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Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

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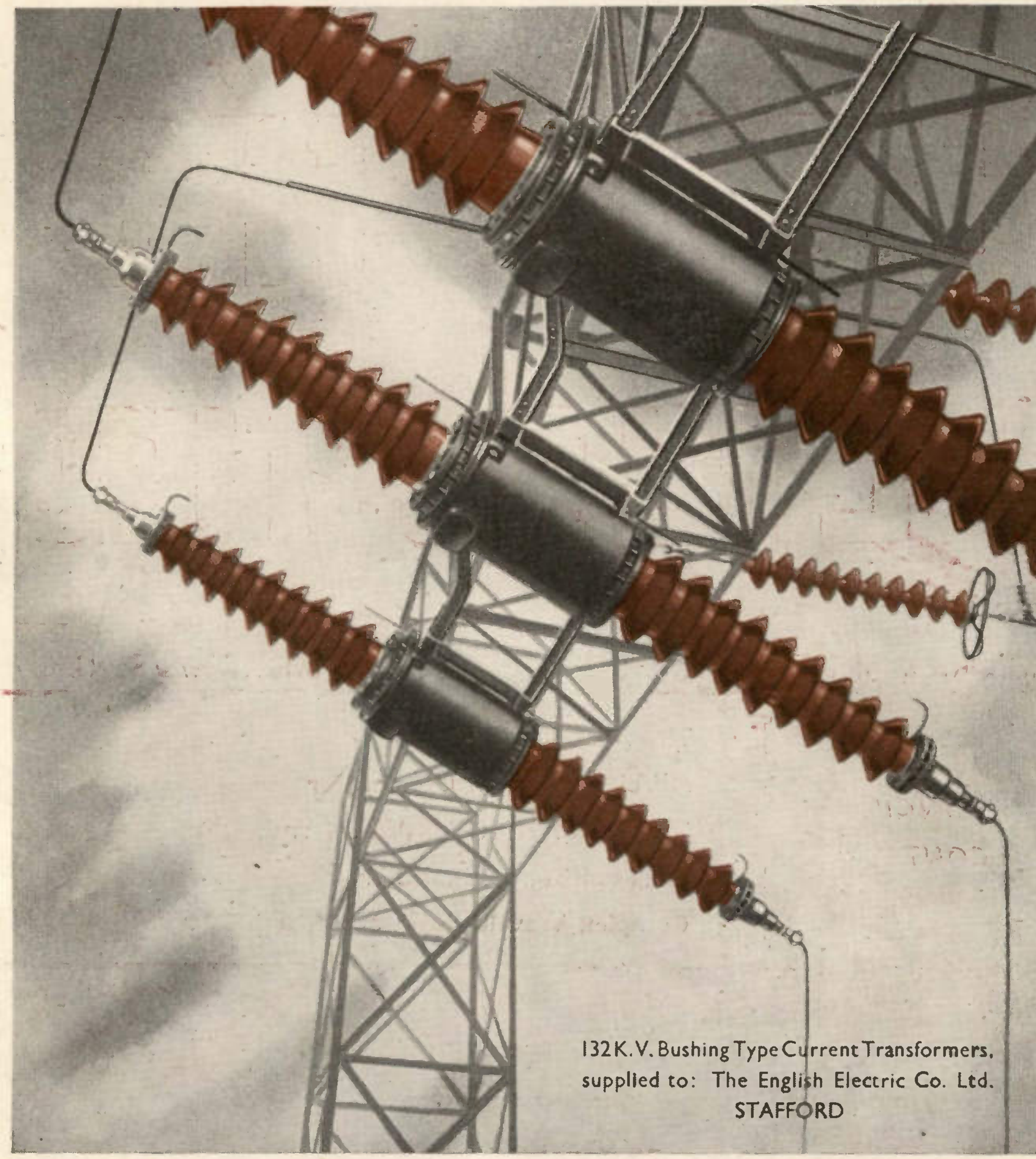
2/- JUNE, 1946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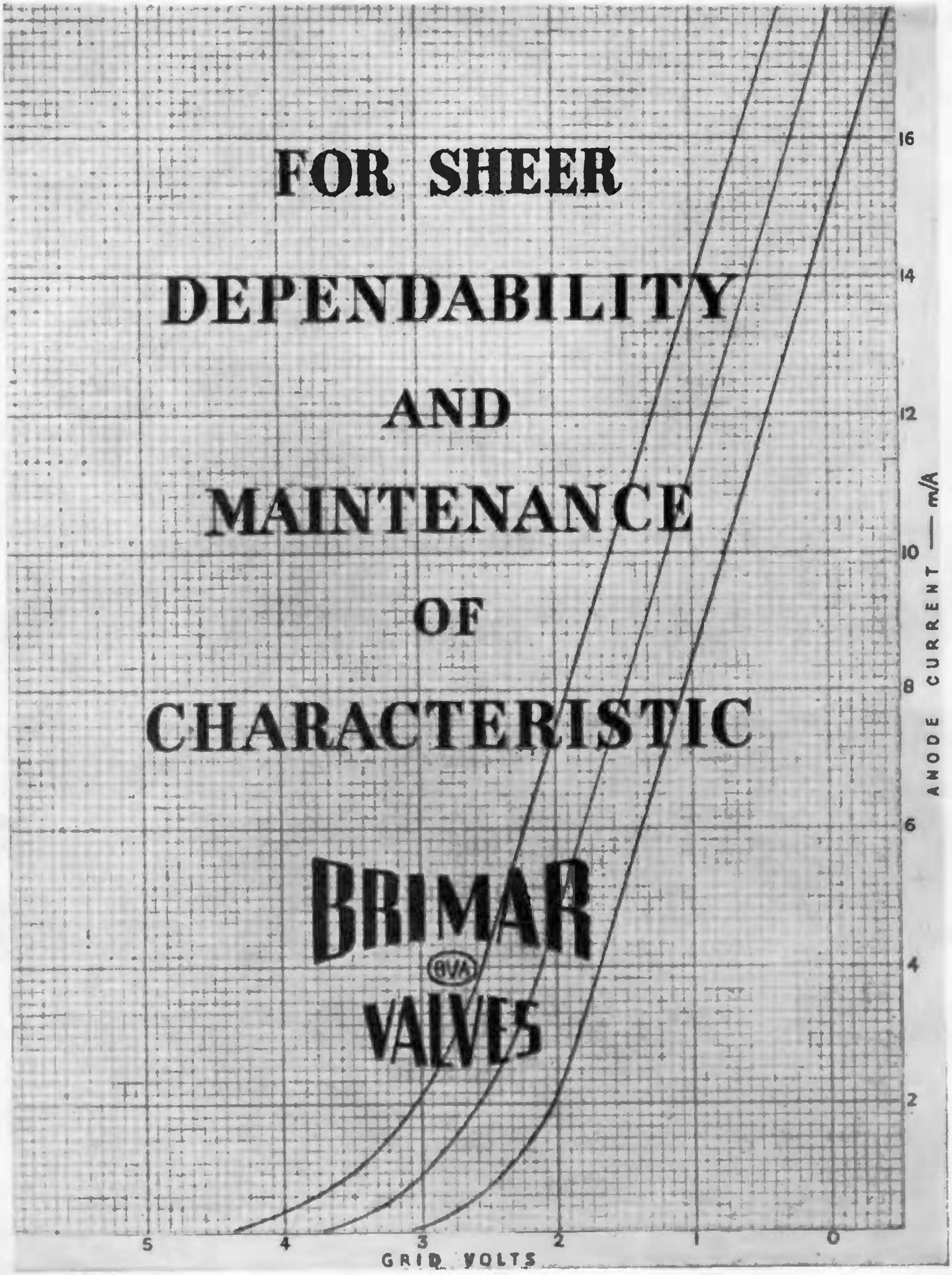
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A

