Wireless World

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Standardizing Television I.F.

THERE is as yet nothing approaching standardization in the frequency of i.f. amplifiers in British television receivers. Some sets work on frequencies that are more susceptible than they need be to interference from the most common sources; to a lesser extent, some of them are apt to radiate oscillator interference affecting other communications. As things are, there is no practicable i.f. value that is completely free of possible interference, but some are far worse than others in this respect.

One of the strongest arguments in favour of adopting a single standardized i.f. band for all domestic television receivers is that the industry would then have a strong case for appealing to the Post Office for "protection" of the chosen band. Indeed, the G.P.O. should obviously come into the picture at an early stage, so that the practicability of giving protection could be discussed before making a final choice.

We believe that a good theoretical case can be made out for setting the i.f. amplifier to cover the band of roughly 34-38 Mc/s, but there still appears to be some lack of agreement as to whether this standard (already adopted in several commercial receivers) will show itself in actual practice to be the best that can be chosen. With well over a million television receivers already in use, we should imagine that the experience on which a quick decision could be made is already available.

Naturally enough, those concerned with all the various branches of radio communication likely to be effected by the choice of i.f. value are anxious that their own particular frequency channels should be taken into account in coming to a decision. So, of course, they should, but it seems to us that the approach to the problem should be at least as much statistical as purely radio-technical.

The transmitting radio amateurs adduce particularly convincing arguments in pleading that television receivers should not embody i.f. amplifiers working within the allotted amateur bands. There are as many amateur stations as all other kinds put together, and many of them are in densely populated areas; most other stations are in open country. Therefore the average viewer stands a greater chance of suffering from an overpoweringly strong "swamp" signal from an amateur station than from any other. The argument appears to be irrefutable. No conscientious amateur transmitter wishes to interfere with the viewer's enjoyment of television, and equally the viewer should be protected from the most probable source of interference. The case for using an intermediate frequency value outside the amateur bands seems to be proved. No i.f. channel can be found that it not already allotted to some other service, but we feel sure the problem can be solved in a spirit of sweet reasonableness on a strictly rational basis.

The Geneva Conference

WE wish that international radio problems could be settled in the same spirit as the simple little internal matter discussed in the preceding paragraphs. When *Wireless World* celebrated its 40th anniversary last year, we promised our readers that the attainment of that age would not be taken as a licence to adopt those attitudes generally associated with middle age. Sighing for the past is traditionally an attribute of the over-forties, but, at the risk of being accused of breaking a promise, we cannot help hankering after the good old days of 1938, when, at the Cairo Convention, frequency allocation problems were amicably settled between the nations on a rational basis by men having predominantly technical interests. Nowadays the scene at such conferences seems to be dominated by what a forthright American contemporary described as "high-power political characters."

However, despite the apparently inevitable East-West cleavage, a considerable measure of success was attained at the recent Geneva conference (reported elsewhere in this issue).

It would appear that saturation point has been reached in many of the bands, and the only possible means of easing the situation seems to lie in the improvement of transmitting techniques. The agreement—signed by sixty-five of the seventy-four participating countries—lays great stress on the need for mutual goodwill and co-operation. Metaphorical iron curtains are not barriers to radio waves.

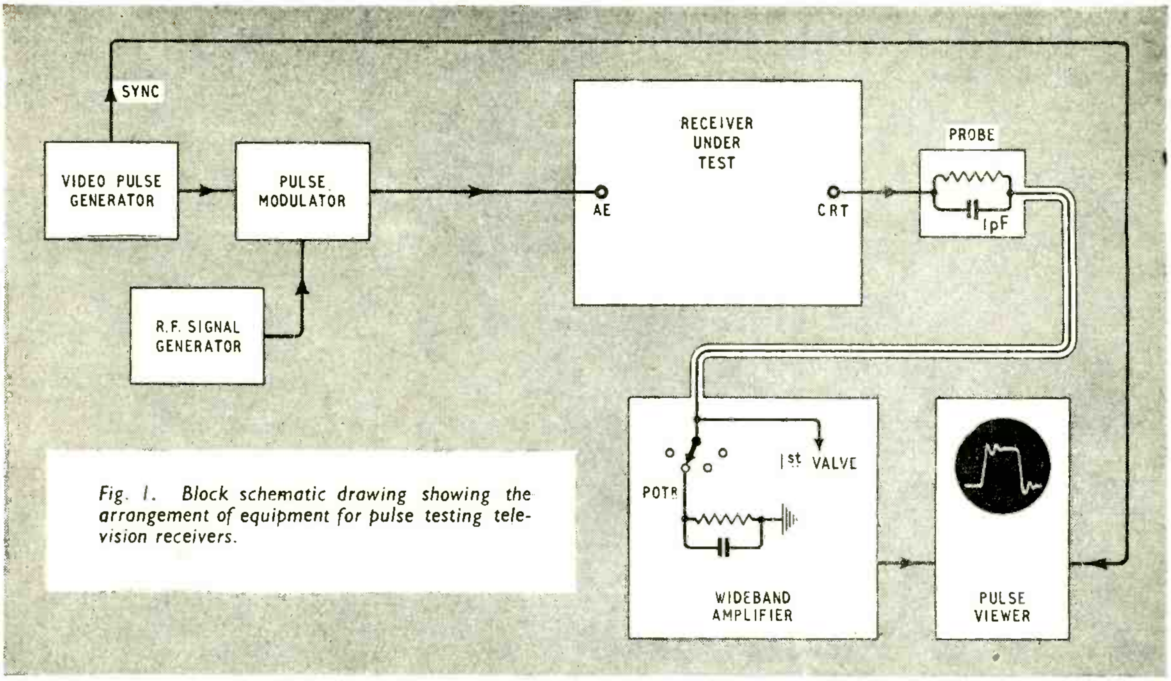


Fig. 1. Block schematic drawing showing the arrangement of equipment for pulse testing television receivers.

TELEVISION SET TESTING

Advantages of Pulse Technique : Type of Equipment Required

By M. V. CALLENDAR,* M.A., A.M.I.E.E.

IT has been normal practice, at any rate until recently, to test television receivers and other television apparatus by continuous wave methods. Thus the usual tests applied to a broadcast television receiver have been: (1) selectivity curve for r.f. and i.f. stages, (2) video frequency characteristic of video stage. These measurements are, of course, supplemented by qualitative observations on the B.B.C. test card C, noting especially the degree of clarity of the 2.5-Mc/s bars, and by looking at picture transmissions. Unfortunately, the transmitted picture quality is still too variable to make this a satisfactory test unless repeated on a number of programmes, and there is even some variation in quality with the test card. To ensure a uniform and continuous transmission, most receiver manufacturers have installed a test pattern transmitter of their own, but it is by no means easy to make this really distortionless.

In some cases, the following additional test has been used: (3) characteristic for modulation frequency versus video voltage at the c.r. tube, obtained by injecting a carrier modulated at video frequency into the aerial terminals.

The use of this test has been restricted by the fact that a special wide-band modulator unit has to be made, the modulation arrangements of a normal signal generator not being suitable. The characteristic for phase-delay against frequency is as important as the amplitude characteristic in determining the response to the impulsive signals of which a television transmission is composed; unfortunately, this characteristic is very difficult to measure and, in consequence, has never been seriously considered as a normal test.

Even supposing that all the above c.w. tests (including that for phase delay) were made, how much further are we with regard to knowing the performance of the set on impulsive signals? In theory, the performance of any network on pulses is completely determined if the amplitude and phase characteristics are known and for many circuits (minimum phase shift type) a knowledge of the amplitude characteristic alone is theoretically sufficient. Unfortunately, the calculation of the pulse response from the c.w. characteristic of a receiver always requires an impracticable amount of labour, and is virtually impossible in many cases.† The best that can be done is to make a rough empirical estimate, based upon experience of previous results of pulse tests upon apparatus of similar c.w. characteristics; this may be supplemented by a knowledge of the calculated pulse response of the simpler individual circuits for which such calculations have been made.

If we compare measured pulse responses of a number of receivers with the corresponding frequency

* E. K. Cole, Ltd.

† W. M. Lloyd, in a valuable paper "Single Sideband Receiver Design" (*Journ. Television Soc., Nov.,* 1950), succeeds in calculating the response for a simple r.f. amplifier, but is compelled to employ drastic approximations in most cases.

characteristics, the fact that stands out is that a comparatively large overshoot, or other form of pulse distortion, may correspond to an almost unnoticeable peak (or other deviation) in the frequency characteristic; for this reason estimates of pulse response from frequency response are never wholly reliable.

Why not, then, use a standard pulse input as the normal method of test, using c.w. methods only in certain cases (e.g., initial alignment of r.f. and oscillator circuits) where they are convenient?

This brings us at once up against the fact that there are no agreed standards, and no really suitable test apparatus readily available; the technique, in fact, of pulse testing is not yet fully developed, and this article is intended to be a contribution to that end.

Since any waveform can be built up from a series of steps, it is clear that a generator producing a step or unit function voltage must form the basis of any such test. We must also have a pulse modulator for tests with r.f. or i.f. units, and a specialised c.r. oscilloscope (termed a "pulse viewer") with a wide-band amplifier to examine the output from the receiver. The best form for the step or pulse, and the most convenient design for the whole equipment, can, however, only be ascertained after considerable practical experience of this type of test. The following considerations have largely determined the design:—

(a) While it is possible to use pulse methods to test the low frequency response of the receiver, this would complicate the equipment; a low frequency check is not usually necessary on conventional receivers, and where necessary (e.g., on multi-stage video amplifiers), it can be made more easily by c.w. methods.

(b) Practical equipment does not necessarily respond in the same way to positive and negative going steps, and both responses are conveniently seen if a short pulse is used for testing; for similar reasons, it is necessary to have both negative going and positive going pulses available. The pulse length should not be less than about 4 μsec, to ensure that the disturbance caused by the start of the pulse does not affect the end; it is useful also to have pulses of 10 μsec and 15 μsec lengths available as well, as respresenting the blanking interval used on the 625 (or 525)-line and the 405-line systems respectively.

(c) To cover all types of television apparatus, a rise time (10 per cent to 90 per cent) of less than 0.02 μsec for the whole test apparatus chain would be the ideal. Practical difficulties multiply rapidly, however, if it is attempted to reduce the rise time for the complete chain of test equipment below 0.05 μsec, since the rise times of amplifiers in cascade may be added quadratically, this allows of testing equipment with rise times of down to 0.07 μsec and is thus just adequate to cover television receivers including the 625-line system (nominal bandwidth 5 Mc/s). Any over or undershoot arising in the test equipment must be kept extremely small (say less than 2 per cent).

(d) The pulse viewer must be equipped with one time scale suitable for viewing the pulse as a whole, and another (say, 2 μsec for the whole scan) for measuring rise times. The time base must be of the triggered type, and a synchronizing pulse with a lead of about 0.25 μsec must be available from the generator to enable the front of the pulse to be observed in cases where the delay in the apparatus under test is small. The front or back of the pulse must be made visible at will on the 2-μsec range by a switch to shift the start of the scan.

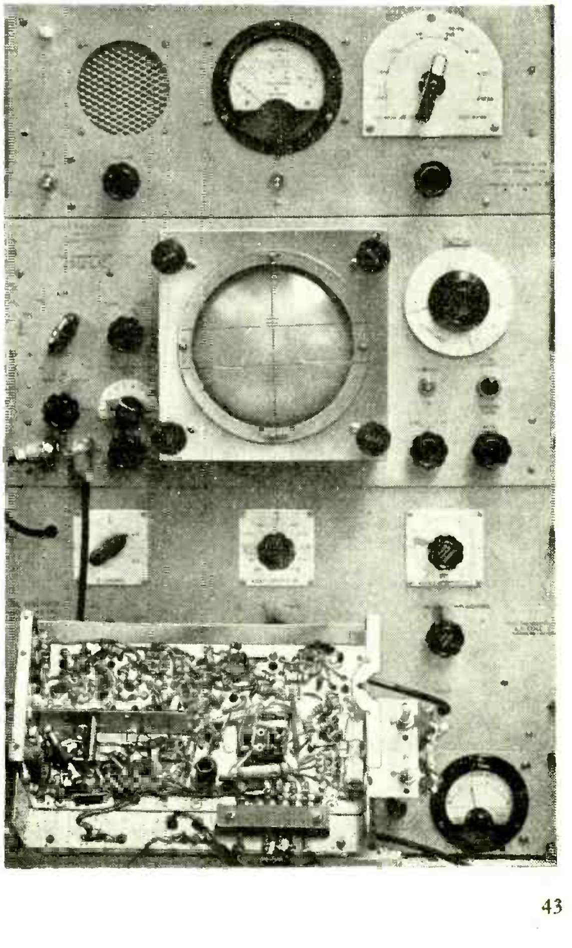
(e) The input impedance to the amplifier must be very high (e.g., capacity not more than 3 pF) to avoid disturbance to the conditions at the point of test.

Description of the Apparatus:—The illustration shows three rack-mounted pulse tests units designed for use on the above lines for mass-production testing, and the block diagram, Fig. 1, indicates the usual test set-up for a broadcast television receiver.

The pulse generator employs a multi-vibrator whose frequency is adjustable from about 10 kc/s to 30 kc/s, including a third valve (cathode follower) to ensure quick charging of the timing capacitor. The multi-vibrator feeds a delay line giving the required lag or lead for the sync pulse, which is extracted via a two-stage shaping amplifier. The video output pulse is shaped by a three-stage corrected amplifier, with output attenuator which can be connected in the anode (for negative pulse) or the cathode (for positive pulse) of the third valve. The pulse modulator is included in the generator and employs two valves in order to balance out the video pulse; even so, a fairly high level of r.f. input to the modulator (at least 0.1 V) is required to make negligible the excitation of the receiver by the residual video voltage existing at the modulator output.

The wide-band amplifier uses 6 stages, with inductive correction. A sufficiently low capacitance input can only be obtained by using a probe which

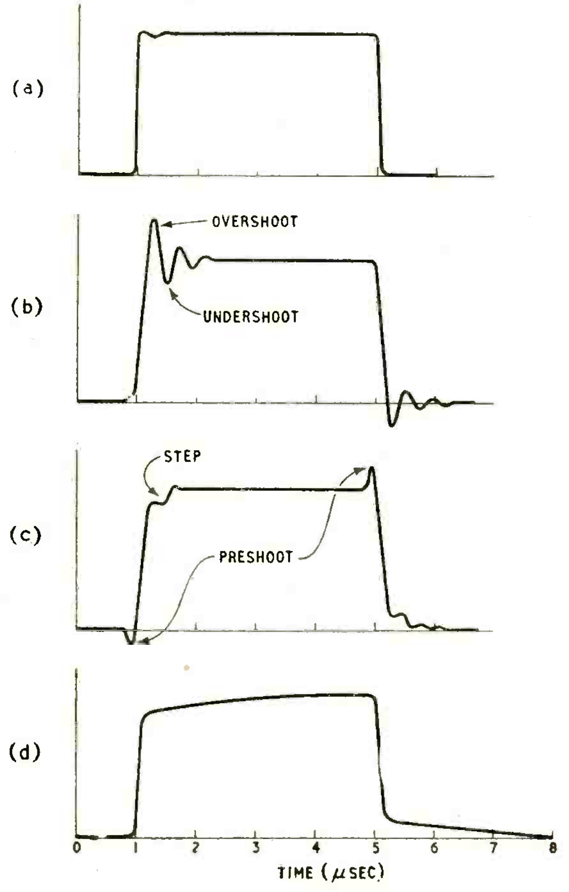
Test rack on line production of television receivers. A chassis is on test, and the actual output pulse is seen on the tube, with the 10 μsec scan in use



forms part of a capacitance corrected potentiometer; to counteract the loss (about 30 db) in the potentiometer, a rather high gain (total of 60 db) is required from the amplifier. The normal range of pulse amplitudes from about 1 to 100 V is covered with the 2.5-pF probe, and smaller pulses can be examined by an alternative probe provided that a proportionally higher capacitance input can be tolerated. The output stage presents the chief design difficulty; to obtain the required output (up to 50 V) at the bandwidth (8 Mc/s) it is necessary that the pulse be always positive going at the output valve grid (hence switch shown for positive or negative input) and that the valve used should have a high anode current at $V_g=0$. A wide-band r.f. rectifier circuit is included to enable modulators or transmitters to be tested.

The pulse viewer uses the well-known VCR97 tube, with a simple time base of the type where a capacitor is charged through a resistance from a voltage high enough (relative to the actual scan voltage required) to give a sufficiently linear time scale. An X shift control, with large-diameter scale, enables a time calibration with units of 0.01 μsec to be obtained on the 2-μsec scale, and this can be checked at any time against the built-in marker oscillator operating at 5 Mc/s. Pulse amplitude is readily measurable by a meter on the Y shift. A transparent card, with horizontal lines at 0, 0.1, 0.9 and 1.0 in, is clipped against the face of the tube when measuring rise (10 per cent to 90 per cent) times. A similar card, made matt to take soft pencil marking, is used to delineate the shape of pulses manually without the expense and delay of photographic methods, and as many paper prints as desired can be taken from the transparent card on an ordinary blue print or similar machine.

Fig. 2. Pulse waveforms (a) before transmission through a television receiver and (b), (c) and (d) after transmission as explained in the text.



It should be noted that a qualitative check on the distortion is obtained by viewing the pulse on the actual picture tube.

Results Obtained With Receivers :—Oscillogram (a) in Fig. 2 represents the test pulse, and the words "overshoot," "undershoot," "preshoot" and "step" appended to the other oscillograms represent a suggested nomenclature for the various common forms of distortion of the pulse.

When commercial receivers were first tried out on apparatus of this type the results were somewhat horrifying. Thus oscillogram (b) was obtained from a receiver giving pictures well up to commercial standards, with a noticeable, but not usually very objectionable, overshoot, showing as a white line bordering the right side of black objects (or black line for white objects). On the other hand, oscillogram (c) was obtainable from a receiver which exhibited a rather appreciable lack of definition on some pictures. This oscillogram also shows a spike, best called a "preshoot," which appears before the main transition and shows up on the picture as a line bordering the left side of objects. This often occurs in single sideband receivers and is due to phase shift at frequencies near the carrier.

A "tailing" or "smearing" effect, most often observed on captions, corresponds to an oscillogram of the type shown at (d). If a very long "tail" is seen in the course of a broadcast programme, however, it is fairly safe to attribute it to the transmitter.

It is thus clear that, while a perfect oscillogram will give a perfect picture, some experience is required to assess the degree of deterioration of picture quality corresponding to a given oscillogram. The following limits are put forward as corresponding to a just negligible deterioration in quality on a *good* 405-line transmission.

(i) Short overshoots (less than, say, 0.3 μsec duration) and very short undershoots (less than 0.2 μsec) to be less than 6 per cent.

(ii) Longer overshoots and undershoots, including "steps" and "tails," and second overshoots to be less than 3 per cent.

(iii) Rise and fall (10 per cent to 90 per cent) times not to be worse than 0.16 μsec.

A good commercial definition would still be obtained if the percentages given were doubled and the rise time increased by 50 per cent.

It is found in practice that, owing to the fact that a band-pass having a sharp cut-off (say, at 2.5 Mc/s) produces a strong oscillation when pulse excited, a compromise is necessary between the requirements of a short rise time and a low degree of oscillation. The best rise time is obtained when a relatively square-topped band-pass is used, with the response at r.f. carrier frequency 6 db down on that peak, while for minimum overshoot and preshoot, a rounded curve, with carrier about 3 db down only, is best. In the latter case some cathode compensation in the video stage must be added to avoid "tailing."

A further difficulty is that the best compromise varies with the quality of the transmission, the type of subject viewed, and with the viewer; some viewers have been known who felt that a large overshoot gave a three-dimensional quality to the picture. On quite a large percentage of the programmes transmitted, a rise time as bad as 0.4 μsec or a *short* overshoot of 20 per cent (as measured on the fast pulse test) would not be noticeable and on some few transmissions a boosted top response, which would show up as an overshoot on these tests, would actually be desirable.

For viewers in remote areas (vision peak white field strength 100 μV/m or less) a reduced high frequency response is desirable for improving the subjective signal-to-noise ratio. Thus there is as good a case for a picture quality control as there is for the usual tone control fitted to sound receivers.

In spite of the uncertainties outlined in the foregoing description, experience over the last two years has proved the pulse test equipment to be quite indispensable for laboratory design work.

As regards production of broadcast receivers, the greatest weakness in the past has been a relatively large variation in actual performance between individual sets even when trimmed to the closest practicable limits on the usual r.f. curve tracer gear. These variations were sometimes detected on the final test of the receiver on a pattern or B.B.C. transmission, but such a test is of a purely qualitative nature, depending critically upon transmission, setting of controls, and observer, and it was not practicable to reject sets on the strength of it unless the lack of fidelity was quite severe. The introduction of a pulse test on all sets has given an unambiguous and quantitative check; moreover, the test permits of a final adjustment to the video compensation to correct for normal variations in circuit constants (e.g., in stray capacitance at the video output) and in trimming, with the result that the uniformity of the final product is notably improved.

Television Society's Exhibition

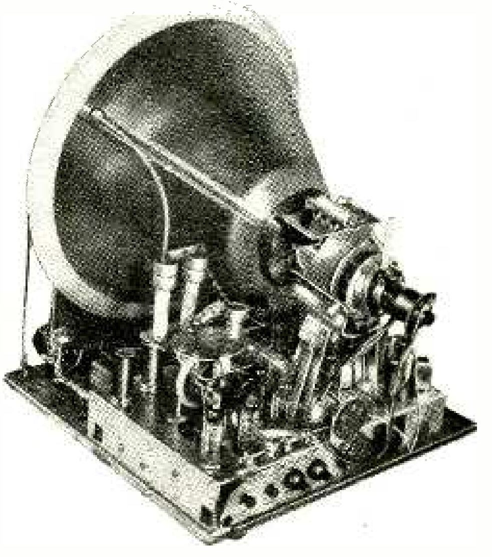
AN exhibition of television and related apparatus was held by the Television Society on 28th and 29th December, 1951 at Century House, Shaftesbury Avenue, London, W.C.2, at which there were some twenty-five exhibitors. The exhibitors were mainly Patron Members of the Society and Members.

The B.B.C. showed a working camera chain in which the camera was trained on visitors and the resulting picture was so placed that the subject could see himself. Pye Radio had a television camera, and some of its associated apparatus, in which remote-control facilities are provided.

On the receiving side, Mullard exhibited a projection receiver with a 25-in picture in addition to 16-in and 14-in direct-viewing sets. They were shown in operation with a test pattern and as an interesting comparison there was a 16-in receiver for 625 lines. Philips also had a projection console model and in a separate room Decca demonstrated front-projection equipment with a picture size of 30 in by 40 in.

A 16-in metal-tube receiver chassis in which the tube is held by a moulded polythene ring for insulation was shown by Ferguson. This set, Model 989T, has a single-valve line-scan circuit, which also provides 14 kV for e.h.t., in which adjustable core saturation is used as a linearity control. The receiver is a superheterodyne tunable over the band 40-70 Mc/s; there is an aerial rejector circuit at 70-100 Mc/s to reduce second-channel interference.

Some interesting test equipment was on view. The most ambitious was undoubtedly the four-rack pattern generator of Bush Radio. Built for factory-production testing, it provides the proper sync waveforms and a



Ferguson Model 989T television receiver with 16-in metal tube.

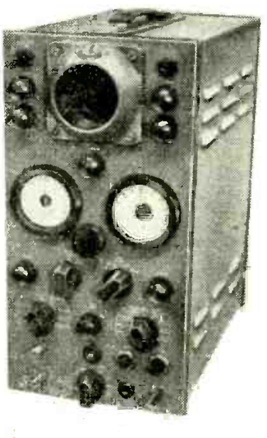
complex pattern as modulation on all five of the television channels. The pattern includes a pulse which occurs on alternate frames and serves as an interlace indicator.

The Samwell & Hutton wobbulator Type 41 covers all the B.B.C. frequencies and 8-18 Mc/s for i.f. alignment and provides a sweep of 10 Mc/s. There are 5-Mc/s and 1-Mc/s crystal circuits to provide calibration pips on the trace. Other crystals provide marker pips at the sound-channel frequency for each station. The r.f. output is 1 μV to 100 mV at 75 Ω and the oscilloscope input must be 1 V for a trace of 4 cm.

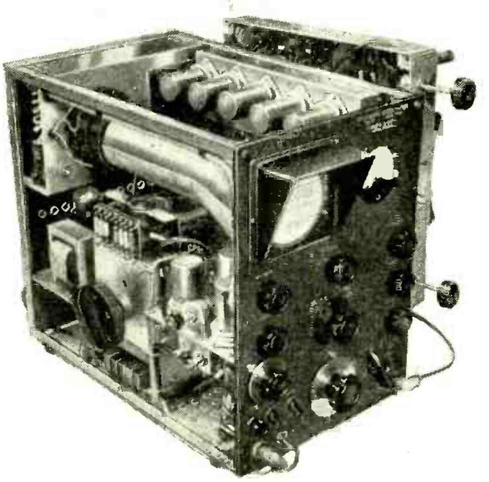
A miniature waveform monitor, type WM3, by E.M.I., measures only 15 in by $7\frac{1}{2}$ in by 14 in and has a $2\frac{1}{2}$-in tube. The vertical-deflection amplifier has two stages, d.c. coupled. The coarse-gain control changes bandwidth as well as gain in three steps and permits pulse rise-times of 0.3, 0.5 and 2 μsec in the low, medium and high gain positions. Provision is made for the measurement of voltage to an accuracy of $\pm 2\frac{1}{2}\%$ over the range of 2 mV to 500 V.

Waveforms Ltd. showed their well-known portable signal and pattern generator and Livingstone Hogg exhibited the Murphy pattern generator. The effect of spot wobble was the subject of a demonstration by Ediswan, using a 15-in receiver and a test pattern. Cinema-Television had a display of test apparatus which included a square-wave generator, and a constant-impedance low-pass filter, a phase-correction unit and a high-speed oscilloscope. Murphy exhibited, in operation, a line-selector which enables any individual line of a television picture to be selected and displayed on an oscilloscope.

Precision oscilloscope tubes, both single and double beam, with flat screens, were shown by 20th Century Electronics, who also exhibited a range of counter tubes.



