from Sutton Coldfield is "piped" from London over a telephone pair and has a cut-off at 5,000 cycles or even a bit lower.

Is the Pentode Responsible?

Wondrous as are the benefits which the pentode valve has conferred on us in other parts of the receiving set, I am not at all sure that the output pentode, so widely used nowadays, is not responsible to a very large extent for the general acceptance of not-so-high-fidelity reproduction. You can "tame" the output pentode to some extent by using "corrector circuits" and heavy negative feedback; but by doing so you don't entirely kill its propensity to introduce one of the most distressing forms of distortion, that concerned with the odd-numbered harmonics. The pentode tends to accentuate the amplification of the upper audio frequencies. Hence, having introduced odd-numbered harmonics, it then proceeds to bring them out strongly. The average listener makes the reproduction "easy on the ears" by applying still more correction (!) by way of the tone control. Thereby he obtains what he terms mellowness—which means a sharpish cut off at 4,000 c/s or less. Not much use giving him—or his set—high-fidelity transmissions!

UNBIASED

By FREE GRID

New Worlds to Conquer

I HAVE heard it stated on the authority of one of its high priests that the Automatic Computing Engine (ACE)—popularly mis-called the electronic brain—is capable of solving any problem that has a numerical answer, but I take leave to doubt the strict accuracy of this statement. For instance, can the ACE give the correct numerical answer to a man who has stood in the dock all day listening to the evidence piling up against him and wondering how many months or years the Court would award him? This is literally and metaphorically a nightmare question now that so many judges have developed the exasperating habit of postponing sentence until the day following the jury's verdict. As I can personally testify, many a hapless wretch owes a duodenal ulcer to this regrettable judicial habit.

One cannot help seeing, however, an enormous future for the ACE in the world of business as well as that of applied science. Already, I am told, chartered accountants, whose job in life it is to tell hard-faced capitalists whether they are living on their own losses or on other people's, are toying with the idea of so robotising their client's offices that floods of pent-up man-power will be released for more vital work, such as filling up football coupons, which will, of course, be checked by another type of ACE specially designed for the Pool promoters.

Surely, too, there is another type of potential ACE customer in the man who is not so much a chartered, as a martyred accountant should he make a slight slip in his calculations whereby he finds himself with insufficient cash to meet his immediate commitments. I refer, of course, to the racecourse bookmaker who, with his faithful clerk, stands in all weathers on a windswept heath shouting the odds. These men have to calculate with split-second, if not with microsecond speed and accuracy to keep their books balanced, and should they fail in this they have to calculate with still greater speed and accuracy the most favourable moment to start running, and, believe me, they have to possess considerable physical as well as mental speed.

Exasperating judicial habit.

I am aware that an ACE costs many thousands of pounds, but money is no object to these men. Only recently I noticed one of them with a hired helicopter hovering over him like Elijah's chariot of fire, and dangling grappling hooks ready to pluck him and his clerk to the safety of the skies in case of dire need.

Suppressio Veri

WE British must seem extremely dull dogs in American eyes, as according to their textbooks and "noosepapers" we never seem to have given the world a single new idea in science. Radar, for instance, we rightly regard as being peculiarly British in origin but little or no credit is given to us for it on the other side of the Atlantic, even in textbooks written by people who ought to know better.

As for the American man-in-the-street, his ignorance is so profound that when talking with one about radar the other day I narrowly escaped provoking international complications. I happened to refer to "our pioneer work in this particular sphere of radio activity" and was at once brought up with a round turn and told that radio-activity was purely an American invention which was first publicly demonstrated at Hiroshima.

The latest example of lamentable ignorance occurs in the May, 1951, issue of *Popular Science*. In it we are told that electric shavers and similar interference-producing devices may be taboo in any future war as the enemy might use their radiations as a guide to his bombers or even as "homing" signals to radio-guided missiles. Apparently American scientists have only just woken up to this danger. They are unaware that long before 1939 aircraft radio operators over here knew when they were passing over a large town, no matter how impenetrable the fog, because their 'plane flew into a veritable cloud of interference. By the law of averages, the manipulation of innumerable electric lighting and other switches keeps up a fairly steady stream of interference with radio, and obviously the foggier, the noisier.

I well recollect the Editor of *Wireless World* drawing my attention to this in the early days of the 1939-45 war when the R.A.F. were dropping leaflets over Germany. As a result of his remarks I invented a pilotless pamphlet-carrying 'plane in which the leaflet-dropping mechanism

His ignorance is so profound . . .

was actuated by the radiated interference ascending from the towns and cities over which it flew. The number of pamphlets released each time was strictly in proportion to the strength of the radiated interference, or in other words to the size, and, therefore, the number of inhabitants of each town. Thus paper wastage was avoided. A further advantage was that the 'plane was able to fly well out of the range of fighters and flak without the necessity of pressurised cabins and other expensive adjuncts of a piloted 'plane. The release of the last packet of pamphlets also served to turn the machine's head round for home.

Unfortunately my invention became so enmeshed in red tape that it never took the air.

Legal Loophole

ALL children born in an American embassy—which is technically U.S. territory—automatically become American citizens. Therefore, in the case of the London embassy they dodge the iniquitous purchase tax on their radio requirements, and in the case of cars are entitled also to immediate delivery. Surely this presents a golden opportunity to the staff at Grosvenor Square to help hard-pressed British parents-to-be by opening a combined maternity home and quick delivery service—for cars—in the basement?