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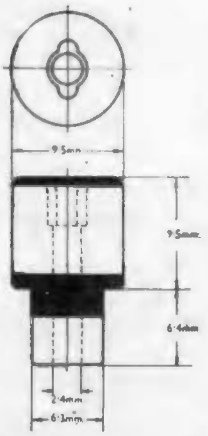

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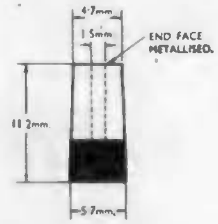

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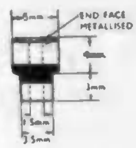

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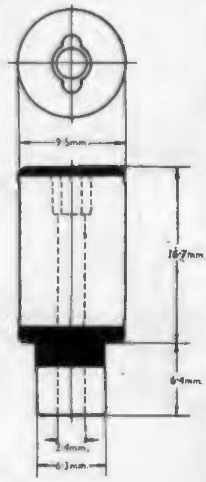

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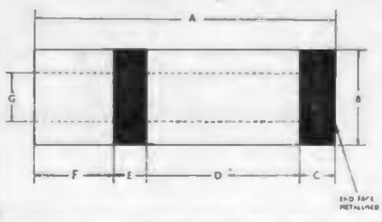

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R. 50768	GCTBC02	20.3	12.7	3.8	6.4	4.6	5.5	5.1
R. 50769	GCTBC03	20.3	15.2	3.8	6.4	4.6	5.5	6.4
R. 50770	GCTBC04	38.1	10.2	5.1	15.7	6.4	10.9	4.1
Q. 2092	GCTBC05	55.9	12.7	6.4	25.4	8.9	15.2	5.1
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TELEGRAMS
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Television

TELEVISION starts again, and the lucky 20,000 set owners have been spending the last week-end before the opening in giving a final touch-up to the cabinet and renewing acquaintance with unfamiliar knobs.