E.M.I. Miniature waveform monitor Type WM3 and (below) Samwell & Hutton television wobbulator Type 41.



Among the private members' exhibits was a new viewing filter shown by C. A. Cove and S. Taylorson of the G.E.C. It comprises a piece of grey fabric with a mesh of 60 threads per inch with a light-transmission efficiency of 60%. It is stretched over the inner face of the clear safety-glass. It is claimed that reflections from the face of the tube are eliminated due to its directional properties.

T. Kilvington, of the Post Office Research Department, showed a timing device for photographing television images. The camera shutter itself gives an exposure of $\frac{1}{5}$th second and operates a mechanism to produce a $\frac{1}{25}$th second brightening pulse which is applied to the c.r. tube. The effective exposure is precisely controlled by this pulse and not by the camera shutter.

An automatic aerial polar-diagram plotter was shown by Belling-Lee; and Acheson Colloids exhibited specimens showing the applications of colloidal graphite which included printed circuits and the screening of television sets by an internal coating to the cabinet.

B.R.E.M.A. demonstrated safety precautions applied to a television receiver in connection with a revision of BS415 (Improvements in Safety of Domestic Receiving Equipment). By pressing buttons it was possible to place defects in various parts of the sets and to demonstrate by lamps the protection afforded by properly placed fuses, cut-out, etc. Tests for the satisfactory isolation of live parts, with a metal finger, a 20-lb straight pull on control knobs, etc., were demonstrated.

RADIO RESEARCH

THE work carried out by the Dept. of Scientific and Industrial Research in 1950, based on the programme of fundamental research drawn up by the Radio Research Board, is summarized in the Report recently issued by D.S.I.R., "Radio Research, 1950."* It opens with a brief review by the chairman of the Board (Sir Stanley Angwin) of the programme of research and of the constitution of the Board. This is followed by a detailed report by the Director of Radio Research (Dr. R. L. Smith-Rose) of the investigations conducted mainly in the Radio Division of the National Physical Laboratory—which includes the Radio Research Station at Slough and its outstations.

Whilst a very large part of the report is concerned with matters relating to the propagation of radio waves—along the ground, through the troposphere, via the ionosphere—and, too, the forecasting of propagation conditions, there are interesting sections dealing with research on materials, valve and circuit noise, atmospheric noise at high frequencies, and decimetre wave-measuring techniques.

The section of the Report dealing with research on materials is concerned largely with semiconductors. It is pointed out that the performance of germanium triodes and diodes, is very dependent upon the concentration and nature of the impurities in the crystal. Arrangements have, therefore, been made with the Chemical Research Laboratory for the investigation of techniques for the analysis and purification of germanium.

* H.M.S.O. price 1s. 9d.

Mechanism of Magnetic Recording

Influence of Asymmetrical Hysteresis on the Recording Characteristics

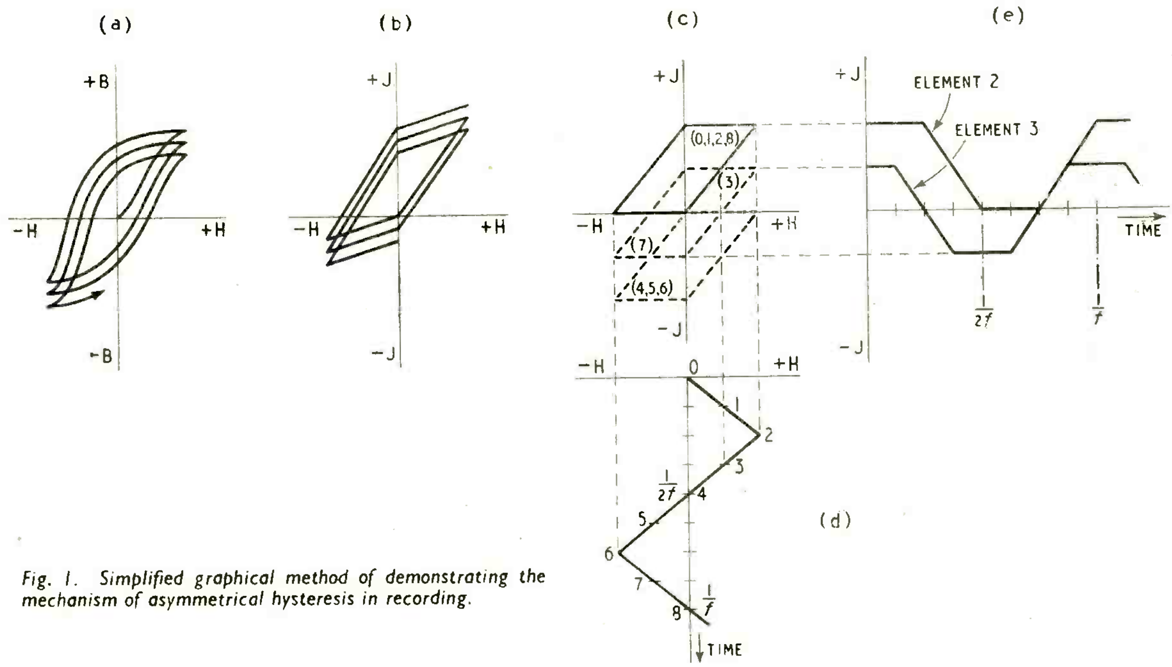


Fig. 1. Simplified graphical method of demonstrating the mechanism of asymmetrical hysteresis in recording.

ALTHOUGH magnetic recording has now established itself as a practicable medium for high-quality sound reproduction, and is widely used in broadcasting and by the record manufacturing companies, no completely satisfactory theory has been advanced to account for all the observed facts.

A recent paper* by P. E. Axon, M.Sc., A.M.I.E.E., of the B.B.C. Research Department, throws new light on the subject and predicts results which are somewhat unexpected. Nevertheless, good correlation between theory and measurement is maintained even when drastic simplifying assumptions are made in order to present the theory in a readily comprehensible form.

The foundation of most attempts which have so far been made to explain magnetic recording has been the stable symmetrical hysteresis loop of the material. Within this framework and with the aid of minor hysteresis loops, recoil paths and the familiar stock in trade of the magnet designer, transfer characteristics have been developed which relate the current in the field coil with the remanent magnetism on the tape. These are satisfactory only to the extent that they show linearization of the characteristic with the addition of high-frequency " bias." A single characteristic of this type implies that, as in the case of a valve characteristic, any distortion remaining should be a function of amplitude and not of frequency. It is known that the *reproducing* gap length affects the response of the system which falls to zero at frequencies where the effective gap length equals an integral number of wavelengths, but it is often stated that the recording gap length is uncritical and that the remanent induction left on the tape is determined only by the magnetic state as each element leaves the gap.

This is only partly true and by using long recording gaps, Axon and his colleagues of the B.B.C. Research Department have proved that, in the absence of h.f. bias, there is not only a cyclic variation of recorded level as the ratio of wavelength to gap length is decreased, but that there is also a cyclic variation of distortion. Briefly, if D is the length of the gap and λ the wavelength at a given frequency and tape speed, it is shown that the magnetic intensity is zero when $D = \frac{3}{4}\lambda$, $1\frac{3}{4}\lambda$, $2\frac{3}{4}\lambda$, etc., and that distortion is zero for $D = 0$, $\frac{1}{2}\lambda$, etc., and reaches a maximum between $D = \frac{1}{8}\lambda$, and $\frac{3}{8}\lambda$ and between $\frac{5}{8}\lambda$ and $\frac{7}{8}\lambda$.

The simplification which Mr. Axon has made to demonstrate graphically the basis of his theory are given in Fig. 1, which, together with the remaining figures, is based on those given in the I.E.E. paper. Fig. 1(a) shows the character of the asymmetry in the B-H curve of a typical magnetic tape material during the first few cycles after the application of an alternating field in which the first quarter cycle is positive-going. It will be noticed that there is a bias of the " centre of gravity " of the loops towards + B. As a first approximation the loops can be drawn with rectilinear

*Read before the Radio Section of the Institution of Electrical Engineers on December 5th, 1951.

sides, Fig. 1(b), and it is also more appropriate to plot H against J, the magnetic intensity ($B = H + 4\pi J$), since J is more nearly related to the magnetic intensity remaining in the tape after it has left the field. Since the tops and bottoms of the loops approach the horizontal, and since it can be shown that they do not progress far towards the symmetrical condition during the time that any element of the tape is in the gap, a single loop of the form shown full-line in Fig. 1(c) may be substituted. If the first quarter cycle had started from zero and been negative-going the equivalent loop would have appeared below the H axis. The position of the loop will be determined by the first maximum value of the magnetizing field to which any element of the tape is subjected after entering the gap, and bearing this in mind we can trace out the magnetic intensity developed in separate elements of the tape when they enter the gap at various phase intervals of an applied alternating field. It will be convenient to use the triangular waveform of Fig. 1(d) and to consider intervals of $\frac{1}{8}$ cycle. It is assumed that each unmagnetized element will instantly acquire a magnetic intensity proportional to the field prevailing at the time of entry into the gap, and the subsequent waveform of the induction can be traced by following the contour of the appropriate loop.

On this basis the history of two typical elements entering at the instants numbered 2 and 3 in (d) are traced in Fig. 1(e). Element 2 enters at the positive field maximum which it retains during the next quarter cycle, while travelling along the top of the loop from right to left, until it meets the J axis, when it falls to zero, follows the H axis from left to right, then rises again. Element 3 jumps to half positive maximum on entering the gap, but although the field intensity is falling, the induction remains constant, travelling along the top of the middle loop in Fig. 1(c) until it reaches the J axis after $\frac{1}{8}$ cycle and then falling down the left-hand side of the loop to an equal and opposite value before following the bottom of the loop from left to right and then rising up the right-hand side. The numbers inside the loops of Fig. 1(c) indicate the elements with which each is associated.

A complete cycle of intensity curves at $\frac{1}{8}$-cycle increments of time of entry into tha gap is shown in Fig. 2. To find the effect of the recording gap width on the amplitude and waveform of the remanent magnetic intensity on leaving the gap, vertical intercepts are drawn at $\frac{1}{8}\lambda$ intervals, and the values at each intercept are replotted as in Fig. 3.

Inspection shows that output is zero at $D = \frac{3}{4}\lambda$. If one regards zero output as rather bad distortion it is not surprising to find this curve flanked by badly distorted versions of the original triangular wave. A similar if less severe focus of distortion occurs at $D = \frac{1}{4}\lambda$. The original waveform comes through unchanged at $D = \lambda$, $\frac{1}{2}\lambda$, and 0, though the latter is obviously a theoretical abstraction since nothing would in fact be recorded under this condition.

To test the validity of the asymmetrical hysteresis hypothesis the B.B.C. Research Department have carried out accurate measurements of distortion using a fixed recording gap of 350μ length, and a fixed

Fig. 2. Magnetic intensity variation with time of elements entering the gap at phase intervals indicated by the numbers in Fig. 1(d).

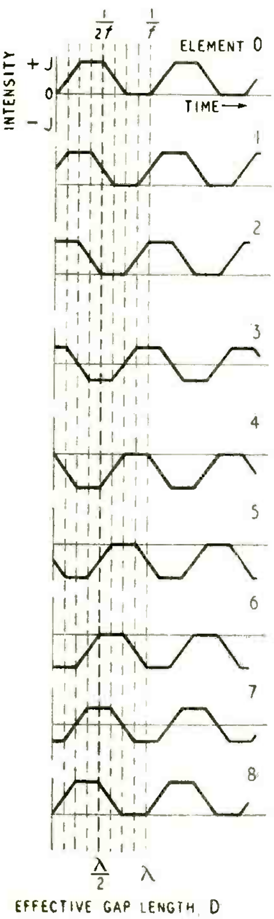


Fig. 3. Waveforms developed by recording gaps of different length, and plotted from amplitudes indicated by vertical intercepts in Fig. 2.

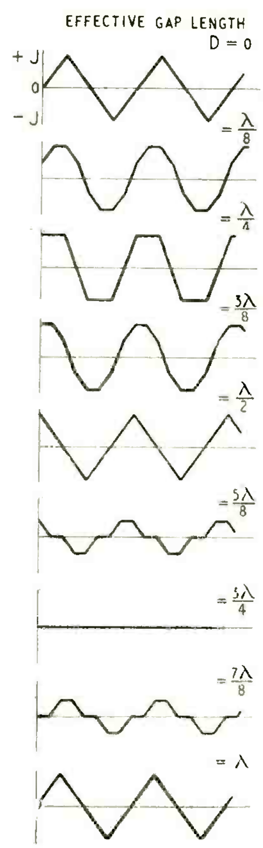
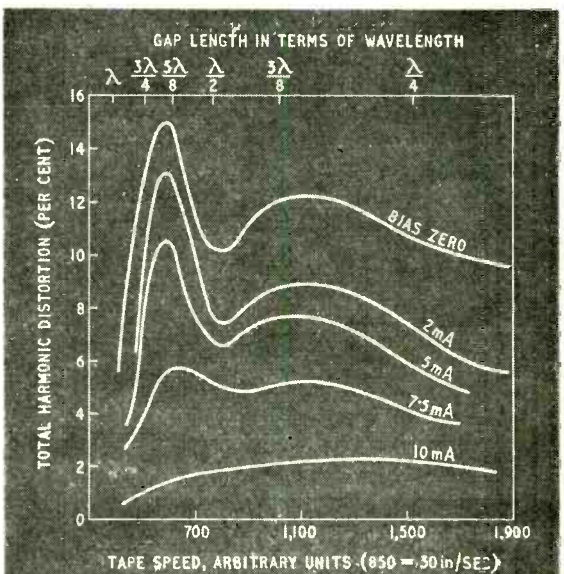


Fig. 4. Experimental verification of dependence of distortion on gap length. As h.f. bias is increased the distortion related to the gap length decreases.



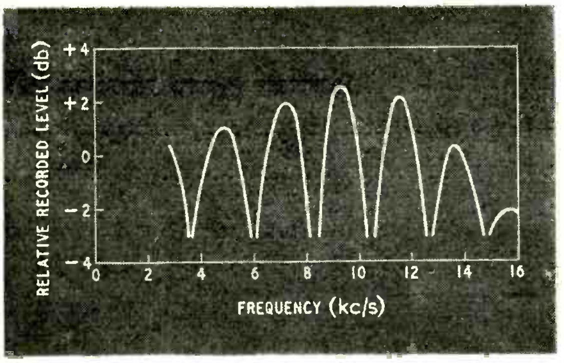


Fig. 5. Overall frequency response with 550-μ recording and 20-μ reproducing head. Tape speed 47.25 in/sec. Zero bias.

frequency of 1 kc/s to enable a single high-pass filter to be used to separate the distortion products. The ratio of gap length to wavelength was varied by altering the tape speed.

The results of these measurements are shown in Fig. 4 and the predicted minima of distortion at $D = \lambda$ and $\frac{1}{2}\lambda$ are clearly evident; maxima appear between $D = \frac{5}{8}\lambda$ and $\frac{3}{4}\lambda$ and $D = \frac{3}{8}\lambda$ and $\frac{1}{4}\lambda$.

The effect of recording gap length on the recorded level was investigated by using a fixed gap of 550μ (physical) and constant tape speed (47.15 in/sec). The ratio D/λ was varied by changing the recorded frequency and the results are shown in Figs. 5 and 6. The latter represents a plot of frequency against gap length on the assumption that minima occur at $D = \frac{3}{4}\lambda$, $7/4\lambda$, $11/4\lambda$, etc.; in other words the slope of the lines have a slope of $f/4n + 3$. The points obtained from Fig. 5 and a similar plot at another tape speed show a remarkably good fit. The playback head used in these measurements incidentally, was a normal ring type with a 20-μ gap.

From Fig. 5 it will be seen that minima are still occurring at frequencies above 16 kc/s. At 17 kc/s with a 550-μ gap each element of the tape must experience about 8 complete cycles of magnetization, from which it is reasonable to conclude that symmetry has not been reached even after 8 cycles. Under practical recording conditions with a gap of 40μ, a tape speed of 30in/sec and a bias frequency of as high as 100 kc/s, less than 8 cycles of bias will be impressed on any given element while it is traversing the gap.

It follows that the principle of asymmetrical hysteresis can be applied equally well to the case of recording with high-frequency bias. Fig. 7 shows how a graphical analysis, on the lines of Figs. 1 and 2 may be carried out, though far more graphs than are shown there would be necessary for quantitative calculation. After a few cycles (see for example Element 4 in Fig. 7) the pattern settles down to the same steady state, irrespective of the phase at which the element enters the gap, and, unlike the unbiased curves of Fig. 2, the peak intensities are always symmetrical about the horizontal axis. Consequently with adequate bias there can be no cyclical variation of distortion or output, depending on the ratio of gap length to wavelength; and there will be an increase of output when the a.f. component is extracted from the mean of the h.f. intensity fluctuations. The hysteresis asymmetry of the tape material will be impressed on the h.f. intensity variation of each

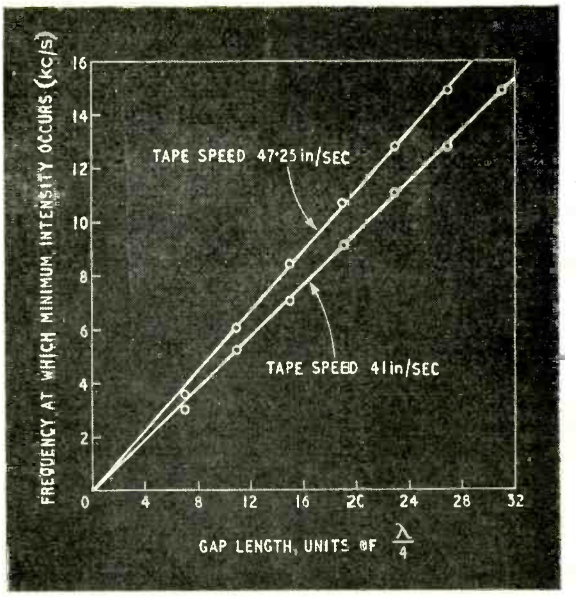
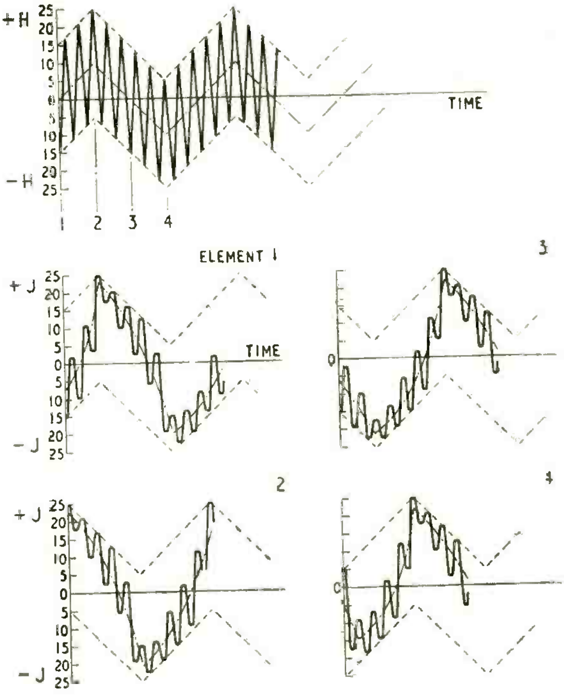


Fig. 6. Relationship between gap length and frequency at which minima occur.

Fig. 7. Elementary graphical presentation of recording with h.f. bias by the same method as Fig. 1 and 2. Signal amplitude 10 units, bias amplitude 15 units. Frequency ratio 1 : 10.



element, and will not affect the a.f. component in the same manner as in the unbiased condition.

That is not to say that distortion no longer exists. The symmetry is not established until a specific minimum amplitude of bias is exceeded. Further

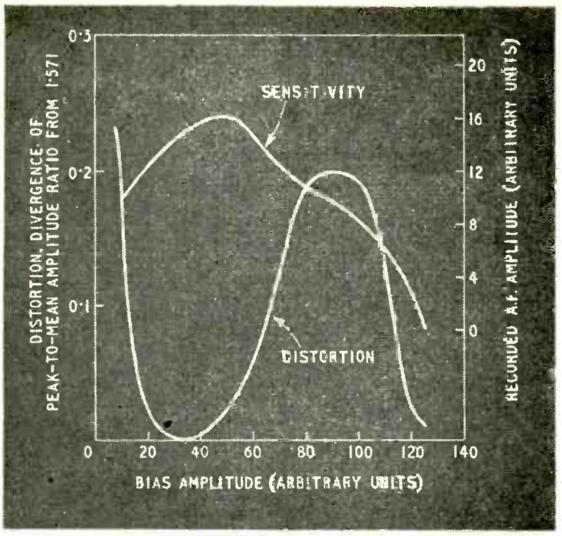
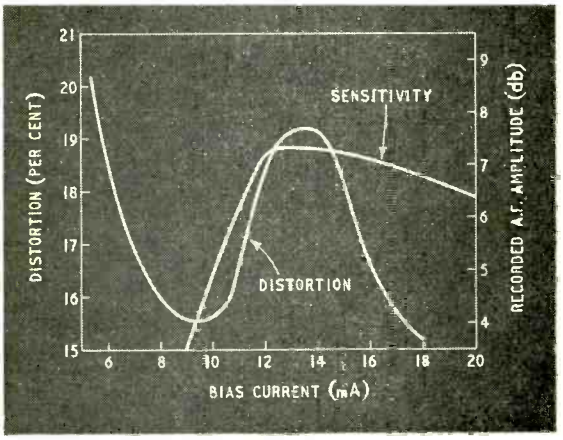


Fig. 8. Calculated variation of sensitivity and distortion with bias amplitude.

Fig. 9. Measured variation of sensitivity and distortion with bias for one particular head and tape speed.



increase of bias amplitude relative to the a.f. amplitude involves the risk of saturation of the tape material on peaks. There is an optimum range of bias values over which distortion is a minimum.

This aspect has been investigated statistically, using calculated peak intensity tables for sinusoidal bias and a.f. components of different amplitudes. The curves of Fig. 8 are based on this analysis and show a strong family likeness to the experimental curves of Fig. 9. The approximate method (peak/mean ratio) used in calculating the distortion, losses in the head at the bias frequency and differences in the scales of the curves would account for much of the detailed discrepancy.

The paper deals with many other factors contributing to the recording process, e.g., the relation between the physical and effective length of the recording gap, the influence of the "remanence constant" of the hysteresis loop and of "magnetic viscosity" on the recording characteristics.

As one contributor to the discussion remarked, the original paper is rather like a quarry; it calls for hard work, but has many rich veins.

HOT STYLUS TECHNIQUE

IF a sharp-edged stylus of the type normally used for cutting a wax master is used for direct recording on a cellulose lacquer disc, the background noise is high and for direct recording it is usual to bevel the cutting edges to form what are termed "burnishing facets." Although this reduces surface noise it also results in some loss of high-frequency response.

It is thought that the production of heat at the burnishing facets is an essential factor in the production of a polished groove surface and the reduction of "horns" thrown up at the edges of the groove. The difference in the power required to cut a disc with a modified stylus of this type supports this hypothesis. It is argued that if heat could be applied independently of the cutting process, a sharp-edged cutter, or one with the merest suggestion of a burnishing facet, could be used, and a high-frequency response comparable with wax recording obtained.

There are two schools of thought on how the heat should be applied. C. E. Watts, in this country, favours general heating of the record surface by radiant heat from a suitable lamp, while in America the general practice is to heat the cutting stylus itself by a subsidiary coil wound round the shank.

Some experiences with the latter technique formed the subject of the opening lecture by M. C. Philip at the British Sound Recording Association's "members night" on 21st December last. Mr. Philip showed a series of curves giving the measured relationship between surface noise and recording diameter with and without applied heat. These indicated that whereas the cold stylus gave increasing noise as the groove diameter fell, the noise with hot stylus *decreased*. In the discussion which followed it was suggested that this might be due to increased temperature at the cutter edges as the rate of removal of heat was reduced, but it was agreed that this point could not be settled unless some method could be devised for measuring local temperature at the cutting edge.

It was emphasized by Mr. Philip that the swarf travels further up the back of the cutter with a hot stylus and that reliable swarf control, by pneumatic or rotary collectors, was essential in view of the fire risk. He had found 44 s.w.g. enamelled copper wire suitable and preferable to nickel-chrome for the heater coil, which should be placed fairly high up the shank. Direct-current heating from an accumulator was ideal, but rectified and smoothed a.c. has proved satisfactory.

NEW BOOK

"**Microphones.**"—Although much has been written on the design and use of microphones the material is widely diffused in the literature, and the space devoted to the subject in general textbooks of acoustics is seldom adequate. Not only does this new book collect all the relevant information in one place, but it presents it in lucid and well-ordered manner against a background of simple physical principles.

Written by the staff of the Engineering Training Department of the British Broadcasting Corporation primarily as a manual for B.B.C. engineers, it will prove equally useful to sound recording and public address technicians; in fact, to all with an interest in sound reproduction.

Published for *Wireless World* by arrangement with the B.B.C., this book is obtainable from our Publishers, price 15s 6d (postage 5d). There are 114 pages and 78 illustrations.

REVIEW OF 460 MC/S

Can Decimetre Waves Relieve Congestion on the Metre Band?

By E. G. HAMER, B.Sc. (Eng.) (Hons.), A.M.I.E.E.*

THE ever-increasing use of radio for mobile and fixed services has led to serious congestion on the frequency bands at present in widespread use. Therefore, the obvious tendency is for the available channels to be allocated to priority services, less serious users being ultimately forced towards the higher frequencies. But these higher frequencies are still regarded as somewhat unattractive, due to decreased technical performance and higher cost, brought about by the need for special valves and circuits.

This has been true in the past of the "business radio" band (460-470 Mc/s) and other frequencies in the same region, but new technical developments, particularly in valves, make the economics of such frequencies more attractive. As to performance, they can, in fact, closely approach that of the lower frequencies, as a loss in one part of the system can be counterbalanced by a gain in another. The aerial is an important factor in this line of attack; for a given physical size the higher the frequency the better the performance can be made. Smaller aerials also have an attraction where "walkie-talkies" are concerned.

It has been shown that frequencies in the band 460-470 Mc/s can give a very satisfactory mobile service, only slightly inferior to that in the lower bands.[1, 2] One of the main reasons for this is that in mobile systems working at the extreme limit of receiver sensitivity the limiting factor is thermal and man-made noise. It has been proved experimentally that in urban areas the total amount of noise in a given bandwidth decreases as the frequency is increased, and up to about 500 Mc/s the decrease of atmospheric noise more than counterbalances the degradation in performance of the receiver. Above 500 Mc/s the noise factor of the receiver is more rapidly degraded and outweighs any improvement due to the decrease of atmospheric noise.

Taking into account these two factors only leads to the conclusion that the optimum performance of a practical receiver in an urban area will be at a frequency of about 350-450 Mc/s. This, of course, takes no account of the increasing propagation losses at the higher frequencies.

Simple mobile services for "business radio" use would normally be confined to the less serious domestic user. Low transmitter power, simple receivers and free running oscillators would probably be used and it would appear desirable that these types of transmission should be restricted to a band of their own to avoid interfering with priority users. One of the dominating factors in the design of this type of equipment is low cost, and this calls for a relaxation on the usual demands for frequency stability. Such simple equipment can give useful ranges of up to one mile in the open and from 60 to 100 yd when used inside a building, but normally it would not be suitable as part of an existing mobile system.

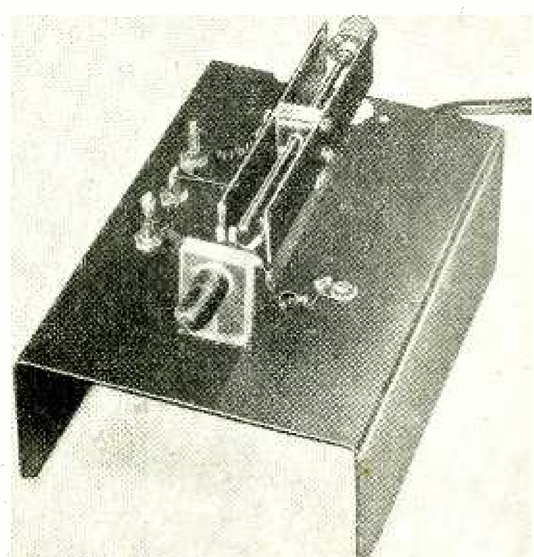
One of the main deterrents in the past to the design of the transmitting equipment has been the lack of suitable cheap valves. In the past the available valves have been of the disc seal or "lighthouse" type, which are capable of operation at much higher frequencies, and hence are really wasted at these frequencies. These types of valve require elaborate and expensive circuits as they have not normal bases. This position was realized and a disc seal valve assembly mounted in a glass envelope on a B7G base (the Osram type

TABLE 1

Performance of Valves as Oscillators

Valve type	Make	Approx. max. freq.	Approx. power output at 450 Mc/s.
EAC91	Mullard	500 Mc/s	0.1 watt
ECC91 (6J6) ..	Mullard	50 Mc/s	0.3 watt
EC5[illegible]	Mullard	500 Mc/s	0.15 watt
EC70	Mullard	500 Mc/s	0.25 watt
12AT7		500 Mc/s	0.5 watt
A1714	Osram	1,000 Mc/s	0.6 watt
Det22	Osram	3,000 Mc/s	1–2 watts

The illustration below shows a slab-line oscillator for 460 Mc/s.



* G.E.C. Research Laboratories Wembley.

[1, 2] References to be found at end of article.

A1714) was developed and led to a considerable simplification of circuit design.

In recent years further valves capable of operating at 460 Mc/s have been added to the various manufacturers' ranges, and Table 1 lists the approximate measured performance of several different types when used as oscillators. The power output to a large extent depends upon the efficiency of the circuit and how much of the power is directly radiated. It has been found that one of the most efficient simple line circuits is that of the "slab" line; this consists of a central conductor with a flat plate along each side. The photograph shows a half-wave "slab-line" with an EC70 valve on one end and a tuning condenser at the other. Where larger powers are required radio frequency amplifiers may be used, or the last valve may be a multiplier. Disc seal valves connected in earthed grid circuits are often used as amplifiers, and Table 2 gives the performance of some types of valve functioning as amplifiers at 450 Mc/s. Table 3 gives the measured performances of certain valves when used as frequency triplers with an output at 450 Mc/s.

In the design of simple equipment the major difficulty is the reduction of heater power to a minimum; one of the few directly heated valves capable of oscillating at 460 Mc/s is the type 958 acorn. The output in this case is extremely low, and where more power is required a valve such as the EC70 would have to be used although it has a 6.3-volt, 150-mA filament.

Amplitude or frequency modulation may be used with the systems concerned, and in the case of the walkie-talkie Fig. 1 shows the circuit diagram of a simple transmitter using a germanium crystal to produce frequency modulation of the oscillator. The crystal is loop-coupled to the oscillatory circuit and the amount of coupled resistance and reactance is varied by passing the speech currents through the crystal.

For a simple receiver the type 958 valve would make a good detector, or possibly a silicon crystal could be used. Where a more elaborate receiver is envisaged triode valves, such as the 12AT7, Mullard EC91, or Osram A1714, can be used as earthed grid radio-frequency amplifiers and mixers. The measured noise factor of such receivers with a single r.f. stage is 6 to 10 db[3]. An alternative method is to use a silicon crystal mixer followed by a low noise factor i.f. amplifier, and this is capable of giving an overall noise factor better than 10 db. The advantage of r.f. valve amplifiers is that more selectivity may be added without lowering the performance of the receiver. After the mixer circuit the remainder of the equipment could be designed using present techniques, although special designs might be necessary for the wide-band circuits required for multi-channel links. One of the best circuits to use for the early stages of a wide-band low-noise factor i.f. stage is a neutralized earthed cathode circuit followed by an earthed grid circuit, and although the voltage gain will be reduced there is a considerable power gain which makes the noise contribution of following circuits negligible. Table 4 gives the measured overall noise factor at 40 Mc/s of the above-mentioned circuit when using different types of valve.

Many kinds of aerials may be used and at a frequency of 460 Mc/s even the more complex types are attractive by virtue of their small physical size. A corner reflector giving a gain of 10 db would be approximately a 4ft cube, and a helical antenna, or an array of helical antennæ, would be nearly the same volume.[1] For mobile systems an array of vertically stacked dipoles could be used, and two half-wave dipoles with a total stack length of one and a half wavelengths should give a gain of 3 db over a single dipole. Such types of aerial are even feasible for the mobile station as when designed as a whip aerial the total length above the roof of a vehicle need not be more than two feet. The fixed station aerial could, of course, be more elaborate and an omni-directional gain of 6 to 8 db over a simple dipole can be obtained in a reasonable physical size.

At a distance of 30 miles over smooth earth the transmission loss at 460 Mc/s would be some 8 to 10 db greater than at 100 Mc/s, and for fixed-station working this could be overcome by the increased aerial gain possible. For mobile services, where a considerable amount of reflection and refraction is taking place, the level of signal to be anticipated is not so readily calculated. In certain cases measured and calculated values have agreed very well, particularly in urban areas. In towns where the signal strength varies rapidly in a fluctuating manner over a distance of a few feet correlation is more difficult, but practical tests have shown the value of mobile systems operating on 460 Mc/s.[1,2]

As the nulls of the standing wave patterns at the higher frequencies are much closer than at the lower, careful receiver design is necessary to reduce the effects of "flutter" as the mobile station moves through the resultant radiation field. Even in densely built-up areas communication is possible in streets, etc., considerably out of line-of-sight of the transmitter. In certain cases, however, such as railway tunnels, communication is possible only on the higher frequencies.[3] The mechanism of this is as yet not fully understood, but it is believed to be due to the additional "grazing" losses at the lower frequencies, as satisfactory communication can be established at frequencies even higher than 460 Mc/s.

When investigating the theoretical propagation loss

TABLE 2

Performance of Valves as Amplifiers at 450 Mc/s

Valve type	Make	Approx. power output
Det22	Osram	1–2 watts
Det24	Osram	5 watts
ACT22	Osram	40 watts

TABLE 3

Performance of Valves as Triplers to 450 Mc/s

Valve type	Make	Approx. power output
Det22	Osram	0.5 watt
12AT7		0.25 watt
12AT7 (pair)		0.5 watt
QQV06-40	Mullard	5–8 watt

TABLE 4

Valve type	Make	Overall noise factor in db
EC91	Mullard	4.0
12AT7		5.5
ECC91	Mullard	5.5
Z77 (as a triode)	Osram	4.0

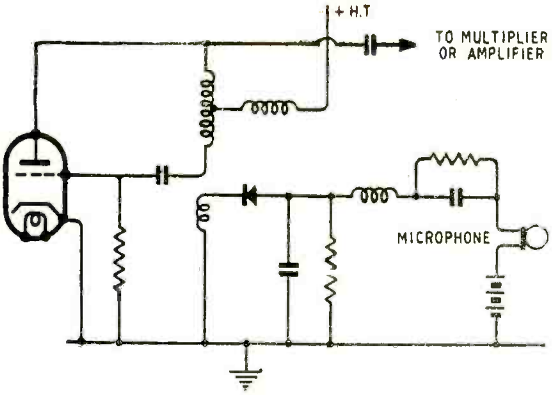
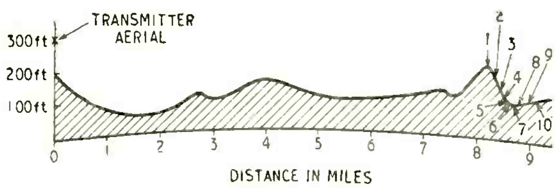


Fig. 1. Circuit diagram of a simple transmitter employing a germanium crystal to produce frequency modulation of the oscillator.



SITE NUMBER	1	2	3	4	5	6	7	8	9	10
THEORETICAL FIELD STRENGTH	3·2	7·2	3·5	3·6	4·1	4·5	4·5	5·2	5·2	5·7
MEASURED FIELD STRENGTH	5·6	12·4	7·2	5·6	7·2	5·6	5·6	7·2	5·6	7·4

Fig. 2. Ground contour to typical sites and comparison of theoretical and measured field strength in μV in half-wave dipole.

the nomograms derived by Bullington have been used,[6] and in many cases have given results very similar to the measured results. Fig. 2 shows a typical contour to a number of sites tested and also the comparison between the measured and theoretical results. The method used was to calculate the free space propagation loss to the site, and then allow for the "grazing" loss due to the first ridge of hills, and the shadow loss relative to free space due to the second ridge of hills. In this instance some 30 measurements were made with the transmitting aerial some 300ft above sea level and over country terrain, with good agreement between theoretical and measured values. Similar tests were made with the identical equipment in a built-up area, with the transmitting aerial approximately 30ft above the level of the roof of the building used and the adjacent buildings. Although consistent results were obtained from some dozen readings, in all cases the measured field strength was some 10 db less than that predicted theoretically, and this is probably due to the fact that the adjacent buildings give additional grazing losses as the height of the aerial is such that first "Fresnel" zone clearance is not obtained for a distance of approximately 0.1 mile from the transmitting aerial. Such a loss is, of course, a function of the height of the aerial above the general roof level rather than its actual height above ground level. Small increases of aerial height above the general roof level would probably give much larger signals and vice versa. In general, a satisfactory service is obtained in built-up areas with good continuous signals even in narrow canyon-like streets, and with little difference between adjacent streets which are radial and circumferential to the fixed station.

In conclusion, it would seem that equipment operating on frequencies of the order of 460 Mc/s is both a technical and economic possibility, in the most adverse case, i.e., mobile systems, there might be some slight degradation of performance from similar equipments operating in the lower frequency bands. American manufacturers have already marketed equipment suitable for these frequencies and such a mobile system is in operation in Chicago.[7]

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[6] K. Bullington, "Radio Propagation at 460 Mc/s," *Proc. I.R.E.*, 35, pp 1122-1136, Oct., 1947.
[7] "450 Mc/s Mobile Equipment," *FM-TV Radio Communication*, 11, No. 5, pp 17 *et seq.*, May, 1951.

MEASURING TELEVISION INTERFERENCE

A REPORT describing a prototype test set for measuring the interference produced by motor car ignition systems at television frequencies has been issued by The Electrical Research Association. The basis of the equipment is a five-stage t.r.f. amplifier centred on 45 Mc/s and taken from a war surplus Type 153 receiving unit having a band width of ±2.5 Mc/s. It is coupled by an attenuator and an 80-ohm line to a dipole aerial.

A special rectifying system is employed, which in conjunction with a peak valve-voltmeter gives readings substantially constant over the range of repetition rates encountered in car ignition systems.

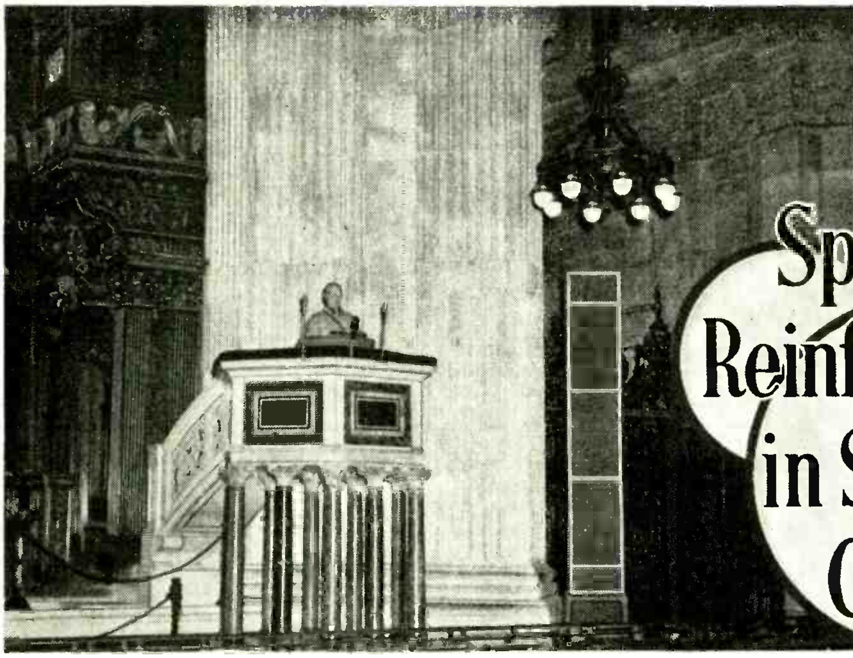
Measurements show that the interference from any individual car is reasonably constant over the frequency range 40-70 Mc/s, so that tests made at any one spot frequency within this range will be representative of the interference throughout the whole television band.

A commercially made measuring set based on this report has been produced and its description in a revised Code of Practice (CP1001) is under consideration by the British Standards Institution.

Limited supplies of this report, M/T102, are obtainable from The Electrical Research Association, Throncroft Manor, Dorking Road, Leatherhead, Surrey, the price being 3s 3d by post.

PICKUP CONSTRUCTION

A KIT of parts and full constructional details for making a lightweight moving-coil pickup has recently been issued by A. M. Pollock, 31, Brooklawn Drive, Manchester, 20. The miniature moving-coil armature is supplied ready made in two types for either sapphire or fibre needles, and the kit includes a special Alcomax magnet to give high sensitivity. Construction can be completed with ordinary hand tools. Prices are as follows: drawings and instructions, 5s; kit of parts, 25s; sapphire styli (0.001 or 0.0025in radius), 7s 6d. each.



Vertical loudspeaker column for the dome area mounted to the right of the pulpit.

Speech Reinforcement in St. Paul's Cathedral

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

Experimental System Using Line-source Loudspeakers and Time Delays

THOUGH the 17th-century architect, Sir Christopher Wren, showed some interest in acoustics and sound insulation, St. Paul's Cathedral (Fig. 1) must be one of the most difficult buildings for speech in existence. Its large size (the volume is about five million cubic feet) and the lack of sound absorptive materials result when empty in a reverberation time at mid-frequencies of about 11 seconds (Fig. 2); even when full the reverberation time is still about 6 seconds. In addition there are several concave surfaces which produce strong echoes; the most obvious of these is the dome and its drum which is 111ft in diameter at the base and which rises to 216ft above floor level. The unaided voice cannot be expected to be intelligible over the whole congregation area. Various speech reinforcement systems have been tried, but none with complete success. The system in use before the one to be described here succeeded in making speech intelligible, but only at a considerable sacrifice in quality.

This article describes a system, developed by the Building Research Station in collaboration with Pamphonic Reproducers Limited, which has been recommended to the Dean and Chapter as being the most suitable for the Cathedral. The description is in terms general enough to be of help in the design of systems for other reverberant auditoria.

Frequency Response.—The smaller the frequency range used the simpler are the lesser design problems, but at the same time naturalness must be maintained. Beranek, Radford, Kessler and Wiesner have recently described experiments[1] with speech reinforcement systems in reverberant auditoria in which they found that the naturalness of the reinforced speech was not affected if the frequencies below 400 c/s were attenuated. They also found that, contrary to their original expectations, the intelligibility was not improved by attenuating these lower frequencies. These results are not quite the same as those found by one of the present authors (Parkin, unpublished). In Harringay Arena, when full, the low-level system in use there was switched alternately throughout a performance of a musical comedy from the normal full-frequency range to a restricted range of 300 to 4,000 c/s. Of 40 listeners distributed throughout the arena, 28 said the restricted range was more natural compared with 9 who said the full frequency range was more natural; 24 said that the restricted range was more easily intelligible compared with 12 who voted for the full range. Thus in this auditorium, where the reverberation time (full) at mid-frequencies was about 5 seconds (Fig. 2), there was a definite result in favour of the restricted range.

In the Royal Festival Hall a similar test was made with about 100 listeners, and here, where the reverberation time (empty) at mid-frequencies was about 2.2 seconds (Fig. 2), there was no measurable difference in either naturalness or intelligibility between the full and restricted ranges. In the empty Coliseum Theatre, London, where the reverberation time at mid-frequencies was estimated to be about 1.2 seconds, it was obvious to the four people engaged in the tests

* Building Research Station, Department of Scientific and Industrial Research.
† Pamphonic Reproducers Ltd.

[1] Beranek, L. L., Radford, W. H., Kessler, J. A. and Wiesner, J. B.; "Speech Reinforcement System Evaluation." *Proc.I.R.E.*, 39, (11) Nov. 1951, pp. 1401-8.

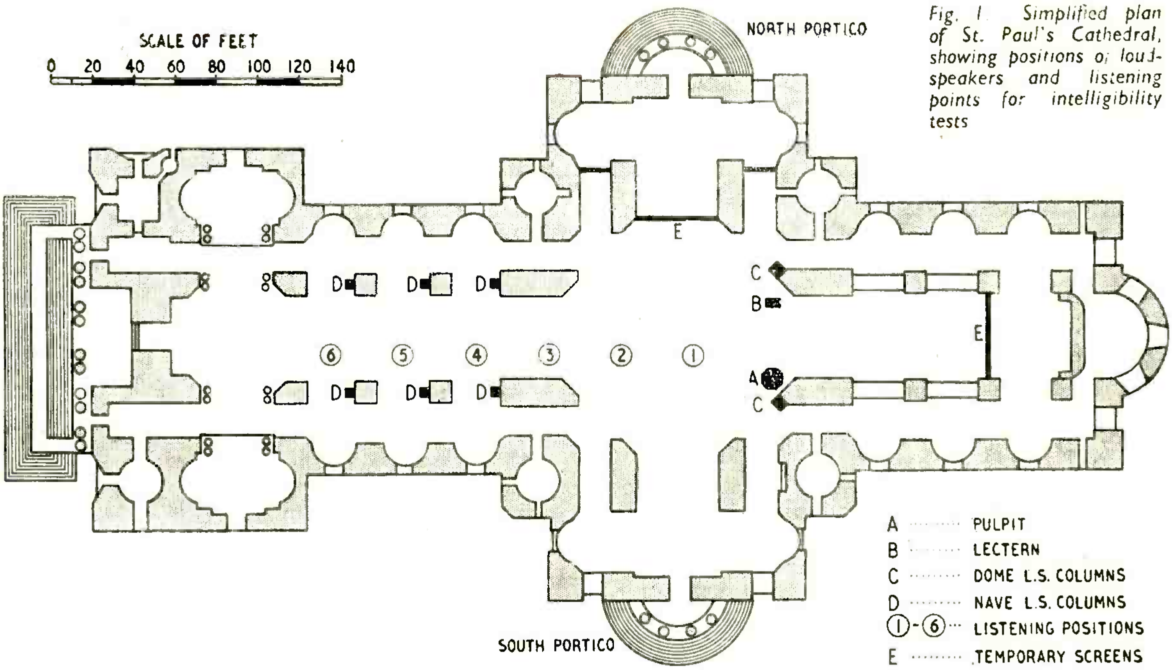


Fig. 1. Simplified plan of St. Paul's Cathedral, showing positions of loudspeakers and listening points for intelligibility tests

that the restricted frequency range was the less natural.

We see, then, that in the most reverberant auditorium the restricted range was better, in the middle auditorium there was no difference between the ranges and in the least reverberant auditorium the full range was better. For St. Paul's Cathedral it could be assumed that the restricted range would probably be better and would certainly not be worse. The range of 250 to 4,000 c/s was decided on for design purposes; this was very close to the range used in the above tests in auditoria and was exactly four octaves.

Direct and Reverberant Sound.—The intelligibility of speech under reverberant conditions depends, in general, on the intensity of the direct sound, whether from the voice or the loudspeaker, being at a greater intensity than the reverberant sound. With a point source of sound, the energy density, in ergs per cubic centimetre, of the direct sound at a given point is given by

$$E_D = \frac{P}{4\pi r^2 c} \quad \ldots \quad \ldots \quad (1)$$

where P is the power of the source in ergs per second, r is the distance in centimetres from the source, and c is the velocity of sound in cm/sec. The energy density of the reverberant sound is given by

$$E_R = \frac{4P}{Ac} \quad \ldots \quad \ldots \quad (2)$$

where A is the absorption in the room.

If directional sound source is used directed towards the congregation, the direct sound energy is given by

$$E_D = \frac{\alpha P}{\beta 4\pi r^2 c} \quad \ldots \quad \ldots \quad (3)$$

where α is the fraction of the energy directed towards the congregation and β is the fraction of the solid angle 4π into which the energy αP is concentrated. The reverberant sound energy is given by

$$E_R = \frac{4P}{Ac}(1-\alpha a_c) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where a_c is the absorption coefficient of the congregation. Thus the greater α is and the smaller β is, the higher will be the intensity of the direct sound in relation to the intensity of the reverberant sound.

If we consider the distance from the source at which the direct and reverberant energy densities become equal, in the case of the point source we get

$$r_1 = \sqrt{\frac{A}{16\pi}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

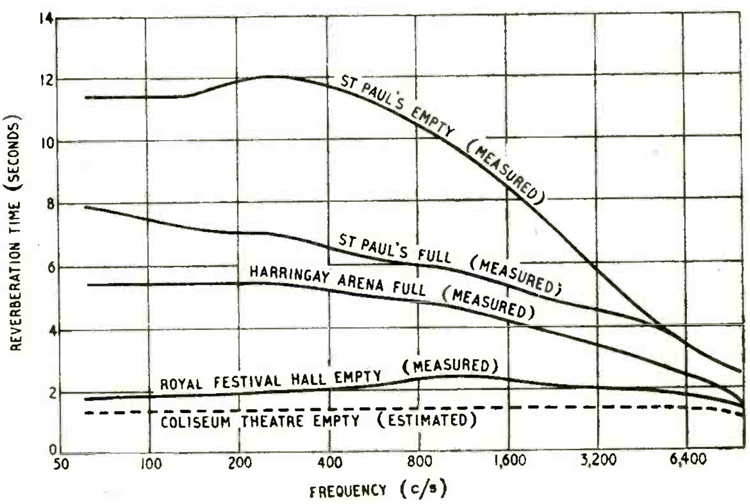


Fig. 2. Reverberation times of some representative large auditoria.

In the case of the directional source we get

$$r_2 = \sqrt{\frac{\alpha A}{\beta 16\pi (1 - \alpha a_c)}} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

Let us assume that we have a directional source in which $\alpha = 0.9$ and $\beta = 0.03$. Then

$$\frac{r_2}{r_1} = \sqrt{\frac{\alpha}{\beta (1 - \alpha a_c)}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

which, when $a_c = 0.7$, gives $r_2/r_1 = 9$. Thus a directional source with these assumed values of α and β can be expected to cover nine times the distance that a non-directional source would cover before the reverberant sound intensity is as much as the direct sound intensity.

(It should be noted in passing that intelligibility is in practice maintained up to greater distances than those given by the absolute values r_1 or r_2 when $E_D = E_R$. This is because of the ability of the ear to distinguish between wanted and unwanted sound, and because the above calculations are concerned with steady-state conditions, whereas speech is transient. Nevertheless, the *ratio* of r_2 to r_1 does apply to actual conditions.)

Line-source Loudspeakers.—Directional sound sources can be divided into three main types: shaped reflectors, e.g., a parabolic surface with a source at the focus; shaped loudspeakers, e.g., mono-planar horns; and loudspeaker arrays, that is several individual loudspeakers arranged in a pattern to give directionality. Now in St. Paul's Cathedral, and in most cases, we need a beam of sound which is narrow in the vertical plane, so that it can be directed towards the congregation and not towards the reverberant volume above, and which is broad in the horizontal plane so that it will cover the required area. While it would be possible to design sound sources with the required directionality of either of the first two types, the third type—the directional array—is the obvious choice. It is simple to design and can be made from standard loudspeakers with great flexibility. A review of directional arrays is given by Olson[2] and the one that most simply meets the requirements is the straight line source.

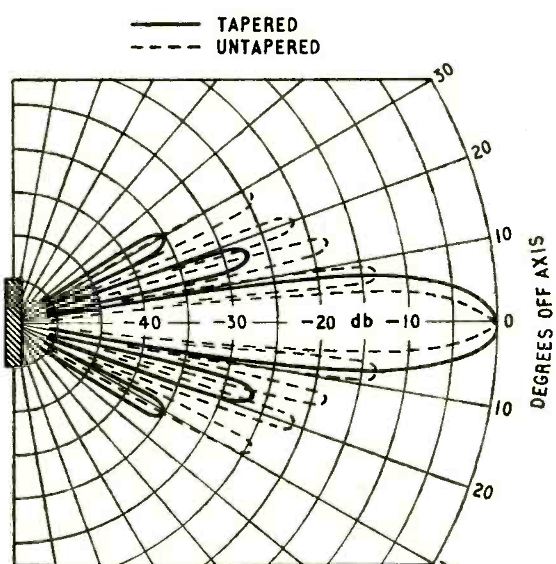


Fig. 3. Directional characteristic at a large fixed distance in the vertical plane of an 11-ft line source at 1,000 c/s.

The theory of line sources has been known for a long time; Wolff and Malter[3] in 1930 gave a summary of their behaviour, together with the results of measurements, and it is surprising that such sources have not been used more frequently. One of the authors (Taylor) installed two such sources at White City in 1932 which are still in use, but there does not appear to be any reference to their use in this country or in the U.S.A., although they have been developed in Germany recently[4] and are now coming into fairly common use on the Continent.

The directional characteristic of a source consisting of a number, n, of equal point sources radiating in phase, located on a straight line and separated by equal distances, d, is given by

$$R_\theta = \frac{\sin\left(\frac{n \pi d}{\lambda} \sin \theta\right)}{n \sin\left(\frac{\pi d}{\lambda} \sin \theta\right)} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

where, at a large fixed distance from the source, R_θ is the ratio of the pressure at an angle θ to the pressure for an angle $\theta = 0$ (the direction $\theta = 0$ is at right angles (normal) to the line), and where λ is the wavelength. In the limiting case where n approaches infinity and d approaches zero so that $nd = l =$ the length of the line, we have the ideal straight line source. Equation (8) then becomes

$$R_\theta = \frac{\sin\left(\frac{\pi l}{\lambda} \sin \theta\right)}{\frac{\pi l}{\lambda} \sin \theta} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

In the practical cases where the source is made up of a number of loudspeakers mounted close together, formula (9) can be used with sufficient accuracy provided that the distance between the loudspeakers is small compared with the wavelength. Thus with a vertical line source we have a directionality in the vertical plane which increases with increasing frequency; in the horizontal plane this arrangement does not cause any directionality. The polar diagram (up to 30 degrees either side of the axis) in the vertical plane of a vertical line source 11ft long at 1,000 c/s is shown in Fig. 3. It is seen that there are secondary lobes which, although the greatest of them is 13 db below the main lobe, might be troublesome in practice. If the line source is "tapered" in strength so that the sound from each element varies linearly from a maximum at the centre to zero at either end, the directionality is given by

$$R_\theta = \frac{\sin^2\left(\frac{\pi l}{2\lambda} \sin \theta\right)}{\left(\frac{\pi l}{2\lambda} \sin \theta\right)^2} \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

Fig 3 shows the directionality at 1,000 c/s of an 11-ft tapered source, and it is seen that the main lobe is slightly broader while the first of the secondary

[2] Olson, H. F., "Elements of Acoustical Engineering," pp. 26-49 D. Van Nostrand, New York, 1947.
[3] Wolff I. and Malter, L., *Journal of the Acoustical Society of America*, 1930, 2, (2), pp. 201-241.
[4] Meyer, E., Building Research Congress Report, 1951, Division 3, Part 1, pp. 43-48.

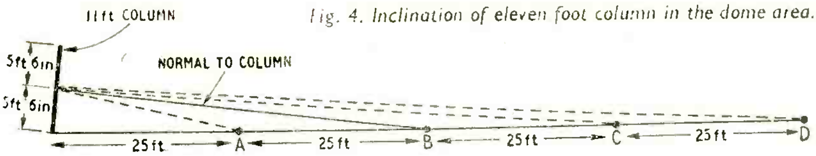


Fig. 4. Inclination of eleven foot column in the dome area.

lobes is reduced to 27 decibels below the main lobe.

We are now in a position to consider the design of loudspeaker line sources (which will be referred to simply as columns) for St. Paul's Cathedral—in the first instance those for the dome area. The two main speech positions were the pulpit and the lectern (Fig. 1) and an obvious decision was to use one column close to each, to be used separately. The horizontal distance to be covered was about 100ft, and the first attempt to cover this area was made using a column mounted about 20ft above ear height and directed down towards the congregation. The expected advantage was that the sound would be nearly all directed into the congregation so that α in equation (3) would be large. It was found, however, that when the dome area was only partly occupied, a condition that the loudspeaker system must contend with, reflections off the stone floor were giving rise to serious echoes. To avoid this, the column was then tried with its bottom at ear height and inclined forward slightly so that the centre of its beam was directed towards the centre of the dome area. The expected disadvantages of this arrangement were that α was smaller and that the sound was at grazing incidence with a corresponding attenuation. In practice, however, these disadvantages were found to be not serious.

This arrangement was, therefore, adopted and it became necessary to determine the length of the column required. It will be remembered that the frequency range to be covered was 250 to 4,000 c/s, and that the directionality of a line source increases with increasing frequency. Without going into detail here, it can be said that in the St. Paul's case a column which was long enough to give sufficient directionality at 250c/s would be too directional at 4,000c/s. Actually, a 6-ft long column for the whole frequency range was tried at one time, but when adjusted so that the listener's ears were at the beam centre when seated, the high frequencies were so sharply beamed that speech became nearly unintelligible when the listener stood up.

It would be possible theoretically to maintain the same directionality over the whole frequency range by cutting off the outer loudspeakers successively with increasing frequency by suitable electrical circuits, but this is rather complicated and has three other disadvantages at high frequencies, at any rate when 10-in loudspeakers are used. The first is that the number of loudspeakers left in circuit is small and cannot then be considered as a continuous line source; the second is that the speakers left in circuit are not tapered properly; the third is that in the horizontal plane the speakers are directional, due to their size being comparable with the wavelength.

In St. Paul's, it was necessary to cover a horizontal angle of about 120 degrees, and Olson[5] shows that, for example, a 16-in loudspeaker at 2,500 c/s is about 10 db down at 60 degrees off the axis. On the whole, the best solution appeared to be to use a cross-over arrangement, and the obvious cross-over frequency to choose was 1,000 c/s which divided the total frequency range into two ranges, each two octaves wide.

Considering the low-frequency part of the column, the highest frequency it had to emit was 1,000 c/s and thus the beam width at this frequency had to be adequate to cover the dome area; it had, however, to be kept as narrow as possible since at lower frequencies the beam would be wider. Any arrangement must be a compromise, since the narrower the beam width the longer the length of the column; the centre of the column is correspondingly higher above the listening plane and thus calls for a wider beam. A consideration of the geometry (Fig. 4) suggested that an 11-ft column would be suitable: this gave a beam width at 1,000c/s of 6 db down at 5 degrees on either side of the axis. In equation (10), R_θ is unchanged if l/λ is kept constant, so that to obtain the same directionality from the high-frequency section of the column at 4,000 c/s, its length had to be one quarter of the low-frequency section, i.e., 2ft 9in.

If we take listener position B (Fig. 4) as our reference point (0 db) then at position A the intensity at all frequencies will be 6 db higher since it is at half the distance from the source; but the intensities at A, C and D, which are off the centre of the beam, will vary with frequency. The actual values will be:

Position	Relative Intensities (db)			
	L.F. Section		H.F. Section	
	250 c/s	1,000 c/s	1,000 c/s	4,000 c/s
A	+5.5	0	+5.5	0
B	0	0	0	0
C	−3.5	−4	−3.5	−4
D	−6	−7.5	−6	−7.5

Thus at 25ft from the source, the frequency response is slightly irregular, but comparatively few people are as close as this since the column is covering a fan-shaped area. At greater distances the response is practically uniform.

(*To be concluded.*)

SOME 1951 ADVANCES

IN a review of their activities during 1951, The British Thomson-Houston Company mention some interesting new developments in the electronics field. One is a very-high-speed photo-electric counter which will count at rates up to 25,000 per minute. Another is a new type of voltage regulator using magnetic amplification—the use of saturable core reactors in conjunction with contact rectifiers has been well known for many years, but recent improvements in magnetic steels and circuit arrangements have greatly extended the scope of this kind of amplification. In the radar field the most important B.T-H. work has been on a magnetic modulator which is designed to eliminate trigger valves of the thyraton or trigatron types and so increase the reliability of the equipment.

[5] Olson, H. F., loc. cit. p. 132.

LOUDSPEAKER RESPONSE CURVES

Presentation Showing Distortion as Well as Total Output

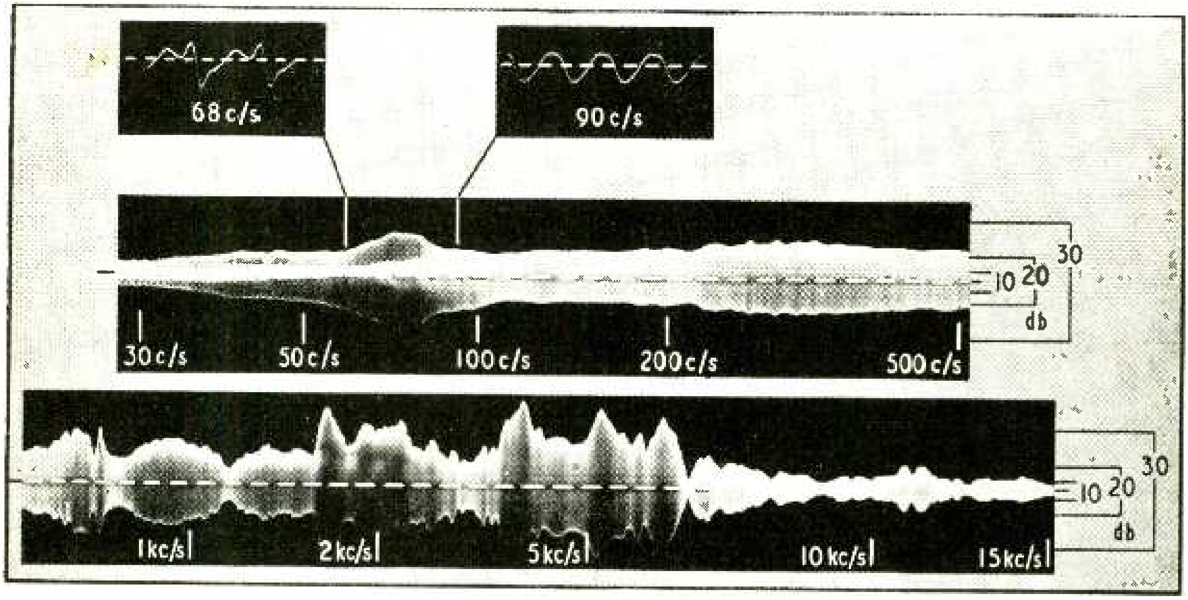
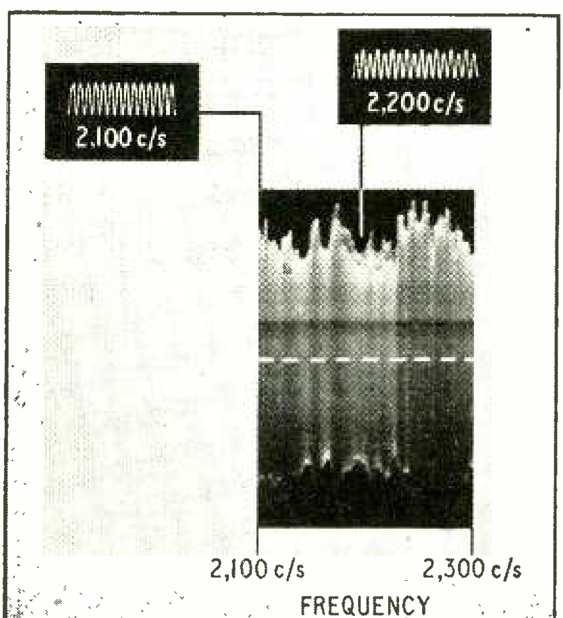


Fig. 1. Oscillographic record of a 10-in loudspeaker, with corresponding waveforms at 68 and 90 c/s.

Fig. 2. Detail of trace with double edge due to the generation of a sub-harmonic (1,100c/s) in the region of 2,200 c/s.



FOR many years the "frequency response curve" giving the relationship between sound pressure output and the frequency of the applied constant electrical input has been accepted as a basis for comparing objectively the relative merits of different loudspeakers. The information which it conveys, though useful, is limited, and unless the conditions of measurement are known it can be misleading. Too often a well-sustained output in the bass is produced by a whole collection of frequencies with very little of the fundamental so optimistically indicated by the figures on the scale below the curve. True, this error can be eliminated, as it is in N.P.L. tests, by the use of filters to ensure that nothing but the fundamental reaches the recorder, but even then the curve does not convey visually the kind of noise which one might expect under working conditions.

Much more information is conveyed by an oscillographic form of presentation of the response curve recently developed by G. A. Briggs of Wharfedale Wireless Works. In this the output waveform is applied to the vertical deflection of a cathode-ray tube while a camera with open lens and slowly moving film expands a record of the trace horizontally.

The virtue of this method is that in addition to the magnitude of the output some indication of the shape of the waveform is impressed on the record. Since the density of the photographic trace is a function of the speed of "writing" of the oscillograph spot, one would expect the trace of a sine wave to be lightest at the centre, where the speed is highest, and progressively heavier towards the edges where the spot is, in fact, momentarily stationary before beginning its return journey. A square wave would give two parallel thick lines with faint uniform shading (if any) between. On the other hand a "chopped" or "limited" sine wave with flattened peaks might be more difficult to distinguish, since there would be some degree of shading. Harmonics, when they are in favourable phase relationship to the fundamental, often show as bright bands where the speed of the trace has been arrested momentarily by a kink or kinks in the waveform. In other phase relationships the harmonics may give a smooth waveform difficult to distinguish from a sine wave without direct comparison by superposition. There will then be no striations on the trace to reveal their presence. Fortunately such waves are often asymmetrical and give themselves away if the relative amplitudes on each side of the datum line through the centre of the trace are compared. Such waveforms are typical of bass response of loudspeakers with asymmetrical compliance in the centring devices associated with the cone.

Fig. 1, which is a curve taken by Mr. Briggs of a typical 10-inch commercial loudspeaker, shows these effects well. The bright band in the frequency range 30-80 c/s is produced by the major kink in the waveform appended at 68 c/s. Above the cone resonance the waveform appears to be much better, but there is considerable flattening of the upper peaks and a slight suggestion of saw-tooth tilting in the record taken at 90 c/s. The flattening is at once apparent in the asymmetry of the trace at 90 c/s.

Many loudspeakers, particularly 8in types fitted with what are known in the trade as "loud" cones, are prone to sub-harmonics at spot frequencies or narrow bands in the frequency range 1,000-5,000 c/s. This fault is also revealed by Mr. Briggs's method of recording, and a good example is shown by the double edge in the middle of the trace detail of Fig. 2. The corresponding waveform with alternate top peaks of increased amplitude is shown above, together with the undistorted waveform at an adjacent frequency.

Though the new form of presentation may not give the whole picture—transient performance, for instance, is excluded—it is an important advance on conventional curve tracing methods, and sufficient examples have been given to show that it provides ample material for skilful interpretation. The curves shown were all made with sine-wave inputs; possibly a series with pulsed inputs of different waveforms could be devised to present an even more detailed picture of a loudspeaker's performance.

Mr. Briggs has already applied the method to the examination of amplifiers and a.f. oscillators, and has suggested that, with a suitably speeded-up gliding tone record, it could be used for showing non-linearity as well as resonances in gramophone pickups.

LETTERS TO THE EDITOR

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

I.F. Interference

IN the January issue of your journal there was a description of an a.m./f.m. receiver for comparing the two v.h.f. systems radiated by the experimental transmitter at Wrotham.

This is stated to have a three-stage i.f. amplifier on 14.1 Mc/s, and I wonder if those responsible for this choice of i.f. are aware that there is an amateur band from 14.0 to 14.4 Mc/s. Any amateur working on this band in the vicinity of a receiver with such an i.f. is almost certain to cause interference, entirely due to the choice of i.f.

It can be argued, of course, that it is very difficult to find a frequency on which to set an i.f. amplifier and be sure that there will not be a transmitter of some kind breaking through, but it is also very certain that the possibility of a commercial station being in the vicinity of the receiver is very small but the possibility of an amateur living close by is quite large.

We amateur transmitters already have our troubles with broadcast interference and television interference; can we beg that designers will take what simple steps they can to avoid adding v.h.f. interference to the list? Make the i.f. 13.1 or 15.1, but don't put it in the middle of our most consistent long-distance band.

Brighton. RICHARD J. DONALD, G3DJD.

Safer A.C./D.C. Sets

REFERRING to C. E. Thorn's letter in your January issue, I am doubtful if his suggestion of using an earthed chassis with one insulated return point per stage would be satisfactory in practice. Although the use of a single point for each stage is usually considered to be ideal, my own experience is that it is usually much better to return everything directly to the nearest point on the chassis.

In this connection I recall reading in an American journal that Mr. Thorn's suggested method had been tried and found unsatisfactory because of the individual return points. The scheme there recommended was an earthed chassis covered on its inside by a layer of insulating material to which was clamped a thin sheet of metal to form the "live" return sheet for all connections. Because of the high capacitance to the chassis proper the sheet formed a satisfactory "earth." If soldered connections are made directly to the sheet, it is obviously necessary to choose an insulating material that will withstand soldering temperatures.

I suggest that the scheme is one worth further investigation. W. TUSTING.

London, N.

Phonetic Alphabets

I AM grateful to you for publishing in your December issue the note on phonetic alphabets, but find its contents most disturbing.

During my service career I wholeheartedly accepted the new "Able Baker Charlie" alphabet as more effective than the older G.P.O. system. But the newest alphabet as introduced by I.C.A.O. appears to have been compiled by and accepted by those without the slightest idea of the requirements of speed and efficiency. What is worse, it ignores the capabilities of modern radio-telephony equipment. For example, take the letter "F" denoted by "Fox" in the Services alphabet, which now becomes "Foxtrot"—much longer. The Services alphabet has a total of 40 syllables against 55 for the I.C.A.O. version. L. E. MOORAT.

Glasgow.

[Many will share our correspondent's dislike of the new I.C.A.O. phonetic alphabet, but in condemning it we must not be too insular. Most of the words chosen have a wide international currency, and so will be widely recognized by those whose mother-tongue is not English. To take the example given, we imagine there is no country into which "Foxtrot" has not penetrated.—ED.]

Jointing Aluminium

WITH reference to A. E. Crawford's letter (your December issue) I do not ask for space for a protracted correspondence on soldering methods, but am compelled to challenge his statements concerning abrasion tinning. He is obviously completely misinformed in considering that a sound mechanical and electrical joint is not required for cable sheaths. A wiped joint on an aluminium sheathed cable is normally expected to, and does, withstand heavy mechanical stresses, conditions of vibration and high internal pressures. Low electrical resistivity in the joint is a *sine qua non*.

The jointing of cables on site is one of the more obvious examples where ultrasonic methods are inapplicable, but as I stated in my previous letter "both (methods) have their own particular application." I also have one comment on the method of test Mr. Crawford recommended for examination of a tinned surface, namely, wiping the hot surface with a cloth. This test is quoted in my firm's leaflet of instructions to jointers and recommended for the examination of abrasion tinned surfaces.

Johnson and Phillips, Ltd., London, S.E.7. P. A. RAINE.

Radio's Responsibilities

IS it not time that the radio technologist, among others, showed some sense of his moral obligations to the rest of society? Like the atomic scientist, he possesses knowledge and ability which can be used either for the benefit or the destruction of his fellow human beings, yet he does not seem to be aware of the responsible position this places him in.

The usual argument is, of course, "I'm only doing my job—it's not my business to enquire into the rights and wrongs of it." This point of view may be an estimable one in the bee-hive or the ants-nest, but coming from a human being who uses intelligence and creative inspiration in his work and does so wittingly, with his eyes open, it is something worse than degrading. Unfortunately, it is perhaps more prevalent in the radio engineering profession than in any other, for the development of radio has been extremely rapid and the technologist has been pushing ahead with such enthusiasm that he has had no time to consider the implications of what he is doing. He has had no time to evolve a tradition, like that of the doctor, which frowns on the use of professional knowledge for the destruction of human life. What is worse, he does not realize that he is rapidly becoming a mere tool in the hands of administrators who regard him only as a kind of soulless thinking machine for putting their Napoleonic schemes into practice.

Of course, the technologist is really very human. He says to himself "My duty to my wife and family comes first and this armament contract happens to pay better than domestic receivers." If the individual technologist has sufficient moral courage he can, of course, make his own decisions. But that is not enough. The radio engineering fraternity as a whole should, through its profesional institutions, at least show some recognition of the fact that it has these responsibilities, and, if possible, come to some agreement on a code of ethics. Until it does so, it will never achieve an honourable position in the eyes of a world which already has good reason to regard technological "progress," and those responsible for it, with fear and distrust.

London, S.W.4. JAMES FRANKLIN.

DIELECTRIC AMPLIFIERS

Power Gains Up to a Million per Stage with High Input Impedance

CERAMIC materials of the barium titanate type have high dielectric constant (permittivity) which is dependent on temperature and also on the strains resulting from the application of an electric field. The relationship between permittivity and the applied field follows, under certain condition, a hysteresis loop similar in form to that of an iron core and these dielectrics are said to exhibit "ferroelectric" properties.

Such dielectrics can be used as a control medium for power amplification, much in the same way as magnetic alloys are used in the magnetic amplifier; the alternating current in a circuit which includes a capacitor incorporating the special dielectric can be varied by the application of a "d.c." control field. The chief advantage of the dielectric amplifier is that it is a voltage rather than a current-operated device and its input impedance can be made relatively high by using a high-frequency power supply and a small capacitance.

Circuits are usually of the balanced push-pull type and a survey of representative arrangements is given in a paper by A. M. Vincent in the December, 1951 issue of *Electronics*. This paper also gives details of the operating characteristics of a range of materials compounded from barium and strontium titanate and barium and lead zirconate.

The titanate mixtures exhibit clearly defined maxima of permittivity (Curie points) in the temperature range -20 to 120 deg. C and a working point giving high gain is attended by sensitivity to temperature changes. The zirconates are less susceptible to temparture, but have a lower possible gain.

By the choice of suitable dielectrics and circuits, temperature compensation is possible, and the principle is quite practicable for use in regulators, servo-mechanisms, and in r.f. circuits at up to 10 Mc/s if lower gains are accepted. The dielectric amplifier is small, and if desired can be used in a wide range of shapes. The cost is low and it is claimed that titanate-dielectric capacitors are cheaper to make than mica or even paper types.

CLUB NEWS

Brighton.—At the meeting of the Brighton and District Radio Club on February 12th, A. Slater (G3FXB) will talk on "DX operating and working." The club meets on Tuesdays at 7.30 at the Eagle Inn, Gloucester Road, Brighton. Sec.: R. T. Parsons, 14, Carlyle Avenue, Brighton, 7.

Cleckheaton.—At the February 27th meeting of the Spen Valley Radio and Television Society, W. G. Merriman will speak on "Electronics in Wartime." The club meets on alternate Wednesdays at 7.30 at the Temperance Hall, Cleckheaton. Sec.: N. Pride, 100, Raikes Lane, Birstall, Nr. Leeds.

Coventry.—"Mathematics Made Easy" is the title of a lecture by T. R. Theakston, B.Sc., to be given to members of the Coventry Amateur Radio Society on February 18th. This meeting is open to the public; tickets are obtainable from the secretary. Meetings are held on alternate Mondays at 7.30 at the Y.W.C.A., Queen's Road, Coventry. Sec.: K. G. Lines, 142, Shorncliffe Road, Coventry.

Birmingham.—Slade Radio Society, which meets on alternate Fridays at 7.45 in the Parochial Hall, Broomfield Road, Erdington, has arranged the following programme for February On the 15th A. G. McGregor of the Midland Electricity Board will speak on "The generation of electric power" and on the 29th J. Y. Freeman (Birmingham University) will deal with "Selected topics from Nuclear Physics." Sec.: C. N. Smart, 110, Woolmore Road, Erdington. Birmingham, 23.

Geneva Radio Conference

Review of Results of Three Months' Work

AT Atlantic City in 1947 it was agreed that the world's radio services capable of causing harmful interference and operating on frequencies below 27.5 Mc/s, should in future operate in accordance with detailed frequency assignment plans which were to include projected as well as working services. These plans were to be drawn up by a number of bodies set up by the Conference.

Unfortunately, owing partly to the inherent difficulties of the problem and partly to the loss of that spirit of give and take which marked the Atlantic City Radio Conference, the frequency planning bodies met with indifferent success. It is true, of course, that a plan for European long- and medium-wave broadcasting stations was agreed at Copenhagen in 1948 and put into effect in March, 1950. In addition plans were prepared for medium-wave broadcasting in the North American Region, for the medium frequency services generally in the Eastern Hemisphere and for all maritime and aeronautical mobile h.f. services. At Mexico City in 1948 a basic plan was produced for h.f. broadcasting for one phase of the sun-spot cycle, but this was not acceptable to a number of important countries, and the subsequent conferences at Florence and Rapallo did not produce plans for the other phases of the cycle. Moreover the planning body concerned with the point-to-point services, which occupy a very substantial proportion of the high-frequency spectrum, was unable to produce generally acceptable plans. It was with this somewhat discouraging background that an Extraordinary Administrative Radio Conference was convened by the International Telecommunication Union at Geneva in August last year.

On 3rd December, after three and a half months' work, an agreement was signed by the representatives of 65 countries—that is all delegations present except those of the Soviet Union and of the eight Eastern European countries which supported her throughout the Conference. The effective date of the agreement is 1st March, 1952. The Conference completed and approved plans for most radio services using frequencies from 14 kc/s to 3,950 kc/s (4,000 kc/s in the Americas) and in most cases set dates on which they will come into effect. Plans were also approved for the high-frequency radiotelegraphy and radiotelephony maritime service and the aeronautical mobile service. For the plans between 2,000 and 4,000 kc/s in the Americas, and between 2,850 and 3,950 kc/s in the rest of the world, and for the h.f. maritime and aeronautical mobile plans, the Agreement provides for piecemeal implementation.

The most difficult and most important problem facing the Conference was to devise a means of bringing into force the high-frequency part of the allocation table (3,950-27,500 kc/s). The solutions proposed differed widely. Many delegations advocated further attempts to prepare complete assignment plans incorporating all projected requirements, although those who held this view were not unanimous on the basis upon which this planning should take place. Other countries considered that the only practicable course would be for each Administration gradually to adjust its operations by appropriate exchanges between working frequencies and by the bringing into use by normal methods of new frequencies where necessary.

The Conference, however, agreed on a compromise which provides that this gradual adjustment process shall apply on a voluntary basis throughout the high-frequency part of the spectrum but that in addition the International Frequency Registration Board (a permanent organ of the I.T.U.) shall prepare plans for high-frequency broadcasting. The I.F.R.B. is to co-ordinate proposed frequency changes.

Special safeguards have been provided for the safety-of-life aeronautical and maritime mobile high-frequency services. In particular a broad programme of frequency changes has been drawn up for the maritime mobile frequency bands to ensure continuity of the service, to minimize interference and to allow for the fact that ships' frequencies in the different bands are harmonically related.

Further Review in 1955

No date has been set for the termination of the period of adjustment but the International Frequency Registration Board will provide periodic progress reports and the Administrative Council of the I.T.U. has been invited to review progress in 1955 with a view to recommending to all countries a date for the beginning of a final adjustment period. During this comparatively short period final adjustments in accordance with the allocation table will be compulsory and the High-Frequency Broadcasting Plan, if drawn up and approved by then, will be brought into effect. The Conference also agreed that before implementation of the allocation table, the International Frequency Registration Board should at the end of the final adjustment period re-examine the position and prepare a draft International Frequency List for point-to-point services. This would take into account the current use of frequencies together with requirements remaining unsatisfied at that time. This List will be considered by a further international conference.

In view of the complexities of the problem and the extent to which the interests of the more developed countries, in the radio sense, inevitably conflict with the others, it is particularly satisfactory that so wide a measure of agreement should have been achieved—albeit with some reservations. In the high-frequency field, of course, the Agreement is very largely permissive and a great deal therefore depends on goodwill and also on the improvement of transmission techniques. By promising to restore order in the spectrum and, in particular, to enable the aeronautical and maritime mobile services to operate in their new exclusive bands in accordance with agreed plans, the Agreement is of great importance in the future development of high-frequency radio services.

WORLD OF WIRELESS

Planning Metre-Wave Broadcasting ♦ Instruments Exhibition ♦ Record Exports ♦ Scottish Research

Continental V.H.F.

WITH the recent reorganization of the broadcasting service in Italy, two of the three programmes are now radiated by f.m. transmitters, of which there are now twelve. Similarly, it is learned from the European Broadcasting Union's *Bulletin* that at the beginning of September there were forty-six v.h.f. transmitters operating in Germany.

With this continued growth in the use of v.h.f. for sound and television broadcasting in Europe, it has been decided by the International Telecommunication Union to hold a conference in Stockholm, Sweden, from May 28th, to which all member countries of the I.T.U. in the European area have been invited. The main purpose is to discuss the allocation of frequencies—either to countries or individual stations—for sound and television broadcasting within the three bands (41-68, 87.5-100 and 174-216 Mc/s) allocated to broadcasting at Atlantic City.

The detailed agenda is not known but the questions of propagation and technical standards are bound to come before the meeting.

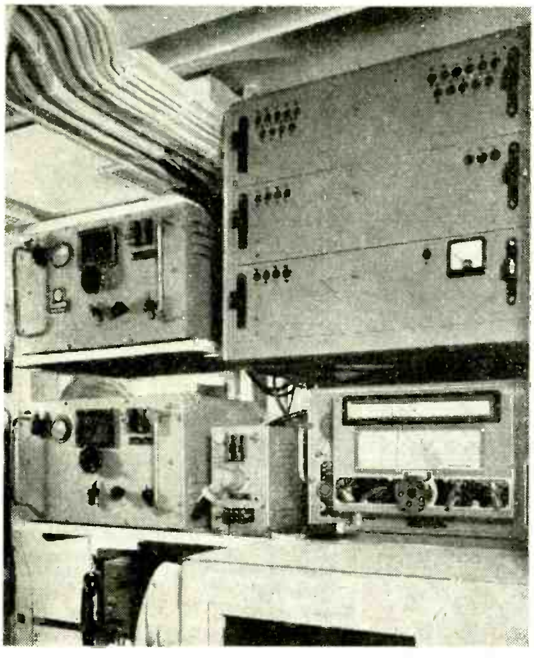
Physical Society's Show

THE thirty-sixth annual exhibition of scientific instruments and apparatus, organized by the Physical Society and supported by 141 exhibitors, will be held from April 3rd to 8th (excluding Sunday, 6th). As in 1951 it will be set up in both the Royal College of Science, Imperial Institute Road, and the Huxley Building, Exhibition Road, South Kensington.

Tickets will again be valid for specified days or morning (10.0-1.0) or evening (6.0-9.0) sessions, and are available from the Society, 1, Lowther Gardens, Prince Consort Road, London, S.W.7. There will be a break (from 1-2) between the morning and afternoon sessions. On the first, second and fourth days the exhibition will close at 9.0 and on the other two days at 5.0. The exhibition will be open to members of the Society and the Press only on the first day up to 6.0.

Radio Exports

NOVEMBER'S exports of British radio equipment of all kinds (£2,235,367, which is as much as in a year before the war) brought the total for 11 months of 1951 to £20,446,795, compared with £17,750,000 for the whole of 1950. According to the Radio Industry Council, the exports of broadcast receivers, which declined after the post-war peak period, increased in value in 1951 to about £5,000,000, the highest figure yet.



RADIO INSTALLATION in the liner "Gothic" has been supplemented for the Commonwealth tour of T.R.H. the Princess Elizabeth and the Duke of Edinburgh by the addition of high-power radio - telephone and high-speed radio-telegraph equipment to cope with State and Naval traffic and to meet the needs of the B.B.C. and the Press. The Marconi 7-kW SWB11X transmitter is the first of its kind to be fitted on board ship. Above the three receivers of the ship's sound reproducing equipment shown here is the aerial splitter equipment enabling any, or all, of the ship's receivers to be operated from the main receiving aerial.

Transatlantic Veteran

MARCHESE Luigi Solari, referred to in our December issue as the sole survivor of Marconi's original band of associates, is also almost certainly the only surviving participant in the transatlantic transmissions of 1901. His book "Storia della Radio," a copy of which he has just sent to us, throws many interesting sidelights on this historic event, during which he was at the Poldhu station. Details are given of the Solari type of self-restoring coherer, used by Marconi for reception. On the vexed—but perhaps not highly important—question as to why, contrary to usual practice, the letter "S" was chosen for the tests, the book adds some information. Apart from being thought to be easily distinguishable from atmospherics, the three dots were easily sent by unskilled telegraphists and also imposed less strain on the condensers than would a test signal like the conventional "V" which includes a dash.

Electronics in Scotland

AS part of its general policy of industrial development, the Scottish Council is going ahead with a scheme for building up an electronics industry in Scotland. The Government having placed a fair share of research and production contracts with Scottish firms the Council hopes to build up technical facilities which can subsequently be applied commercially. The research and development teams of most of these firms, however, are too small for the kind of work the Government is offering, so it has been necessary to form a co-operative group with one large firm (Ferranti of Edinburgh) acting as a "parent" contractor. It will accept large contracts for subdivision amongst the members of the group and will give technical advice and provide training facilities for new staff. The Government has also built a new laboratory block adjacent to Ferranti's which will serve as a base for the work of the group.

PERSONALITIES

Dr. E. C. S. Megaw, O.B.E., formerly Superintendent of Research at the Admiralty Signal and Radar Establishment, Haslemere, and now Director of Physical Research at the Admiralty, has been promoted to the rank of Chief Scientific Officer in the R.N. Scientific Service. Prior to joining the Admiralty in 1946, he was for sixteen years in the Research Laboratories of the G.E.C., where he specialized in the study of transit-time oscillators. Dr. Megaw, who received the degree of D.Sc. from Queen's University, Belfast, in 1946, has contributed a number of articles to our sister journal *Wireless Engineer*.

Anthony W. Martin, M.B.E., Assoc. I.E.E., is among three new directors appointed by E. K. Cole, Ltd. He joined the company as research engineer in 1928 and was appointed chief of research in 1942 and chief engineer in the following year. During the war he was concerned with the development of radar. He will continue to be responsible for the design and technical development of Ekco equipment.

George W. Godfrey, who joined E. K. Cole, Ltd., as radio sales manager in 1945 and three years later became general sales manager (Radio Division), has been appointed an executive director. Mr. Godfrey, who is chairman of the Television Promotion Committee of the British Radio Equipment Manufacturers' Association, held executive positions at H.M.V., E.M.I., Baird and Ultra before joining Ekco.

Walter D. Kemp has left the Planning and Installation Dept. of the B.B.C., where he has been in charge of television recording, and is joining High Definition Films, Ltd., as chief engineer. Before going to the B.B.C. in 1946 he had been with E.M.I. and R.F. Equipment.

Col. W. J. Kent, C.B.E., D.L., chairman of the group of companies controlled by Taylor, Tunnicliff & Co., was created a Knight Bachelor in the New Year Honours.

M. V. Callendar, author of the article "Television Set Testing," was in charge of the research section of Lissen, Ltd., from 1929 to 1933 and with Pye (1933-39) before joining Ekco, where he worked on radar and army walkie-talkie sets Nos. 46, 78 and 88 during the war. He is now engaged mainly on television receiver problems.

E. G. Hamer, author of the article "Review of 460 Mc/s," joined the Admiralty Signal and Radar Establishment in 1940. Towards the end of the war he went to the Middle and Far East, where he was concerned with the establishment of radio maintenance units. In 1947, Mr. Hamer joined the Research Laboratories of the General Electric Company, where he has worked on the development of v.h.f. multi-channel and mobile communications systems.

P. H. Parkin, co-author of the article "Speech Reinforcement in St. Paul's Cathedral," graduated in electrical engineering in 1938 and undertook post-graduate research on dielectric strength of air at high frequencies. In 1940 he joined the Admiralty for work on counter-measures to magnetic, acoustic and pressure mines, and since 1946 has been at the Building Research Station of D.S.I.R., where he is now Principal Scientific Officer in charge of the sound insulation and acoustics section of the Physics Division.

J. H. Taylor, co-author of the article "Speech Reinforcement in St. Paul's Cathedral," was trained at Faraday House. He left Standard Telephones and Cables in 1931 to become one of the co-founders of Pamphonic Reproducers, Ltd., where, except for service as a radar officer in the R.A.F., he has been since then.

IN BRIEF

Licences.—A record monthly increase of 81,950 television licences was recorded by the Post Office at the end of November, bringing the total to 1,113,900. The total number of broadcast receiving licences (including television) in force in the U.K. at that time was 12,525,900.

Marchese Luigi Solari, veteran of the 1901 transatlantic transmission tests. (See opposite page)

Isle of Wight Transmitter.—Despite the Government's shelving of the B.B.C.'s plans for the erection of five low-powered television stations to serve the areas not adequately covered by the main stations, the Corporation's engineers are going ahead with site tests. The Isle of Wight County Planning Committee has approved—with certain provisos—the erection of a 750-ft lattice steel mast and transmitter buildings at Rowridge, Carisbrooke.

"Contacts," used in its literal sense, is the title of a convention being organized by the East Midland Centre of the I.E.E. for April 7th-9th, which will be held at Loughborough College. The first part of the convention will be devoted to the subject of "Light-Duty Contacts in Theory and Practice" and the second to "Heavy-Duty Contacts." Further particulars and registration forms can be obtained from R. G. L. Ryan, the Brush Electrical Engineering Co., Ltd., Loughborough. The convention will not be confined to members of the Institution.

Electronic Instruments.—A course of lectures covering electronic instruments and their applications is being held at the South-East London Technical College, Lewisham Way, S.E.4. The first part of the course covers, in eight lectures, the general subject of instruments, part two (six lectures) deals with electronic computing, and part three (four lectures) with cathode-ray oscilloscopes and their applications. The lectures, which will be held on Tuesdays, began on January 8th and will continue until May 13th. The fees are: parts one and three £1 5s inclusive, part two 12s 6d.

"Sensitive T.R.F. Receiver."—Reprints of the article from our November issue describing a sensitive t.r.f. broadcast receiver are now available from our Publishers; price 1s, or by post 1s 1½d. The reprint includes an introductory article (October issue) on the automatic gain control system embodied in the receiver.

N. American Television.—A network of television relay stations linking Buffalo, N.Y., with Toronto and Montreal, via Ottawa, is planned by the Canadian Broadcasting Corporation. The relay stations, which are not expected to be completed until 1953, are being erected by the Bell Telephone Co., and will permit an interchange of Canadian and U.S. programmes. Each of the fifteen relay stations will be equipped with two pairs of 10-ft square horn radiators. The television stations in Montreal and Toronto will not be ready for some time, although the Marconi studio and O.B. equipment for them was shipped some time ago.

Radio Officers' Pensions.—A supplementary non-contributory pension scheme for radio officers in the employ of the company is announced by the Marconi International Marine Communication Co. The scheme is independent of the Merchant Navy Officers' Pension Fund and National Health Insurance pensions, and is open to radio officers who joined the company prior to January 1st, 1937, and will be 65 before 1978.

S.W. Listening Contest.—This year's short-wave listening competitions, organized by the International Short-Wave Club, will be held during the second and third week-ends in February. Full particulars of the competition, which covers the reception of both amateur and short-wave broadcasting stations on the African continent, are obtainable from A. E. Bear, I.S.W.C., 100, Adams Gardens Estate, London, S.E.16.

B.B.C. Reception.—The mobile transmitter brought into use by the B.B.C. on December 23rd—the seventh of the twelve low-power stations to improve reception of the Home Service—is set up in Folkestone and not Eastbourne as stated erroneously last month.

Manchester Television Centre.—With a view to forming a Manchester Centre of the Television Society, a meeting will be held at 3.0 on February 9th in the Milton Hall, 244, Deansgate, Manchester, 3. Following the discussion regarding the formation of the Centre, a talk entitled "The Television Aerial and its uses," will be given by L. D. E. Perkins (Belling-Lee). Particulars are available from R. Lawton, 10, Dalton Avenue, Whitefield, Nr. Manchester.

INDUSTRIAL NEWS

Emitron valves and cathode-ray tubes, made by Electronic Tubes, Ltd., of High Wycombe, Bucks (a subsidiary of E.M.I.), are now available to the public through the normal channels. They have so far been available only to set makers.

Ediswan-Clix Amalgamation. — The Edison Swan Electric Co. announces that it has acquired the share capital of the General Accessories Co. and British Mechanical Productions, Ltd. All G.A.C./Clix products will be marketed through Ediswan distribution channels.

Columbia-Philips Agreement.—Philips Phonographic Industries, Baarn, Holland, has reached agreement with Columbia Records Incorporated, U.S.A., to co-operate on a world-wide basis for the exploitation of their record libraries, with effect from January 1st, 1953.

Mullards have opened a valve and c.r.t. service depot at Berry Lane, Halifax (Tel.: Halifax 5722), to serve retailers and service technicians in the North of England.

S.T.C.—The London sales office and warehouse of the Rubber & Plastic Cables Division of Standard Telephones & Cables has been transferred to 48, North Row, Mayfair, W.1 (Tel.: Mayfair 4392).

Sobell Service.—New Service depots have been opened by Sobell Industries at Room 15, Regent House, Cannon Street, Manchester, and 135, Renfield Street, Glasgow (Tel.: Douglas 6061). The company's Birmingham depot has been transferred to Emitron House, 117, John Bright Street, Birmingham (Tel.: Midland 2574/5).

Rola Celestion, Ltd., of Thames Ditton, Surrey, announce that the retail distribution of their loudspeakers will in future be handled by the associated company, Truvox, Ltd., Exhibition Grounds, Wembley, Middx. (Tel. Wembley 1212), who will also deal with the repair of speakers.

F. Livingston Hogg has notified us that the Livingston Laboratories are now at Retcar Street, Dartmouth Park Hill, London, N.19 (Tel.: Archway 2442), where all his activities will be concentrated.

Hunts.—So that the registered name of the company includes a reference to its products A. H. Hunt has adopted the name A. H. Hunt (Capacitors), Ltd.

Jay Developments is being formed by Sphere Radio, Ltd., Heath Lane, West Bromwich, to undertake the manufacture of Jay miniature silvered ceramic capacitors. A new factory is in course of erection at Bromford Lane. West Bromwich. Leaflet No. 52 gives data and specifications for these and other types of capacitors.

Du Bois Co.—Shipments of Tri-Sol activated resin cored solded during a recent period of six weeks included 20 tons to the Argentine and 10 tons to Brazil.

Coulphone Radio has now closed down and any communications should be addressed to J. B. Coulborn, Sea View House, St. Bees, Cumberland.

MEETINGS

Institution of Electrical Engineers

Faraday Lecture on "Sound Recording—Home, Professional, Industrial and Scientific Applications," by G. F. Dutton, Ph.D., B.Sc.(Eng.), at 6.30 on February 12th, at the Central Hall, Westminster, London, S.W.1. (Tickets must be obtained from the I.E.E.)

Radio Section.—"Factors Affecting the Design of the Automatic Electron Trajectory Tracer," by K. F. Sander, M.A., Ph.D., C. W. Oatley, M.A., M.Sc., and J. G. Yates, M.A., on February 13th.

Debate on the motion, "In the opinion of this House, the lone worker can no longer make a major contribution to Radio Development" on February 25th. Proposer, Geoffrey Parr; Opposer, M. G. Scroggie, B.Sc.

The above meetings will be held (except where otherwise stated) at 5.30 at the I.E.E., Savoy Place, London, W.C.2.

East Midland Centre.—Junior Members' Night at 6.30 on February 26th at Loughborough College.

Western Centre.—"The Sutton Coldfield Television Broadcasting Station," by P. A. T. Bevan, B.Sc., and H. Page, M.Sc., at 6.0 on February 11th, at the South Wales Institute of Engineers, Park Place, Cardiff.

Scottish Centre.—"The London-Birmingham Television Radio-Relay Link," by R. J. Clayton, M.A., D. C. Espley, O.B.E., D.Eng., G. W. S. Griffiths and J. M. C. Pinkham, M.A., at 7.0 on February 13th, at the Heriot-Watt College, Edinburgh.

North Eastern Radio & Measurements Group.—"An Investigation into the Mechanism of Magnetic Recording," by P. E. Axon, O.B.E., M.Sc., on February 4th.

Address by D. C. Espley, O.B.E., D.Eng., chairman of the Radio Section, on February 18th.

Both meetings will be held at 6.15 at King's College, Newcastle-upon-Tyne.

Cambridge Radio Group.—"Colour Television," by L. C. Jesty, B.Sc., at 6.0 on February 5th, at the Cambridgeshire Technical College.

British Institution of Radio Engineers

London Section.—"Search Radar for Civil Aircraft" by P. L. Stride (Ekco) at 6.30 on February 20th at the London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.

Scottish Section.—"Some Special Oscillograph Techniques" by Prof. F. M. Bruce, M.Sc., Ph.D. (followed by visit to the Electronics Laboratory) at 7.0 on February 7th at the Royal Technical College, Glasgow.

"The Clerk-Maxwell Memorial Lecture" by Prof. G. W. O. Howe, D.Sc., LL.D., at 7.0 on February 14th at the Natural Philosophy Department, The University, Edinburgh.

"V.H.F. Broadcasting" by Paul Adorian, at 7.0 on February 27th, at the Institution of Engineers and Shipbuilders, Glasgow.

North Eastern Section.—A symposium of papers by Student Members at 6.0 on February 13th at Neville Hall, Westgate Road, Newcastle-upon-Tyne.

South Midlands Section.—"Gas Discharge Devices as Switching Elements" by E. A. R. Peddle, B.Sc. (G.E.C. Research Laboratories) at 7.15 on February 13th at Corporation Street Civic Restaurant, Coventry.

West Midlands Section.—"Valve Manufacture," by C. C. Vodden, M.Sc., at 7.15 on February 26th at Wolverhampton and Staffordshire Technical College, Wolverhampton.

Television Society

London Section.—"In Search of the Perfect Raster" by P. J. Edwards (P.O. Eng. Dept.) on February 14th.

"Television Receiver Design" by J. E. Hillyer and A. E. Howard (Plessey) on February 29th.

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

British Sound Recording Association

Portsmouth Centre.—Annual General Meeting. "Development of Tape Recorders" by J. Collinson at 7.30 on February 14th at the Central Library, Guildhall Square, Portsmouth.

Institute of Practical Radio Engineers

Thames Valley Branch.—"Interference on Television Wavebands" by C. W. Cobb and F. Clarke (G.P.O. London Telecommunications) at 8.0 on February 5th at the Wheatsheaf Hotel, Kingston Market Place, Kingston-on-Thames, Surrey.

Institute of Navigation

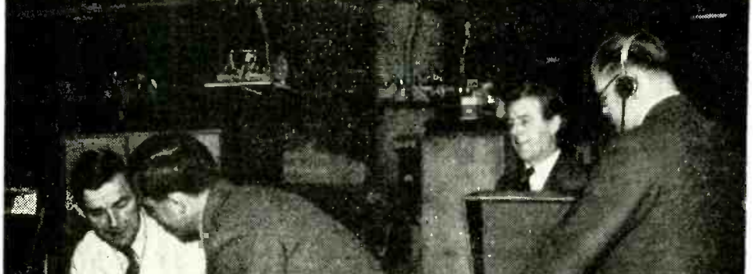
"Navigation Aids for Military Aircraft" by Sqn. Ldr. D. Bower at 5.0 on February 15th at the Royal Geographical Society, 1, Kensington Gore, London, S.W.7.

Institution of Electronics

North Western Branch.—"Development in Multi-Range Electronic Measuring Instruments" by S. R. Wilkins, M.Brit.I.R.E., Assoc.I.E.E. (Avo) at 7.0 on February 20th at the College of Technology, Manchester.

Electro Physiological Technologists' Association

General Meeting with papers and demonstrations at 10.30 on February 9th at the Maida Vale Hospital, London, W.9.



RECORDINGS being made on an E.M.I. magnetic-tape recorder at the receiver-testing bench at the company's Hayes factory for the B.B.C's overseas programme "A Good Job", which recently featured the radio industry.

EQUALIZATION

How to Find the Right Values for Tone-correcting Circuits

By "CATHODE RAY"

WHAT are commonly called tone controls and tone correction circuits are known by the professionals as *equalizers,* because they are meant to make the overall gain of an amplifying system equal at all frequencies. For instance, if Fig. 1(a) is the frequency characteristic of, say, a sound recorder, it can be put right by an equalizer with a characteristic like Fig. 1(b). The overall result, seen by adding the two together (c), is flat.

A great deal of information has been issued about this sort of thing. But unless one is exceptionally good at calculations and electrical circuit theory, putting it into practice is hard work, and slow too. Judging by the advertisement pages during the last few months, there must be a good many people beginning to take an interest in sound recording in general and tape recorders in particular. The frequency characteristic of the recording head and tape is so very far from flat that considerable equalization is quite essential. The gramophone enthusiasts have been familiar with the same sort of problem for quite a while. And in the form of pre-emphasis it crops up in frequency modulation. Tone controls are useful in radio receivers and many other kinds of amplifiers. So altogether this subject must concern a largish percentage of *Wireless World* readers. But there seems to be a gap between those who are content to follow cut-and-dried circuits and those who can work everything out for themselves from first principles. Is it possible to find suitable component values for correcting given departures from the flat without spending a lot of time performing intricate calculations?

Well, I have recently been devising an amplifier for a tape deck, and quite frankly I couldn't spare the time to work out the equalizing circuits to a fraction of a decibel in the approved manner. The method I did use can be explained in one article; and having a suitable audio oscillator and output meter I was able to check that the results were quite good enough for practical purposes. The method is applicable, of course, to other systems than tape recorders, and even to r.f. circuits such as detector output filters.

Before we get down to some examples it would

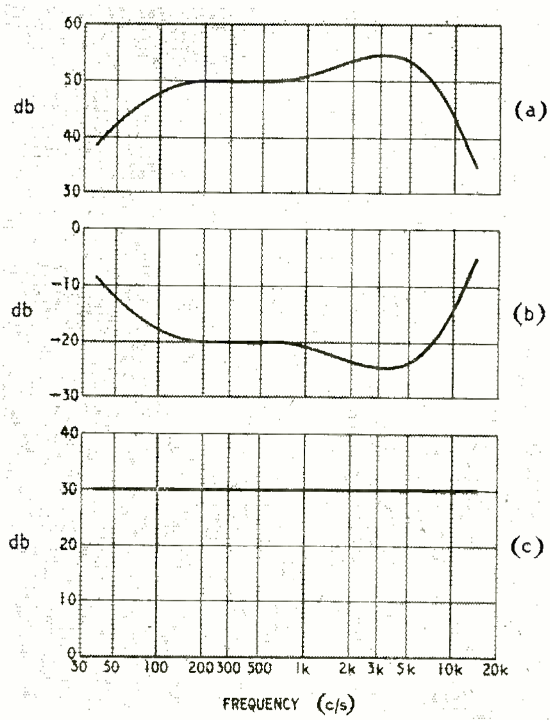
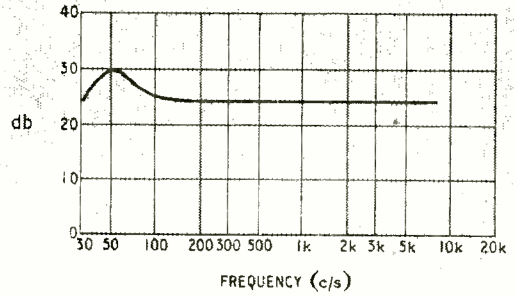
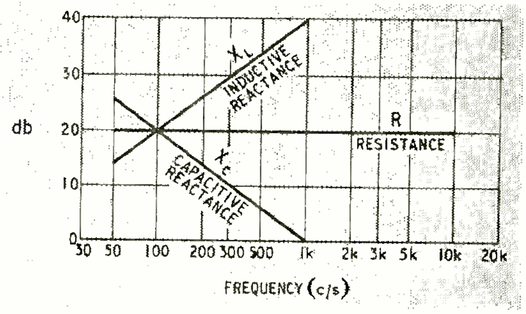


Fig. 1. (a) Example of a hilly frequency characteristic to be equalized; (b) required frequency characteristic of equalizer; and (c) extremely satisfactory result of adding (b) to (a).

(Below left) Fig. 2. 6db rise at the low-frequency end would be unlikely to cause frequency distortion, but it might easily cause non-linearity distortion by overloading the output stage because it is double voltage and fourfold power.

(Below right) Fig. 3. Frequency characteristics obtained by passing a constant current through resistance and the two kinds of reactance. There is no significance in the zero position of the db scale; the only purpose of the scale is to show the slope of the reactance lines—6db per octave.





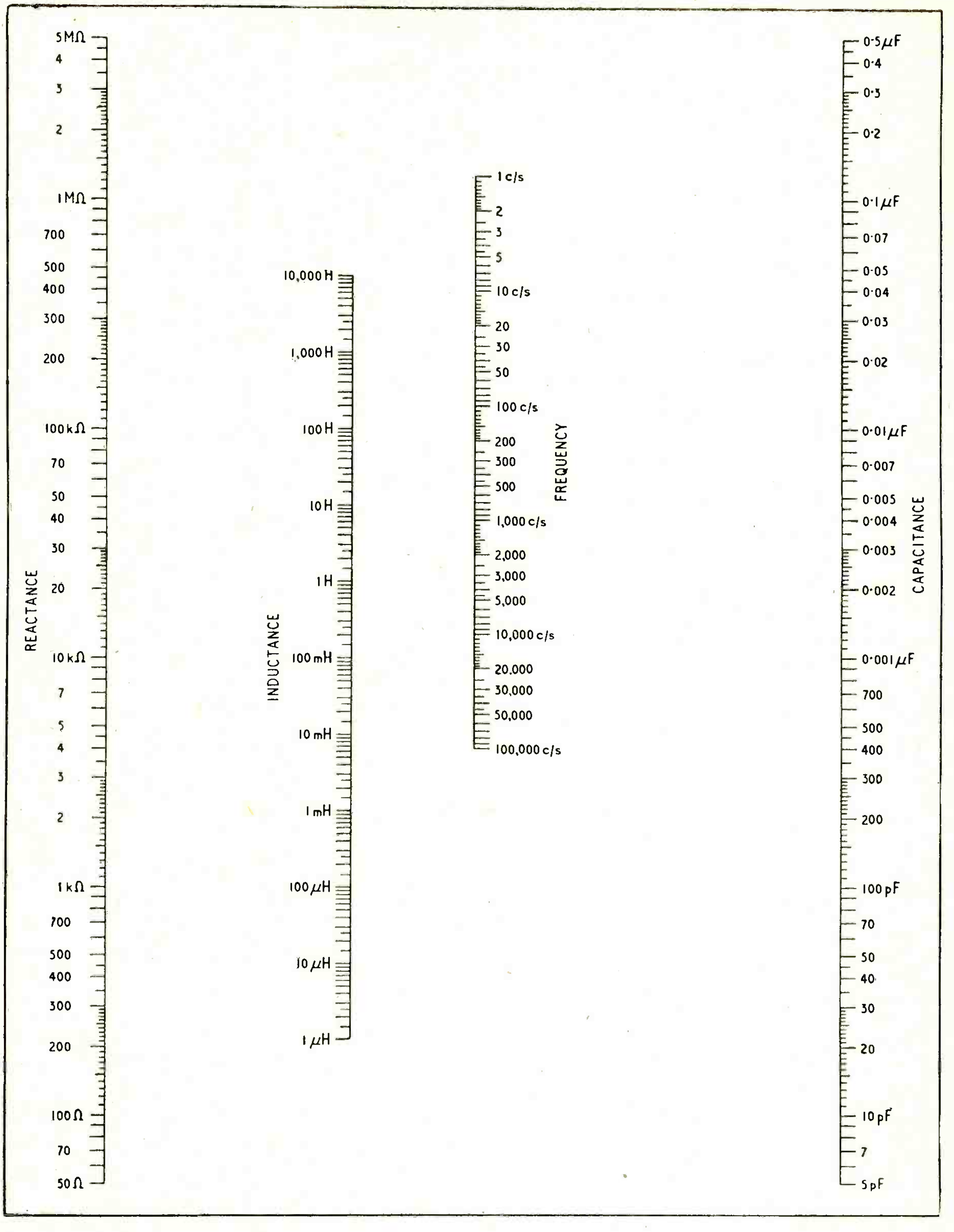


Fig. 4. By using a stretched thread or ruler edge to pass a straight line through any values on two of the scales (such as a capacitance and a frequency) the same line points out the corresponding values on the other scales (such as the reactance of that capacitance at that frequency, and the inductance which would tune that capacitance to that frequency).

probably be a good thing to pick out and remind ourselves of those principles that we are going to employ.

Perhaps we should start by asking why we want a flat frequency characteristic at all. The stock answer is that anything else is what is commonly called frequency distortion, so of course we want flatness. But while one could not deny that that is theoretically correct, it misses the point. To criticize an amplifier whose frequency characteristic shows a bump or hollow of a db or two, on the ground that it would introduce frequency distortion, shows a lack of practical understanding. For it is a kind of distortion that is accepted daily without a thought, being in fact quite inevitable. However perfect the amplifer and other reproducing equipment, and even if they are abolished altogether by bringing the source of sound into the same room as the listener, the reflections from the walls make the overall frequency characteristic look like a panorama of the Alps. So if the amplifier has a slight uneveness here or there in its characteristic it is just about as likely to improve the overall result as to make it worse.

But that is no excuse for going to the other extreme and not bothering at all about the frequency curve. The ideal of flatness is quite right, but the most important reason is not to avoid frequency distortion but *non-linearity* distortion. That may sound strange. But look at Fig. 2, for example. The 6db bump in the extreme bass might well improve the overall frequency characteristic by helping to compensate for the falling off that is typical of most loud speakers below about 80c/s. If so it could hardly be condemned for causing frequency distortion. But consider what will happen in the output stage if one attempts to run it at its full rating. Any very low-frequency full-amplitude sounds, such as one gets in organ music, will apply double the maximum allowable signal voltage to the grid, causing large quantities of the worst kinds of distortion. Alternatively, if one cuts down the volume until the bump comes within the acceptable distortion limit, the power output is reduced to one quarter, so that what should be perhaps a 4-watt output stage is reduced to an effective 1-watt rating (so long as the programme is liable to contain strong low notes).

For this and other reasons it is wise to aim as far as possible at a flat frequency characteristic, not only for the system as a whole but for each part of it separately. A droop of a few db at each end may not matter much in one link of the chain, but it is a common tendency in every one of them, and if tolerated the separate slight droops may add up to so many db that the loss is really serious and the frequency distortion can no longer be disguised by the inevitable irregularities of listening conditions.

But when it is necessary to include something whose nature it is to depart seriously from the straight and level, then one must make the best of it with tone correction. To avoid the overloading or power-limiting trouble it is advisable to do what is necessary at a low-level stage in the system, particularly if the correction is considerable—say 10db or more.

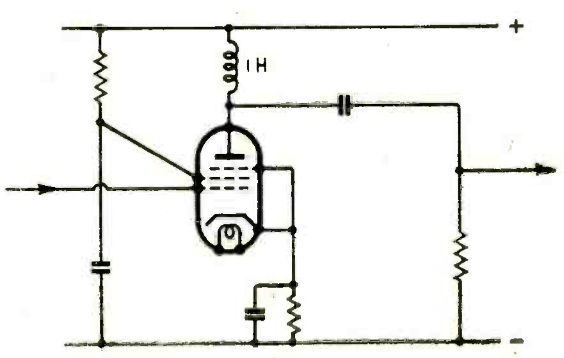
The basis of tone correction is the fact that reactance (unlike ordinary resistance) varies with frequency. Inductive reactance is directly proportional to frequency, and capacitive reactance is inversely proportional. If a certain alternating current is passed through a resistance, the voltage across it is the same at all frequencies. The resistance can be said to have a flat frequency characteristic. But if the current is passed through a reactance, the voltage rises or falls with frequency, depending on whether the reactance is inductive or capacitive. If inductive, doubling the frequency doubles the voltage; if capacitive it halves it. When it is frequency that is doubled (or halved) the usual way of expressing it is to say it is raised (or lowered) an octave. And when it is signal level that is doubled (or halved) the usual way of expressing it is to say it is raised (or lowered) 6db. Therefore if the current through a reactance is kept constant at all frequencies, the voltage across it varies 6db per octave. The basic characteristics of resistance and the two kinds of reactance are compared in Fig. 3. These are the raw materials of tone correction, the art of which consists in blending them to get the desired effects.

Simple Example

A tremendous amount of time and effort is saved in all this sort of work by making use of an abac or nomogram due to the late W. A. Barclay and reproduced (with modifications) as Fig. 4. This, and a similar one connecting voltage, resistance, current and power, together make a comprehensive guide to choice of components. As you see, Fig. 4 has scales of reactance, inductance, frequency, and capacitance; and if the values of any two of these are known the corresponding other two can at once be found simply by laying a straightedge across the scales. A piece of thread will do, but I prefer a strip of Perspex or other transparent material with a fine straight line scratched down the centre. Somewhat similar abacs, covering audio and radio frequencies separately and so having rather clearer scales, are included in "Radio Data Charts, 5th Edition, by J. McG. Sowerby; the audio one is No. 22.

Clearly, if the characteristic to be equalized happens to slope 6db per octave it can be compensated by using the signal voltage developed across a reactance. But it must be remembered that the necessary condition is that the current must remain the same at all frequencies regardless of the variations in reactance. Theoretically this necessitates a signal source of infinite resistance, but in practice it is usually enough to derive it from an r.f. pentode, having an r_a of one or two megohms. It may even be good enough to connect a relatively high resistance in series with the reactance. Of course, this means that only a small fraction of the available signal voltage can actually

Fig. 5. Example of an equalizing circuit consisting of a stage of amplification in which the usual resistance coupling is replaced by inductive reactance. The result is Fig. 6.



be used. So the amplification of the stage is largely or even wholly thrown away. It may be necessary to have one or possibly more than one stage for tone correction only, over and above those needed for amplification.

To take a simple example, suppose the usual coupling resistor in a typical amplifier stage is replaced by a coil of, say, 1 henry (Fig. 5). The g_m of a suitable high-resistance valve might be 1.5mA/V, and its r_a 2MΩ. So long as the coupling impedance is well below this, a practical approximation for the voltage gain of the stage is obtained by multiplying the impedance (in kΩ) by the g_m (in mA/V). At 1,000c/s, say, the impedance of a reasonably low-resistance coil would be almost entirely reactance, and can be found from $X=2\pi f$, or by using Fig. 4; and in this case comes to 6.28kΩ. So the voltage gain at this frequency is $6.28 \times 1.5 = 9.4$, or 19.5db. There is no need to work it out for other frequencies, because it rises with frequency at 6db per octave. At least, within limits. When, towards the low-frequency end, the reactance of the coil falls until it is no longer much larger than its resistance, the slope gradually flattens out. And at the high-frequency end a point will be reached when the reactance is no longer much less than the source resistance, r_a, and again the slope will flatten out, as in Fig. 6.

If the characteristic to be equalized flattens out somewhere, the aim must obviously be to proportion reactance to resistance so as to make the equalizer fit. That may be the point at which some people fear they are getting out of their depth. If so, good! Because I hope to be able to show that it is really quite easy.

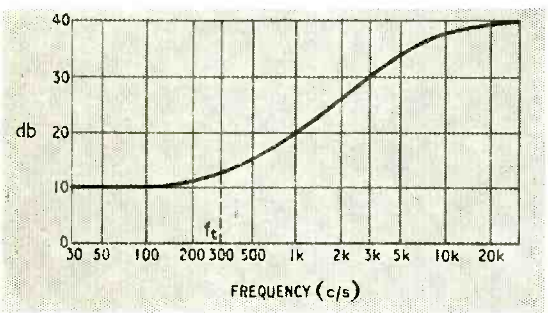
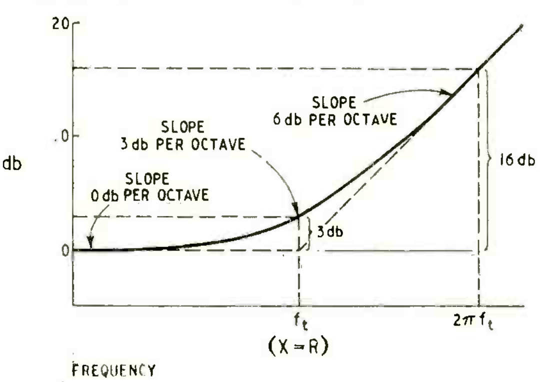


Fig. 6. Type of frequency characteristic obtained by Fig. 5.

Fig. 7. Enlarged view of the bend in Fig. 6. This shape of bend is standard for all non-interacting circuits having resistance and one kind of reactance.



Looking at Fig. 6 again, we see that at the extreme left the curve is flat, due to the fact that the reactance of the coil is so small that it is negligible compared with its resistance. In effect, then, one has a resistance coupling of low gain. At the middle frequencies the reactance swamps the resistance and provides the standard slope of 6db per octave. Around the frequency marked f_t the curve is neither one thing nor the other; the two parts gradually merge. Now this is the key to the whole situation: *f_t stands for what I call the turning frequency, because the slope is half-way—3db per octave—and it is the frequency at which the resistance and reactance are equal.* It is also 3db above the point at which the level and sloping parts would meet if produced, so it is fair to think of f_t as the frequency at which the effect of the reactance is beginning to be noticeable. All this can be seen more clearly in Fig. 7, which is a magnified view of the bend. No calculation of any kind is needed, for f_t can be read off from Fig. 4, given the resistance and inductance (or capacitance); and all the particulars of the situation are delightfully easy to remember.

Designing a Bass Lifter

What is usually wanted, of course, is the value of inductance or capacitance needed to put f_t in the right place, and that is just as easily found. A good example to work out is a bass lifter to compensate for the loss which occurs in the making of disk records and which usually amounts to 15db at 50c/s, sloping off at 6db per octave. What happens below 50c/s is rarely of more than academic interest, because few reproducing equipments are capable of handling full level there even if it were provided. So we shall assume that the slope can be allowed to flatten out when it reaches 15db above the general level.

We need the opposite kind of slope to Fig. 6, so the coil will have to be replaced by a capacitor. And as that alone is incapable of feeding anode current, some conductive path having a relatively high impedance at all concerned frequencies must be provided in parallel. Fig. 4 shows that a coil to have a reactance of 100kΩ at 50c/s would have to be about 320H, and with so many turns would probably need a Mumetal case for keeping out hum, and altogether would be much bulkier and more expensive than a 100-kΩ resistor. Much more resistance than 100kΩ would not bring anything like a proportionate gain, because it would reduce g_m; and much less would bring unnecessarily little. For remember that even at 50c/s the real coupling element—the capacitor—should have a substantially lower impedance than the feed resistor if the 6db per octave slope is to be maintained up to or nearly up to that frequency. Allowing for the fact that resistances and reactances add up at right angles to one another, 30kΩ should be ample. Fig. 4 shows the nearest stock capacitance is 0.1μF, which is 32kΩ at 50c/s. With a 1.5mA/V valve, the 50-c/s voltage gain (neglecting the small loss due to the 100-kΩ shunt and the grid leak of the following valve) is $32 \times 1.5 = 48$, which is a little over 33db. This falls off at 6db per octave, and after dropping 15db should be level. So for the rest of the frequency scale we want a resistance coupling giving a gain of about 18db, which is a voltage gain of 8. This is g_m times the required resistance, which is therefore 5.3kΩ. Having neglected some items at 50c/s we know this to be an overestimate and would have no hesitation is rounding it off to 5kΩ. So the required circuit is Fig. 8. Here the coupling has been connected to −h.t. instead of +h.t. so as to avoid making most of the signal currents go through the h.t. source, but it is nevertheless effectively in parallel with the anode feed resistor.

Using the Abac

You may think the foregoing procedure is not so very simple, and I agree. I shall now show how I would do it. Anybody who knows enough about recording characteristics to be wanting to do this job at all would know that the bend of the curve is round about 250-300c/s. This is where resistance and reactance should be equal. Pivoting the line about that frequency on Fig. 4, one looks for a standard capacitance value in line with a suitable number of ohms. 0.05μF (which requires 10 or 12 kΩ) might be considered, but its reactance at 50c/s is seen to be 60kΩ, which is getting rather too near 100kΩ for the feed shunting to be neglected. So 0.1μF (generally an easier value to buy) and 5 or 6kΩ is an obvious choice. With Fig. 4 the whole process takes perhaps half a minute. And the result, Fig. 9, is quite good enough.

Of course, one has to make sure that the 50-c/s boost is not being lost because of inadequate blocking capacitance in relation to the grid leak resistance. This resistance would probably be at least 0.5MΩ so as not to shunt the anode feed resistance too much. Say 1MΩ. The blocking capacitance, being in series, tends to cut off the very low frequencies. But the loss at 50c/s will be negligible if the turning frequency is, say, 20c/s. Fig. 4 shows that the capacitance which equals 1MΩ at 20c/s is 0.008μF, so the next larger stock value—0.01μF—would do nicely.

And what about the very high frequencies? The output capacitance of one valve, plus the input capacitance of the next valve, plus the stray capacitances of valve holders, resistors, capacitors, and wiring, might be estimated at 30pF (it need not be more if the wiring is reasonably intelligent). It comes in parallel with, say, 5kΩ at the high-frequency end. Fig. 4 shows the corresponding turning frequency (where the loss due to strays would be 3db) is above 100kc/s. So it is hardly enough to worry about at audio frequencies, even of the "hi-fi" order! But if one were attempting high gain in a straight amplifying stage, with 250kΩ coupling resistance feeding into a triode, whose Miller effect brought the effective stray capacitance up to 150pF, the turning frequency would be about 4kc/s, which is quite another matter.

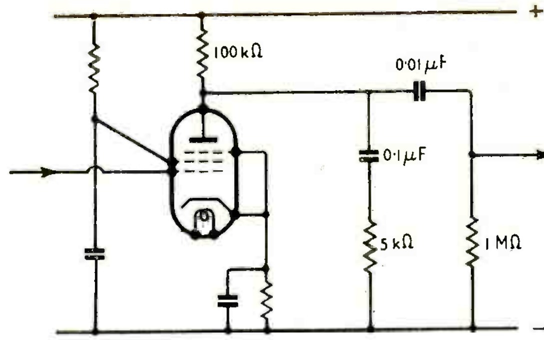


Fig. 8. Circuit designed as described, to compensate for loss of bass in gramophone recording.

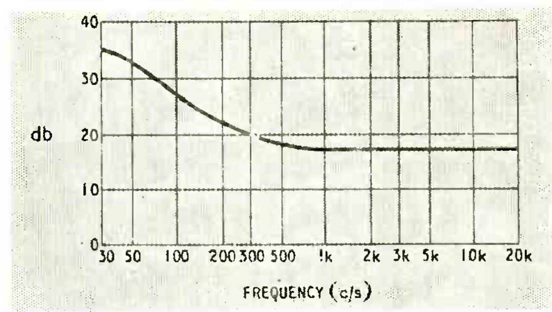


Fig. 9. Freqency characteristic of Fig. 8., including effects of 100-kΩ feed resistor, 1-MΩ grid leak, and 0.01-μF blocking capacitor.

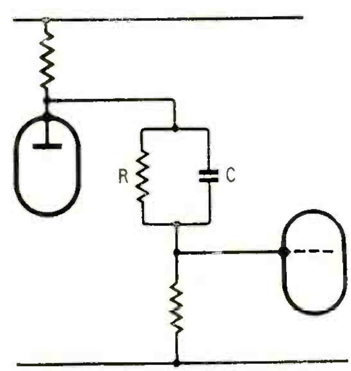


Fig. 10. Another example of tone-correcting circuit, in which the reactance is in series with the source. This is a common method of boosting the top frequencies.

Pre- and De-emphasis

Armed with Fig. 4 (or its equivalent) and the f_t idea, one has only a few minutes work to find suitable component values for amplifier circuits, putting in deliberate frequency distortion where it is required and avoiding it where it is not. Even if the values are only required as a basis for experiment, it saves an awful lot of time to have them nearly right from the start. Of course, one needs some practice to tackle the more complicated requirements with confident speed. So far we have been conveniently assuming that the slope to be corrected is 6db per octave. Often, as in f.m., that slope (pre-emphasis) is due to a tone circuit of the kind we have been considering, so will not only have the right gradient but also a bend shape that can be exactly fitted by the equalizer. As I explained some while ago* it is the custom among f.m. types to reckon emphasis (pre- and de-) in microseconds. There is something to be said for this, because the number of microseconds is equal to L/R (in microhenries and ohms) in the pre-emphasis circuit and CR (in microfarads and ohms) in the de-emphasis circuit. For instance, to correct the usual 50 microseconds of pre-emphasis one needs 50 microfarad-ohms in the receiver; so if 1MΩ is a suitable resistance the capacitance to go with it must be 50pF. *If you divide one million by the number of microseconds you have the frequency at which the rise or fall amounts to*

* "Pre-emphasis and De-emphasis," May, 1947.

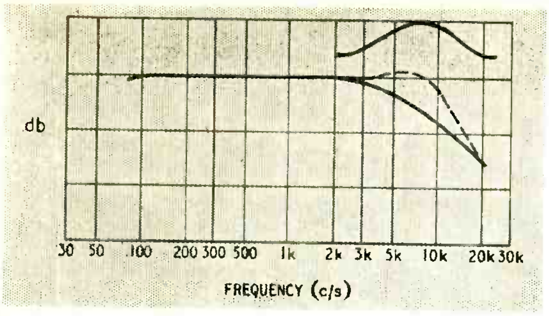


Fig. 11. A blunt resonance curve, added to a frequency characteristic with a droop, is useful for building out a shoulder, as shown dotted.

16*db*—so in this case it would be 20,000 c/s. And this 16db frequency links up with our f_t scheme because it happens to be $2\pi f_t$. So the turning frequency for a 50-microsecond circuit is 20,000 divided by 2π (roughly 6), or 3,200c/s. But note that what I have just said in italics applies only to the sorts of circuit that come into effect with increasing frequency, such as L and R in series for pre-emphasis, or C and R in parallel for de-emphasis. For those that work with falling frequency—such as Fig. 8—the 16db frequency is not $2\pi f_t$ but $f_t/2\pi$. There is no catch like this with my f_t 3db clue, which applies to all kinds of resistance/reactance tone circuits, including some I have not mentioned, such as Fig. 10, where the tone circuit CR is on the "source" side, and boosts the signal at the upper frequencies. The simple turning-frequency fact is not only easier to remember and (with Fig. 4) to use, but is safer.

But the slope to be corrected does not always chance to be 6db per octave. If it is 12, the solution is obviously to have two correcting stages. And if it is not exactly a multiple of 6 but is fairly close, a little over- or under-correction will probably not be noticed by ear. Remember, too, that the slope flattens out again where the infinite-source-impedance condition begins to break down, as in Fig. 9, and with a little jugglery a double-bend curve which is 6db per octave at its steepest can be made to compensate reasonably well for, say, a 4db slope.

If no combination of simple resistance/reactance pairs yields the desired result it may be necessary to use both kinds of reactance at once to form a tuned circuit. This is particularly useful when one wants to prolong a flat characteristic at one end and then let it cut off sharply, as in Fig. 11. An advantage of Fig. 4 over the kind of abac in "Radio Data Charts" is that at one stroke it shows both capacitance and inductance needed to tune to a given frequency, and also their reactance (which, of course, is equal at that frequency). This reactance value gives some guidance to the amount of resistance the circuit should have, for it should not be much less than the reactance, otherwise the circuit will resonate sharply; and while this may be useful for producing a steep slope in one stage it is generally unwise because of the transient distortion it causes.

Still another device is negative feedback with reactance in the feedback circuit. But we are getting right beyond *simple* tone correction. So let me summarize my recommended procedure, which can be made to cope with most of the situations one actually comes across:—

(1) Examine the frequency characteristic to be equalized, and see if it can be analysed into horizontal and 6 (or 12, or 18) db per octave sections. If so, note the turning frequencies.

(2) Sketch out circuits with reactances to give slopes in the opposite directions.

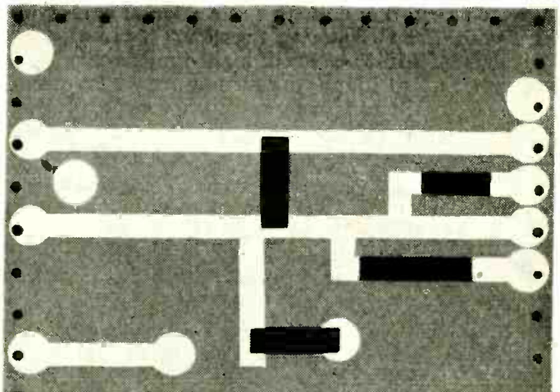
(3) Use Fig. 4 with the straightedge pivoted at the turning frequency, to find the reactance to go with a resistance that gives the right level for the adjoining flat section.

ADHESIVE RESISTORS

A NEW type of resistor has been developed by the American Bureau of Standards for use on printed circuit units. It consists of a strip of asbestos paper sprayed with a mixture of graphite or carbon black and silicone resin. This composition is slightly adhesive and is protected, prior to the actual use of the resistor, by a thin film of polyethylene.

Strips cut to the required size are stuck on to the printed plates and then subjected to a heat treatment involving temperature of the order of 300 deg C, which not only hardens the graphite-resin mixture but also causes it to adhere firmly to the silvering on the printed circuit plate. Resistance values can be varied over wide limits by changing the graphite or carbon content of the mixture.

Owing to the high processing temperature these resistors are only suitable for use on ceramic or other heat-resisting base plates. Investigation is well under way with lower temperature processes and it is expected that it will soon be possible to produce adhesive strip resistor suitable for the more commonly used types of plastic materials.



Courtesy Nat. Bureau of Standards, U.S.A.

Typical printed circuit showing adhesive tape resistors bridging gaps in the "wiring." Reproduced from "National Bureau of Standards, Technical News Bulletin."

Is *Information Theory* of any Practical Use?

ALTHOUGH modern Information Theory owes its existence mainly to the efforts of communication engineers, it is now being applied to many other branches of science in which transmission of information is a vital function. Physiologists, computing and radar engineers, statisticians, mathematicians, neurologists, physicists, psychologists, phoneticians and economists are all discovering that it has something for them. As a result, this strange child of the older Communication Theory (Hartley Law and all that) has now grown out of all recognition and communication engineers are beginning to look at it with the perplexed eye of a father who wonders whether he really was responsible. In fact, they are beginning to ask themselves whether this block off the old chip is now of any real practical use to them.

Information Theory is not in any way concerned with the meaning, value or truth of messages. It regards information merely as a commodity, and defines it simply as a change in what is already known—whether that change is in the sequence of symbols of a code message or in the structure of a waveform carrying speech, music or television images. Thus the amount of information received is proportional to the "amount of change" it has caused, and since this change can be measured the information is put on a quantitative basis.

One type of unit in which information is measured is the *logon*—the smallest possible change that has any effect on what is already known. Another one is the *bit* or *b*inary dig*it*. This comes from the notion that any message transmitted down a channel has been selected from a finite number of possibilities by a series of simple yes-no choices, as in the binary code.

This selection idea is very important in Information Theory. Modulation, for instance, is regarded as the encoding of symbols selected from a finite "alphabet" into signals suitable for the channel. The symbols forming this "alphabet" (which can be, say, amplitude levels of a television waveform) are known also at the receiving end, and demodulation is a matter of selecting them according to the code signals which come in and so reconstituting the "message." If something is known about the statistical structure of the "alphabet" (probabilities of the symbols occurring) at the receiving end, a certain amount of "guessing" is possible in reconstituting the message, and this facility is known as redundancy. Elimination of redundancy would save quite a lot of bandwidth in our communication channels but it would also destroy this facility for "guessing," which allows us to bridge the gaps in a message broken by noise or imperfect transmission. So redundancy, in spite of its name, is quite a good thing to have.

There is no doubt that Information Theory has some value as an aid to the understanding of communication techniques which are already established. But then, of course, it is very easy to be wise after the event. What engineers would really like to know is whether the Theory can be used in a more active way, for improving techniques and devising new ones. This was the main theme of a recent informal discussion at the I.E.E. following an introductory lecture by E. C. Cherry; the title was "What Practical Benefits can Communication Engineers Expect from Modern Information Theory?" Some of the speakers thought that the Theory might help to concentrate effort on profitable lines of development by indicating clearly the limits of what was possible. For example, C E. Shannon had evolved a formula which represented an upper limit of the capacity of a particular channel for conveying information; this might provide a yardstick against which various modulation methods and codes could be assessed.

The lecturer stressed that one useful concept provided by the Theory was that the significance of an item of information went in proportion to its unexpectedness. More information, for example, was conveyed in the steep portions of a waveform than in the relatively flat portions and this fact suggested the desirability of expanding the more significant or "steep" parts of a "message" and contracting the remainder, in order to improve the utilization coefficient of the channel.

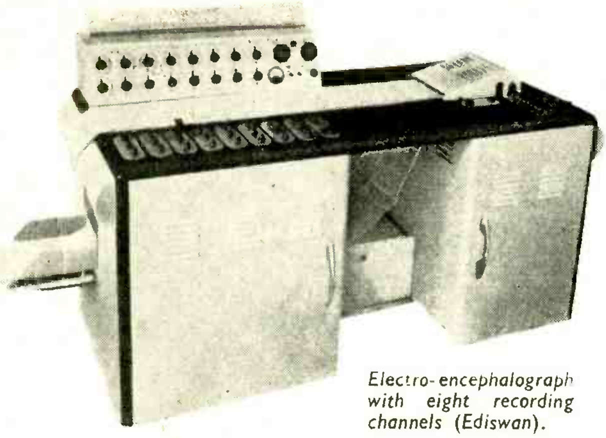
The idea of redundancy was also thought to be fundamental and suggestive. (This had been brought out earlier by a gramophone record of speech in which the waveform has been clipped top and bottom and so reduced to a series of identical pulses having only significant spacing—it was nevertheless intelligible.) The Vocoder had already shown that if such redundancy in speech could be reduced a great compression of telephony bandwidths would be possible. Information Theory, however, suggested that a good deal more compression might be achieved by alteration of the statistical structure of the signal—and the same applied to television.

In general, speakers felt that Information Theory opened up the possibility of greater economy in communication systems in future by the planning of the system of coding to suit both the channel and the message.

HEARING-AID BATTERIES

L.T. as well as h.t. hearing-aid batteries are now covered by the revised edition of the British Standard BS966, originally published in 1949. "Dimensions and Nominal Voltages of Batteries for Valve-Type Hearing Aids," as it is called, specifies the designation, nominal voltages, dimensions and methods of connection. The test to be employed to determine the contact resistance of battery socket contacts is also given.

Copies of BS966:1951 may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1, price 2s, post free.



Electro-encephalograph with eight recording channels (Ediswan).

STUDYING BRAIN WAVES

Electronic Techniques in Electro-encephalography

IN the human brain there are something like ten thousand million cells, interconnected by a vast, complex network of nerve fibres. Each cell can be imagined as a tiny accumulator, taking in and putting out electricity to the accompaniment of chemical changes—only its capacity is so small that charge and discharge currents amount to no more than electrical impulses in the external circuit. Such impulses are the signals of the brain's communication system.

Under certain conditions whole masses of the cells act in synchronism, and then the impulses add together in a periodic fashion to form a continuous waveform strong enough to be detected. Fig. 1 shows the kind of thing. Records such as this are the everyday language of electro-encephalography. As well as contributing towards our general understanding of the mechanism of the brain, they are widely used in the diagnosis of brain disorders and even have some value in psychological tests. A person's electro-encephalogram is as individual as his fingerprints, and so far no two have been found alike.

If the electro-encephalographer is able to get at the brain itself during an operation, he has potentials of up to about one millivolt to work with, but otherwise he must be content with what gets through to the surface of the scalp, after something like twenty-fold attenuation in the skull. At first, the mirror galvanometer was used for recording, but nowadays, of course, the brain waveform can be amplified until it will drive quite a robust instrument, and without imposing too much of a load on the human generators. The electro-encephalograph, then, is basically a high-gain amplifier (10^5 to 10^7) coupled to a recording instrument, although in practice it usually contains six or eight channels to permit simultaneous recording from various parts of the brain. Pen recorders are generally used for routine work as the EEG* is immediately available and the recording medium, paper, is cheap (each patient requires about 40 yards).

The low periodicity of the EEG waveform (1-30c/s) presents something of a problem in amplifier design. Direct-coupled stages would be ideal, but they are difficult to keep stable at such high gains. On the other hand, RC-coupled stages with sufficiently long time-constants tend to "block" with momentary overloads. The usual way out is a compromise, with RC coupling in the early high-gain voltage-amplifying stages and direct coupling in the later power-amplifying stages.

Interference is another problem. To avoid extraneous pick-up, most EEG amplifiers use balanced push-pull stages throughout—interference signals will generally be in the same phase at both grids and so will balance out at the anodes. In particular the input stage is designed to have a very high discrimination against these "in-phase" signals. The early stages are also vulnerable to 50-c/s mains hum from the power supplies, so it is common practice to build them as a pre-amplifier and run this from batteries. There are, however, different ideas on the subject. The Ediswan electro-encephalograph, for instance, has a pre-amplifier with batteries for h.t. and grid bias and mains-derived stabilized d.c. for the heaters, while the Marconi instrument is run entirely from the mains.

Apart from reducing interference, another reason for having a balanced input to the EEG amplifier is to permit a number of channels to be connected to the scalp without "cross-talk." The electrodes are usually arranged in lines as shown in Fig. 2. This method of working from a pattern of electrodes on the head is very useful in locating particular sources of activity, such as tumours. (A tumour in the brain generally produces a low-frequency rhythm of 1-3 c/s.) The electrodes are connected to the amplifiers in such a way that the signals from those on either side of the source give deflections in an opposite sense, and so the "focus" can be found.

Perhaps the strongest form of electrical activity in most people is the "alpha rhythm," arising at the

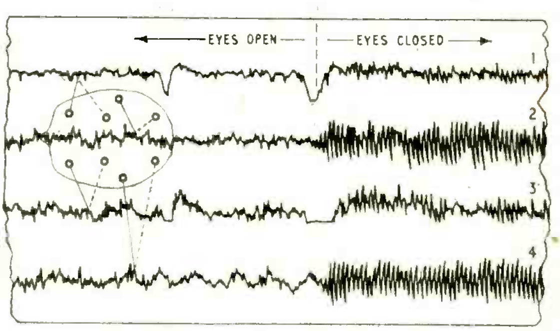
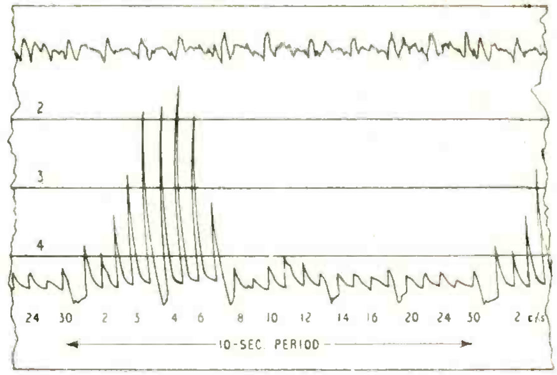


Fig. 1. Section of an EEG record showing the pairs of electrodes on the patient's head from which the four traces were obtained. These are "alpha rhythms" and it can be seen that they are strongest from the back of the head (channels 2 and 4).

* EEG is a general abbreviation used for the science, the instrument, the waveform, the record, and so on.

Left: Fig. 2. Showing the "helmet" used with the Marconi electro-encephalograph for holding electrodes in contact with the head.



Right: Fig. 3. Section of an EEG record carrying an automatic frequency analysis of the waveform in channel 1.

back of the head. It is most pronounced when the brain is at rest, and seems to have a lot to do with the mechanism of vision for there is a very marked drop in amplitude when the eyes are opened—especially if they occupy themselves with any kind of pattern—and a rise again when they are closed (see Fig. 1). The effect may be useful in character tests, for people who tend to think in visual images have small alpha rhythms while those who think in abstract terms have large ones, and in both types the rhythms are unaffected by opening or closing of the eyes. People who use both kinds of thinking show the "responsive" type of alpha rhythm in Fig. 1. A popular theory just now is that the alpha rhythm is part of a scanning system for converting the spatial electrical images on the "screen" of the visual cortex (projected there by the eyes) into ordinary time-sequential brain signals.

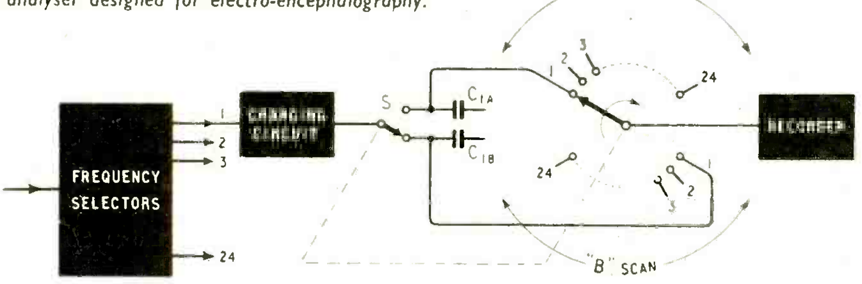
The frequency of the alpha rhythm is about 10c/s but there is generally a periodic rise and fall in amplitude which suggests the beating together of several frequencies, and when the rhythm is analyzed it shows a number of components between 8 and 13c/s. Most EEG records do, in fact, contain periodicities which are not obvious to the eye but all the same have a definite significance in the study of the brain. To sort them out, electro-encephalographers often resort to the waveform analyzer. A rather interesting one has been developed by Ediswan from an original design by Dr. W. Grey Walter. Used in conjunction with an electro-encephalograph, this will do a frequency analysis every 10 seconds and automatically write it on the part of the EEG record to which it refers. The record looks something like Fig. 3. Each period of 10 seconds along the time scale represents a complete frequency spectrum. The spikes stand for particular frequencies and the height of each one indicates the integrated amount of that frequency component present in the waveform over the 10 seconds. How is it done? The simplified block diagram in Fig. 4 will give some idea.

After amplification, the EEG waveform goes to a bank of 24 frequency selectors which separate the components, and the output from each selector serves to control the amount of charge received by a capacitor through a pentode. The 24 capacitors, with charges proportional to the frequency components, are then scanned by a motor-driven rotary switch and the resulting voltages go to a recording pen to give the "kicks" shown in Fig. 3. (This pen, incidentally, is displaced along the EEG record so that it writes out the analysis at the correct place.) To give a continuous analysis, two sets of 24 capacitors are provided, C_{1A}-C_{24A}, and C_{1B}-C_{24B}, and the rotary switch is arranged to work the switch S so that one set is being charged while the other is being scanned and recorded. The frequency selectors are actually two-stage amplifiers with frequency-selective feedback—in fact RC-oscillator circuits—and they have resonant characteristics similar to ordinary tuned circuits. These are used because the conventional tuned circuit is not very satisfactory at the low EEG frequencies.

A somewhat simpler method of analysing the waveform is by use of the human ear, which is in itself an extremely sensitive harmonic analyzer. It has been found, too, that if the EEG is being observed on a c.r.o., an audible pulse locked to the sweep is a help in detecting some consistent disturbance when the signal/noise ratio is very high.

While the type of EEG record in Fig. 3 will give a great deal of information to anyone who can be bothered to look for it, as a method of presentation it is not particularly happy. The main trouble is that it does not give a *geometrical* picture of the brain's electrical activity. However, the problem has been taken up and various attempts have been made to display the brain pictorially. One of the early systems used a cathode ray tube to represent it; the pattern of electrodes on the head was "scanned" by a high-speed rotary switch while the beam of the tube was deflected across the screen in a corresponding pattern, the

Fig. 4. Simplified block diagram of automatic frequency analyser designed for electro-encephalography.



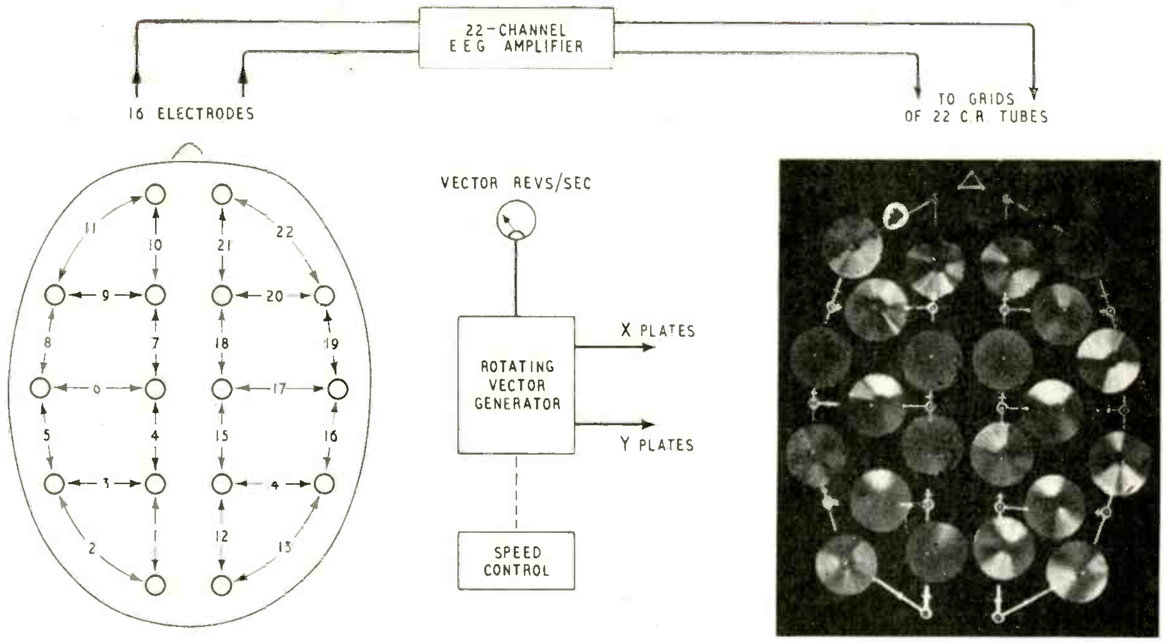
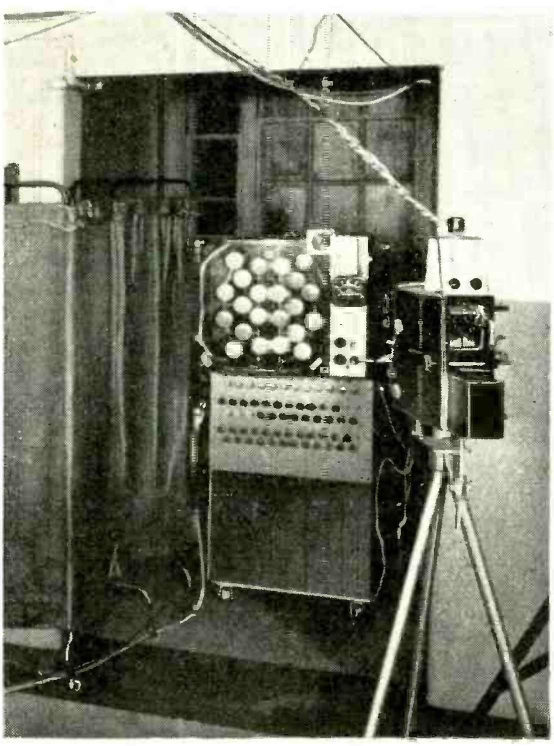


Fig. 5. Essentials of Grey Walter's "toposcope" for giving a pictorial presentation of the electrical activity of the brain. 22 small cathode ray tubes are mounted in a transparent plastic screen (right) which represents the arrangement of electrodes on the patient's head (left).

Display console of the "toposcope" installed at the Burden Neurological Institute. The camera in the foreground is for making permanent records and is remotely controlled by an operator who is in a position to observe both the display and the patient.



brain potentials being used to modulate the beam intensity.

This method, of course, only gave an indication of the relative amplitudes of the electrical sources, with their positions. A more recent apparatus, devised by Grey Walter and Shipton, shows frequency and phase relations as well. But it does not work on the scanning principle and instead of a single tube to represent the brain it uses a number of small one—in fact, one for each EEG channel. Sixteen electrodes are arranged on the head as in Fig. 5 to provide a total of 22 channels. Each channel, then, takes an EEG from a particular part of the brain, amplifies it and presents it on a c.r. tube at a corresponding position on the display.

The amplitude of the EEG is apparent from the brightness of the tube. Its frequency, however, is indicated in a rather unusual way. Each tube is like a p.p.i. radar display, with a radial vector rotating about the centre of the screen. If a signal of the same frequency as the rotational speed is applied to the tube, a section of the screen will be brightened and the remainder darkened. So to find the fundamental frequency of an EEG it is only necessary to alter the speed of the vector till a stationary sector appears. Two bright sectors would mean a frequency of twice the vector speed of course. Phase relations are easily indicated as the vectors on all the tubes come from the same generator and rotate in synchronism. If the same signal was applied to all the tubes they would all be brightened at the same instant and the sectors would point in the same direction—indicating the same phase. Thus with different signals on the tubes the phases are given by the relative "bearings" of the sectors.

The rotating vector is generated in much the same way as in radar. An oscillator produces the necessary deflection waveform and this is fed through a magslip to the X and Y plates of the tubes to give the rotating effect. The motor driving the magslip has a speed control and an indicator to show the revs/sec of the vector.

While plenty of information about the brain can be obtained simply by measuring its "standing" voltages under "quiescent" conditions, a great deal more can be discovered under "operating" conditions. So electro-encephalographers often make the patient do things or give him drugs or apply stimuli while observing the EEG. Repetitive stimulation from a pulse generator is particularly useful as it can be controlled and related to the EEG record with great precision. It is often used to evoke special brain rhythms which are not spontaneously generated by the patient under passive conditions—in much the same way as radar pulses will evoke responses from a transmitting aerial which cannot be found by ordinary d.f. because it is not radiating. The stimulation can be applied to the brain through various channels but the eyes are used most as it is easy to impulse them with a flashing light, and they produce good electrical signals.

One difficulty in dealing with these special brain rhythms is that they usually require a certain critical frequency and phase of stimulation to keep them going. Without this, the action of successive stimulating impulses would not be cumulative and the rhythm would fade out. Consequently, a great deal of trial-and-error searching is necessary to find the right frequency and phase. To avoid the tedium and uncertainty of this process H. W. Shipton has devised a system in which the brain generates its own stimuli at the correct repetition frequency. This is done by using the brain rhythm as the frequency-selective element in a positive-feedback loop, as shown in Fig. 6. After going through a conventional EEG amplifier the brain wave actuates a trigger circuit which, in turn, fires a gas discharge lamp. The flashes of light from this stimulate the eye, which sends impulses back to the brain via the optic nerve. By adjusting the variable time delay—provided by a CR time constant in the trigger circuit—the lamp can be made to fire at the correct point on the brain rhythm to keep it going. If the required rhythm is obscured by other rhythms in the EEG and so fails to actuate the trigger it can be picked out by switching in the filter—this is actually a resonant amplifier of the "RC-oscillator" type.

Incidentally, this method of stimulus has been particularly useful in diagnosing doubtful cases of epilepsy. The brain of an epileptic person is characterized by having certain groups of cells which are very easily excited and a fit is caused by these going into oscillation; a large-amplitude low-frequency waveform is generated, and this spreads until the whole brain is behaving something like a "motor-boating" amplifier—with, of course, violent results in the nervous system. Since the oscillation is caused by positive feedback in the brain, a similar effect can be induced artificially by the external positive feedback loop in Fig. 6. Examination of the resulting EEG record then shows up any epileptic tendencies.

Another interesting example of the brain being used in a feedback loop—negative this time—is provided by an apparatus devised by Bickford for automatically maintaining anæsthesia at a constant level. It works on the alpha brain rhythm, which has the property of decreasing in amplitude as the patient falls asleep, so giving an electrical indication of the degree of unconsciousness. After amplification the alpha rhythm serves to control the plunger of a syringe which applies liquid anæsthetic to the patient. Thus a servo system is formed. If the patient tends to regain consciousness his alpha rhythm increases and so applies more anæsthetic; if he goes under too deeply the flow of

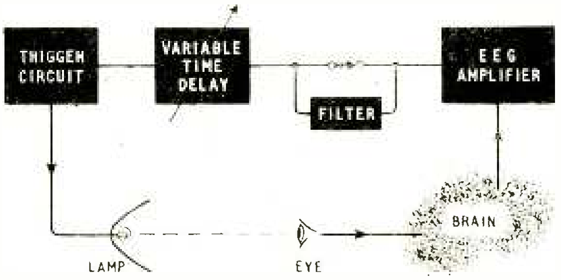


Fig. 6. The brain generates its own stimuli at the required repetition frequency in this feedback arrangement.

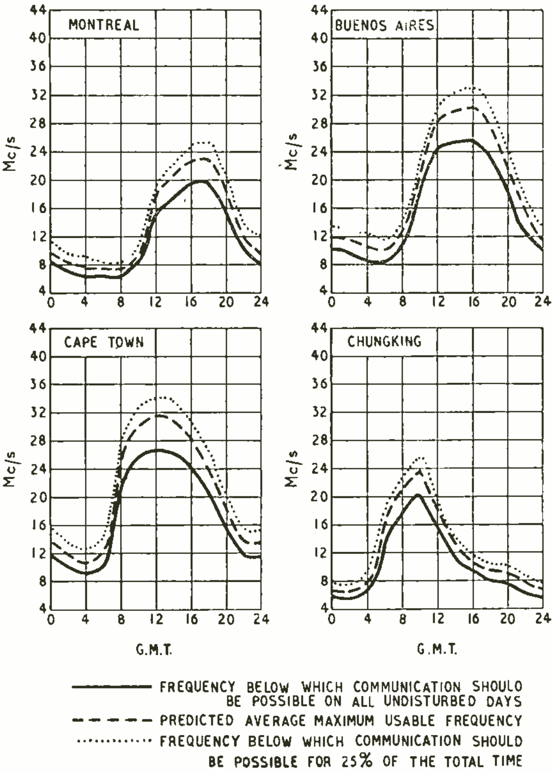
anæsthetic is decreased. The actual level of unconsciousness at which the servo finally balances itself—shown by the amplitude of the alpha rhythm—can be controlled by altering the gain of the amplifier. During the last war a similar system was devised for maintaining a constant degree of wakefulness in pilots and drivers who tended to doze off without knowing it, but here, of course, a stimulator was used instead of the anæsthetic syringe.

Short-wave Conditions

Predictions for February

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

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



Oxide Cathode Life

Investigations into the Causes of Loss of Emission

A PAPER* read recently at the Institution of Electrical Engineers described the results of work by the Electronics Division of the Post Office Research Station (with its associated small valve factory) on the development of long-lived valves. The Post Office is interested in such valves mainly because of the need for them in submarine repeaters and other inaccessible apparatus; but their development is of considerable moment to others as well.

Apart from structural failures, with which the paper was not concerned, the life of a valve depends mainly upon the rate at which the emitting qualities of its cathode deteriorate with use. Loss of emission is the disease; if its causes are completely understood, we are more than half-way on the road towards finding a cure. There are two main accepted causes of oxide cathode deterioration: poisoning by attacks from residual gases, and the development and growth of interface resistance; on both of these the paper throws much new light.

Interface resistance was the subject of a recent article in *Wireless World*.† The authors of the paper agree with Eaglesfield in accepting Eisenstein's view that interface resistance is due to the growth of a film between the cathode body and the oxide matrix, and that its production is due to deliberately introduced impurities, chiefly silicon.

They find, though, that the film does not increase in thickness as the valve ages. It appears to build rapidly up to its maximum thickness, after which a steady change in its nature sets in; it is to this change that the increase in resistance is due. They consider that it is caused, in part at any rate, by deactivation of the interface by gas poisoning, much as the matrix itself is deactivated; hence the complete elimination of residual gas would be likely to check the growth of interface resistance, in addition to ensuring longer life for the emitting surface of the cathode.

A method has been developed of making a triode or pentode measure its own residual gas pressure. As electrons flow from cathode to anode some collide with gas molecules. The positive ions, so formed, travel to the negatively biased control-grid and set up reverse grid current I_{rg}, from which the residual pressure can be derived. It has, however, been found more convenient to use a "vacuum factor":

$$k = \frac{I_{rg}\ (\mu\mu A)}{I_a\ (mA)}$$

Investigation of the behaviour of the residual gas under working conditions showed that when k was plotted against time there was always a sharp initial rise, followed by a slow, roughly exponential fall until a value k_0 (the "residual vacuum factor") was reached; the value of k_0 is constant. The area enclosed by the $k=f(t)$ and k_0 curves is a measure of the residual gas driven into the cathode and has been named the "gas integral." It was found that valves with a high gas-integral were short-lived and that a low gas integral was an indication that long life might be expected.

Here, then, was one method of forecasting valve life after a test of comparatively brief duration; reliable tests of this kind are clearly needed for dealing with valves whose working lives may range up to 60,000 hours—say seven years of continuous running! Another of great value that has been evolved is the low-temperature total-emission test. Under working conditions emission is limited by the space charge; to measure the total emission there must be no such limiting factor. It is also desirable that the cathode temperature should be low enough for ionic equilibrium to be maintained within it. The method developed is to use the control grid as collector, making its potential +5V and earthing the other electrodes; for 6.3-V valves the heater is at about 2.6V.

In practice, valves are taken from the life-test rack, where they are running under working condition, and put through the total-emission test. The total emission, after a given number of working hours, can thus be plotted as a percentage of its original value.

The authors have no doubt that the amount of barium used for gettering the average valve is amply sufficient to absorb all residual gas *if* (and that is one of the big problems) physical association of gas and getter can be established. They have given much attention to the preparation of electrodes and supports and to pumping, gettering and ageing valves. It has been found that when residual gas is reduced (by methods suited so far to the laboratory rather than to the mass-production factory) to amounts far smaller than those in commercial valves, no deterioration in the emission occurs after thousands of hours of use. The authors' estimates are always conservative; they see no reason why valves, with assured lives of 40,000 hours or more, should not be produced.

Poisoning of the cathode by occluded gases released from metal parts produces non-emitting patches on the surface of the cathode, which may be small and evenly distributed, or large and irregular. The authors in their investigations have found a new and unexpected source of cathode-poisoning gas. "A gas derived either directly or indirectly from the heated glass envelope," they state, "is more destructive in action than any of the normal gas so far examined." This gas is believed to be water vapour, which has been shown to have dire effects on a cathode at 1,000° K.

A second possibility is that the water vapour reacts with metallic carbides in the valve to produce unsaturated hydrocarbons of the acetylene type, which dissociate to form non-emitting carbon patches on the cathode.

R. W. H.

* "The Life of Oxide Cathodes in Modern Receiving Valves." G. H. Metson, S. Wagener, M. F. Holmes and M. R. Child.
† "Valve Cathode Life." C. C. Eaglesfield. *Wireless World*, December, 1951.

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WHY 47?

The Reason for the Oddness of Preferred Values

"DIALLIST" recently disposed of the impression that when a resistor is marked 47,000 ohms it is necessarily something quite different from a 50,000-ohm resistor. As he pointed out, a usual tolerance is ±10%, so the "47-kΩ" resistor would be within its rights if its actual resistance were anything between 42.3 and 51.7 kΩ. For most purposes, then, 47 and 50 are interchangeable.

That being so, why "prefer" 47 to 50? Or 22 to 20, or 68 to 70, or any of the other new-fangled numbers to the easily remembered 10, 25 and 50?

It all arises from the fact that it is impossible to manufacture anything *exactly* to a given value. There must always be some tolerance, however small. And the cost goes up very steeply as the tolerance is reduced. So it is wasteful to specify a closer tolerance than is really necessary. In ordinary receiver circuits there is rarely anything substantial to be gained by keeping the values of components, except those required for tuning, within closer limits than ±10%. In fact, many of them can be allowed a ±20% tolerance, which means that one marked 50 may be anything from 40 to 60.

In the old days, the main standard values were 10, 25 and 50, with their multiples of ten. Assuming a ±20% tolerance, the allowable spread of each value is shown here in the right-hand column of Table I:

TABLE I

Nominal value	Acceptable values for ±20% tolerance
10	8–12
25	20–30
50	40–60
100	80–120

All is well so far, but what intermediate values would you choose? Even with such a wide tolerance as 20%, there is a large gap between nominal 10 and 25. A likely value would be 15, which would spread from 12 to 18, and so would begin where the nominal 10 left off. But there would still be a gap from 18 to 20. If a standard value of 20 were added, this would spread from 16 to 24, so components that measured between 16 and 18 would be in rather an ambiguous position, since they could be sold as either 15 or 20! Similarly for those between 20 and 24.

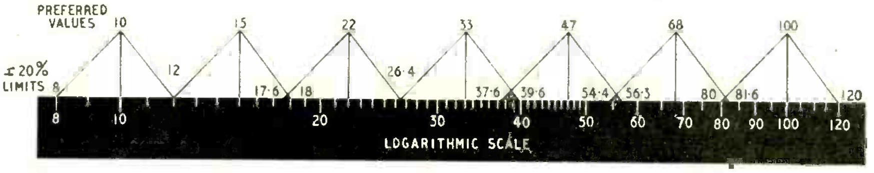
So our tidy, sensible round-number scheme is already beginning to look a little less tidy and sensible. It was this that led to the idea of choosing nominal values such that the usual tolerances would include all possible values without any gaps or overlapping. The problem was to divide the whole scale from 10 to 100, so that each division would represent the same tolerance spread from a nominal value. Obviously, if this were done from 10 to 100 the same plan would work for 1 to 10 and 100 to 1,000, and so on, covering every possible value.

Musical readers will see that this is the same kind of problem as what they call equal temperament—the dividing-up of the octave into a number of equal intervals corresponding as nearly as possible to the existing musical scales. But, as they know, it is impossible to make equal divisions correspond *exactly* with the simple ratios required for perfect tuning, and the equal temperament whole tone—corresponding to tolerance in our problem—cannot be exactly the 9:8 ratio that makes a true whole tone. Another similar problem, a little nearer our subject, is the dividing-up of the 1:10 ratio, or decade, into the ten equal-ratio parts we call decibels.

Starting off with the widest standard tolerance, ±20%, we see from the above table that the top-limit value is in every case $1\frac{1}{2}$ times the bottom limit. We want to make the first standard value 10, and, as we have seen, the corresponding limit values are 8 and 12. Multiplying 12 by $1\frac{1}{2}$ brings us to 18, which is the top limit for 15. The top limit for the next preferred value would be $1\frac{1}{2}$ times 18, which is 27, and the number that 27 is 20% more than is 22.5. That is already beginning to look a little odd. Proceeding in the same way to the next preferred value, we find it to be 33.75, which is worse. But that is not the worst of the matter because it turns out that we do not arrive, as we had wanted, at 100. It falls between two of the preferred values found in this way. After all, it is rather too much to expect that a sequence based on a previously chosen tolerance would end up exactly on 100. One could, of course, abandon the idea of trying to fit the series exactly into a decade scale, but that would sacrifice the immense advantage of having the same numbers repeating as multiples of ten in both directions without limit.

So it is necessary to begin afresh. The kind of scale on which a given ratio is represented everywhere by the same length is the logarithmic scale, with which slide rules are marked. If we try to divide the 1 : 10 slide-rule scale into equal lengths representing $1:1\frac{1}{2}$ we see, as we have already found by calculation, that it does not go exactly. The nearest whole number is six times, and the ratio represented by one-sixth of the whole scale is about 1 : 1.468, instead of the 1 : 1.5 we wanted. The corresponding ± tolerance is just under 19%.

Now, if 47±20% is considered rather odd, what would people say about 46.4195 etc. ± 18.96 etc.%, which is the sort of thing a mathematically perfect preferred-value system would give! This was considered rather too much to swallow even in the interests of science, so it was decided to accept slight overlapping of some of the divisions in order to retain the standard tolerance figures and also to allow the "perfect" nominal values to be rounded off to not more than two significant figures. The sequence so obtained is 10, 15, 22, 33, 47, and 68; and it starts all over again with 100, as shown in the diagram:



So we see that if, for example, we had a vast stock of resistors of every possible value between 8 and 80, we could sort them out into six piles labelled 10, 15, 22, 33, 47, and 68, without any of them being more than 20% high or low. And 36 piles would provide for every value between 8 ohms and 8 megohms.

Half the tolerance, ±10%, or a 9:11 ratio, is represented by half the distance on the logarithmic scale; so twice as many piles are needed, the new ones being centred on the limit values for the 20% classification. There is no difficulty in deciding on 12 as the first of these additional preferred values, because that is exactly 10+20% and 15−20%, but there might be a difference of opinion about some of the others. As a matter of fact, the correct approach is to begin with the smallest standard tolerance, ±5%, and divide the decade into 24 sections. The exact tolerance with no overlapping would then be about ±4.8%, but this allows no margin for any rounding off of the nominal centre values. When they have been rounded off to the two-figure numbers that give the smoothest sequence, the ±5% values are 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, and 91. Crossing out every alternate one leaves the ±10% values, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, and 82; and repeating the process leaves the ±20% values, 15, 22, 33, 47, and 68, as before.

So the whole list of preferred values can be set out as shown in Table II.

TABLE II

20%	10%	5%
10	10	10
—	—	11
—	12	12
—	—	13
15	15	15
—	—	16
—	18	18
—	—	20
22	22	22
—	—	24
—	27	27
—	—	30
33	33	33
—	—	36
—	39	39
—	—	43
47	47	47
—	—	51
—	56	56
—	—	62
68	68	68
—	—	75
—	82	82
—	—	91

There is no attempt to divide the values any finer for the higher-grade components having standard tolerances of ±2% or ±1%; so if you wanted, say, 80Ω ±2%, it would either have to be ordered as a non-preferred value, which might not be readily obtainable, or searched for out of an 82-Ω wider-tolerance batch.

Incidentally, resistors with silver or gold bands in addition to the usual 3-band colour code are not, as might be supposed by the uninitiated, of a particularly select kind; their tolerances are 10% and 5% respectively. The more choice 2% and 1% components are distinguished respectively by an uninteresting red or brown. If there is no tolerance colour at all, ±20% must be assumed.

"CATHODE RAY."

MANUFACTURERS' LITERATURE

Industrial Electronic Equipment; a well-illustrated booklet showing various applications, from Philips Electrical Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Counter Tubes, halogen quenched and ethyl formate quenched; technical details in leaflets from E. K. Cole Ltd., Southend-on-Sea, Essex. Also a booklet describing the Ekco **Airborne Search Radar** equipment.

Moving-coil Microphone, type 4035A; specification in a leaflet from Standard Telephones and Cables Ltd., Connaught House, Aldwych, London, W.C.2.

Television Cables (downlead); a technical data leaflet from British Insulated Callender's Cables Ltd., Norfolk House, Norfolk Street, London, W.C.2.

Instrument Cases and Racks in a catalogue from Alfred Imhof Ltd., 112-116, New Oxford Street, London, W.C.1.

Capacitors for industrial applications; technical details in leaflets from A. H. Hunt Ltd., Garratt Lane, London, S.W.18.

Coaxial Connectors catalogued in a leaflet from Transradio Ltd., 138A, Cromwell Road, London, S.W.7.

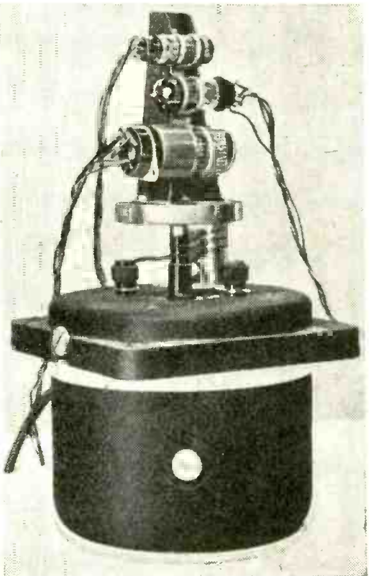
Test and Measurement; a catalogue of equipment (2nd edition) made by Taylor Electrical Instruments Ltd., Montrose Avenue, Slough, Bucks.

Manufacturers' Products

New Equipment and Accessories for Radio and Electronics

Vibration Generator

THE industrial vibration generator made by Goodmans Industries, Ltd., Axiom Works, Wembley, Middlesex, is for testing radio and other equipment for ability to withstand mechanical vibration.



Goodmans industrial vibration generator set up for testing miniature valves.

It consists of a large permanent magnet having an armature actuated by a moving coil. A sturdy connecting rod transmits the movement to a carrier or table according to the nature of the equipment being tested. In the illustration a small table is carrying three different types of valve undergoing tests for microphony and general ability to withstand vibration.

The moving coil can be driven either by a fixed or variable frequency oscillator or by a 50 c/s a.c. mains supply. Without assisted cooling it will handle up to 40 watts but with forced air cooling this can be raised to 120 watts. The magnet pot is 6½ in in diameter, weighs 26 lb and the impedance varies from 7 to 16 ohms according to the method of operation. The price is £65 which includes a felt-lined instrument carrying case.

Magnetic Coating Compound

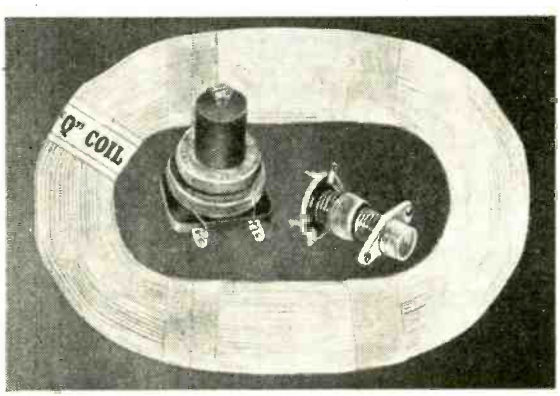
MAGNETIC recording is effected by the use of coated tape or film. For special requirements such as for high-speed computors, however, the magnetic medium may be disposed on the surface of a drum, and the Minnesota Mining & Manufacturing Company, 167 Strand, London, W.C.1, has produced a magnetic dispersion intended for application to rigid surfaces by spraying or dipping. It will adhere to the rigid surface of a variety of metals and plastics—in some cases after the application of a primer—but not to a flexible material such as a thin tape. It is known as Dispersion B25S and is supplied in quart tins with an instruction leaflet.

Miniature Coils

RECENTLY introduced by Osmor Radio Products, Ltd., Bridge View Works, Borough Hill, Croydon, Surrey, is a range of miniature coils measuring 1 in high only and fitted with adjustable dust cores. There are over 30 types in all covering the requirements of aerial, r.f. and oscillator circuits for a tuning range of 13 to 2,000 metres.

Polystyrene formers are employed and a good design feature is that the soldering tags are carried by a disc of bakelized material and not by the polystyrene, which is rather heat sensitive.

The superhet coils are designed for an i.f. of between 450 and 480 kc/s and there is an i.f. filter and an all-wave choke; the series also includes a spiral-wound frame aerial small enough for use in "personal" portables. The coils cost 4s each (frame aerial 2s 6d).



Specimens of Osmor miniature coils and spiral-wound frame aerial.

RANDOM RADIATIONS

By "DIALLIST"

Electrogremlins

YOU HAVE, no doubt, observed the queer proneness of wireless and other electrical gear to break down at times when it is impossible to get replacements. Early closing days, for instance, and week-ends. And Christmas, with the appropriate shops closed for anything up to five days was a wonderful opportunity for the electrogremlins to get busy with their pranks. Fate was, however, kind to me, for I detected and nipped in the bud an incipient fault in the wireless set on December 22, when it was still possible to buy what was needed. She did me a second good turn, too; for whilst I was in the shop I was inspired with the idea that it might be a good thing to replenish my stock of 60-watt and 75-watt lamps. It was lucky that I did, for when I got home I found that there had been no spares of either kind left; and I was able to smile when a 75-watt lamp expired with a sharp "pink" on Christmas Day and a 60-watter did likewise on Boxing Day. Not quite so fortunate was a dear old lady, whose home is not far from mine.

First Aid

Calling to see her on Christmas morning, I found her almost in tears. Her wireless set refused to work, she did so want to hear the King speak and doctor's orders prevented her from going to someone else's house to do so. I said I would see what I could do. It was a smallish set, so I carred it off to my workshop, hoping for the best. One of the handiest ways I know of making a quick examination of a sick set is to use a pair of prods connected to the resistance-measuring section of a multi-range meter. It worked like a charm in this case, for in a very short time indeed I had found a radio-frequency choke which showed infinite resistance between its terminals. A rummage through the junk box unearthed something that would do and it duly took the place of the choke with the "dis." The set was no longer silent; but it was not working properly. It might be all right for a minute or two, but then symptoms of motor boating developed. The prods disclosed that a grid resistor, colour-coded as being of one megohm, had an actual resistance many times greater. That was easily replaced. Things were then a whole lot better, but reception was noisy and the volume level was poor and wobbly.

Unwanted Ohms

If one resistor had been faulty, might not there be others whose values had suffered changes? There were! I found two anode decouplers which had managed to wander from their original orange spot class well up into the yellows. When they had been replaced the set worked well enough for speech to be intelligible and music not too awful. That, anyhow, was all I had time to do. But I had found half a dozen other resistors that were, so to speak, sailing under false colours; and when I took the set back to the old lady I impressed upon her that she must ring up a wireless shop as soon as it reopened and have the whole thing properly serviced. What worries me is that there seem to be rather too many untrustworthy resistors about nowadays. Or have I just been unlucky with resistors? I don't know. What I do know is that when a fault develops one of the first questions I have come to ask myself is: Could it be due to a dud resistor? And too often it is. What are your experiences?

Poor Fish!

A LEICESTER READER sends me an account of a puzzling effect observed by a friend of his, together with an explanation which I do not find entirely satisfactory. The said friend had a home-built a.c. receiver, working from a 3-pin wall socket. Having acquired an aquarium, he rigged up a 15-watt lamp to illuminate it, connecting the leads to phase wire and neutral at the input to the mains transformer of the set. The idea was that when the set was switched on the fish, snails and whatnot could be watched, bathed in gentle light. On switching off, peace should have been restored to both listener and whatnots; but it didn't work out like that. Turning over the switch duly silenced the set; but it left the lamp glowing, what is described as, cherry red. Two electrical crimes become immediately apparent: in the first place, it is clear that the set had only a single-pole switch; secondly, the plug must have been wired wrongly, with the result that the switch was in the neutral "leg." That much emerged at once when the "effect" was investigated. The set had a mains filter, consisting, it is stated, of a 0.1-μF capacitor from each mains lead to earth. My reader's explanation that one of these provided the return path won't do, for at 50 c/s the reactance of a 0.1-μF capacitor would be over 30,000Ω and not enough current could have passed to produce the dimmest glimmer from the lamp. Either there was a leak to earth from the neutral contact of the lampholder *via* water and filling pipe, or (as I think more probable) the capacitor was of 1 μF. Anyhow, the moral is that one should always be careful to wire up a 3-pin plug properly and that the on-off switch of a receiver should be of the double-pole variety.

The Seeing Eye

DID YOU, I wonder, see the Oxford and Cambridge rugger match on your television receiver? If so, you can hardly have helped being struck by the remarkable light-sensitiveness of the tubes used in the television cameras. Sometime before the end of the game the commentator began to complain of poor visibility; play was largely on the side of the field remote from his box and he kept on saying "The ball's gone into touch, but the light is so bad that I don't know how it happened . . . Can't see whose ball it is." Meantime, there was no sign on the television screen of the gloom of which he so often spoke. Viewers saw clearly not only the players and all parts of the ground, but even the spectators in the stand on the opposite side. The screen left one in no doubt about whose ball it was, for there was the touch judge as plain as a pikestaff, with his flag raised and his disengaged hand pointing in the appropriate direction. The television camera is far more sensitive than the human eye and I suggest in all seriousness that commentators on outdoor events in winter should be provided, as a matter of course, with this means of supplementing the shortcomings of human eyesight.

It's A Gift

HAVE YOU EVER NOTICED what an uncanny knack some people, with very little theoretical knowledge, have of tracking down faults in wireless gear with speed and certainty? And, on the other hand, some men who know the last thing about the way in which each bit and piece functions are often hopelessly at sea when it comes to diagnosing the cause of a breakdown. Give them time and they will find out what is the matter; but the fellow fortunate enough to be endowed with the trouble-spotting instinct will be far quicker than they in putting an unerring finger on the faulty lead, valve, or component, even though he possesses but a tiny part of their knowledge of how things work. It's a gift and I only wish I had it. One of the best radar mechanics I had during the war was a Scottish crofter who, in civil life, had never handled any electrical apparatus more complex than a flashlamp. Put that man on to the job of locating a mysterious fault in a radar receiver containing the best part of a hundred valves, and nine times out of ten he would have got the answer and put things right before your hard thinking had been able to reduce the possible causes of the trouble to less than about a dozen. Combine the gift of fault locating with sound knowledge of theory and you have the perfect serviceman, worth his weight in gold.

Purchase Tax and All That

THE PRESENT unconscionably high rate of purchase tax is not exactly helping the progress of wireless. I am not thinking only of its effects on the sales of broadcast and television receivers, but of the way in which it cramps the style of the amateur experimenter—and there is no need to remind you of the good work which has been done, and still could be done, by such. I know of one young fellow who will make his mark one day if he has a proper chance of developing the bright ideas that crowd into his brain; but it is no small handicap to him, with his present salary, to find that purchase tax raises the cost of three valves that he needs to try out one promising device from £1 18s to £2 14s 7d. If you are fond of figures, you may find it interesting to work out just how much a broadcast listener, paying income tax at 8s 6d in the pound on all earnings beyond those needed to provide bare necessities, must earn if he wants to buy a receiver costing £28; and what percentage of the total is mopped up by income tax and purchase tax. Try it. You'll be surprised!

UNBIASED

By FREE GRID

Hospital Wireless

AT this damp and dismal time of the year when our spirits are drooping, our temperatures and tempers rising and our noses running, it is fitting that I should write about hospitals. In pre-broadcasting days hospitals were cheerless places with nothing to pass the weary hours. I well recollect an occasion when I was myself incarcerated in one; the only literature available was an old railway timetable which enabled me to plot in imagination slow-tempo journeys from Gravesend to Bury St. Edmunds and other sepulchrally suggestive places.

The coming of broadcasting changed all that. Wards were wired up for headphones fed by a master set, and, since there were no official funds available for this purpose, it was done voluntarily by local radio societies, wireless-set manufacturers and others who undertook not only to install but to maintain the apparatus. But all that was in the days of long ago, and, although I do not doubt that there are a large number of hospitals where wireless programmes are still available at every bedside, I know also from personal experience in recent months, as a visitor at several metropolitan hospitals, that in many cases there is to-day a far different tale to tell. Headphones with broken leads, soundless sockets, weak signals and atrocious quality are only a part of the sorry story.

The trouble is one which could be so easily remedied, but it appears to be nobody's job to see to it.

Another gripe I have is against the wretchedly uncomfortable, old-fashioned and thoroughly unsuitable type of headphones available. Is not the hearing-aid type more suitable for a bedridden patient who dislikes having his few remaining hairs torn out by the roots? Cannot something be done also to provide patients with simple talking-book units—preferably tape recordings—similar to the disc type which benefit blind folk? In at least one hospital the photographic industry has beaten us to it by providing microfilm-book units where the patient "turns the page" by means of a simple bell-push type switch. But for patients with defective eyesight sound recordings would be better, and, in any case, most people prefer being read to. But all these things are at present just luxury "extras." The first task is to get at least two radio programmes to every hospital bed in the country; but whose responsibility is it to provide the funds?

This was an admitted stumbling block in pre-nationalization days, but even now the problem is as great, for apparently the radio installation was not nationalized with the hospital. Although everything from the X-ray apparatus to the electric light and plumbing is looked after by proper maintenance engineers, it seems to be nobody's business to see to the radio gear which falls into rags and tatters like Cinderella—or should I say Radioella—while the stepmotherly State looks grimly on. Won't some M.P. act the part of Prince Charming and ask a question about the matter in the House?

Temperature and temper rising.

Seen in the Crystal

WHEN broadcasting began many people saw in it the doom of the gramophone, instead of which it has provided a tremendous boost to the sales of records which have now reached a figure far in excess of what would have otherwise been attained. Now this is partly due to the fact that the hearing of a piece of music which takes your fancy, naturally makes you want to buy a permanent record of it. But, despite this, I don't think so many records would have been sold if listeners had been compelled to crank up a separate gramophone of the so-called "acoustic" type every time they had wanted to hear a record. It is, I think, only because records can be played with a minimum of effort through the ordinary amplifier and loudspeaker of the domestic wireless set that they have become so popular.

The question which arises in my mind is whether television will perform a similar office for the home ciné as sound broadcasting did for the gramophone. On the face of it the question looks rather absurd because you certainly can't buy a ciné film of anything which takes your fancy on television. Even if you could do so, the home ciné—except to its own particular devotees—is a bit of a nuisance to drag out complete with screen, etc., every time you want to show a film. It is in much the same position as the "acoustic" gramophone which I have already mentioned.

But the time is coming when you *will* be able to buy a film of anything which takes your fancy on television and you will be able to view it on the screen of your television set. The film will, however, not be a ciné film; in fact, the "film" is more likely to be a disc which you will "play" through special P.U. terminals on the set. Baird recorded television on a disc long years ago and in a few years the idea will, in my opinion, be developed commercially. It will be possible to use an automatic record-changer as for gramophone records. Of course, the recordings could equally well be made on film or on magnetic tape. This "radiogramoscope," as it is likely to be called, will probably appear about the time of *Wireless World's* jubilee in April, 1961.

Vision of 1961.

B.B.C. Headache

I HEAR it rumoured that Scottish nationalists are asking for the artificial "bars" radiated from the Kirk O'Shotts television station (now undergoing tests) to be arranged as a St. Andrew's cross instead of a St. George's cross as is the present practice of the B.B.C.

This would give the B.B.C. engineers a bit of a headache, for these bars are, of course, produced electronically by the use of two pulse generators. The diagonal cross would certainly be much more difficult to generate.

If, however, the powers that be agree to pander to this nationalism, then what will happen should there be a similar request from the Welsh at the opening of the Wenvoe station? It would be extremely difficult, if not altogether impossible, to generate a leek electronically. The only suggestion I can make is that a worm's-eye view of the Welsh national emblem should be shown, i.e., a circle. This, I understand, would not be an easy matter to produce but it would certainly provide a stringent test for receivers. But, after all, as those of you well versed in heraldry and hagiology know, the problem should not arise, for the St. David's cross has the same crucial form as St. George's.