After the programmes have been running for a month we shall probably wonder if they were ever suspended, so easy will it be to slip into the old habit of dropping everything about 8.30 p.m. and sitting with eyes glued to the screen.

There is some extraordinary fascination about television. It is the biggest time-waster ever introduced into a home, except possibly patience and jig-saw puzzles. Once the set is installed it is no good making up one's mind to read or do something else that evening. The clock strikes and click!—on goes the switch to see what's on. Whatever it is, the strength of mind to switch off again is beyond most lookers.

In a recent address to the S.M.P.E. a member of the RKO staff suggested that " live talent " on the television screen was all wrong and that the bulk of the programme should be from carefully edited films—a miniature cine show in the home, in fact, except for news items.

Index to Vol. XVII

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There will be a large number of lookers who will not share this view—part of the charm of television is its intimacy and the feeling that the performance is given for the family. What if the actors do " fluff " a line occasionally? It reminds us that we are looking at flesh and blood instead of the cold flawlessness of the cinema screen.

The B.B.C. have promised most of the old favourites back again—Picture Page on Thursdays, Children's Hour on Saturday or Sunday, full-length plays twice a week, and even the television garden (will it be the same without Mr. Middleton ?).

A final word of sympathy for those would-be lookers who are either waiting patiently for a receiver or for an extension of the service to their area. Londoners can only say, " Come up and see it sometime."

The Decca Navigator

Fig. 9. Battery-driven portable receiver, showing control panel. The dials are viewed through the circular windows on top.

Fig. 10 (left). Ship model of Decca Navigator, mains driven, with remote indicator dials

IN the art of navigation, positions on a map are specified with reference to a system of co-ordinates. One such system is that of latitude and longitude. It is the most generally used, because it was established a long time ago and is related to the world as a whole. Over any area small enough to be treated as flat, it approximates to the most convenient system of co-ordinates—the Cartesian, consisting of two sets of parallel straight lines at right angles to one another, as in ordinary graph paper.

But the subdivision of degrees into minutes and seconds, and the need to add two letters to specify the quarter of the globe, is not so well suited to the fast-moving world of to-day. Therefore, especially for military purposes, local maps are overprinted with a standard grid, like squared paper rulings, which can be subdivided decimally to any desired exactness. Grid references are quick and easy to give and locate, and are less liable than latitude and longitude to be confused in communication; but they are not directly adapted to any system by which one's position can be found. In radar, for example, grid references have to be converted from measured ranges and bearings.

In the Gee system, described in the October, 1945 issue, the quantities directly measured on the receiving instrument are the differences in time required for synchronised radio pulses to travel from fixed transmitters whose positions are known. For any particular pair of transmitters all points of constant time difference lie on a hyperbolic curve. A set of hyperbolæ, each marked with its appropriate time difference, can therefore be drawn on the map around the pair of transmitters (say, A and B in Fig. 1); and the Gee receiver indicates directly which curve it is on. A second pair of transmitters, A and C, gives a second set of hyperbolæ intersecting the first and therefore forming with it a system of co-ordinates by which one's position on the map can be directly plotted from the readings of the navigating instrument.

The Decca system also depends on time differences from pairs of transmitters and therefore uses the same type of hyperbolic grid; but the time differences are measured at the receiver as *phase* differences in unmodulated C.W. signals from the transmitters. This enables the receiver to be so designed that the grid co-ordinates can be accurately read off a pair of dials rather more easily than telling the time by a clock, so dispensing with the need for a skilled operator. Other important advantages will become apparent from the description of how it works, which now follows.

Suppose the transmitters A and B in Fig. 1 are both radiating pure C.W. of exactly the same frequency. These two trains of waves establish, over the area around, an interference pattern, which can be represented by the set of green hyperbolic curves. For example, at all points equidistant from A and B (represented by the straight line 14) waves from both arrive in phase. In travelling from this line towards A, along the shortest route from B, one finds the waves from A arrive increasingly out of phase with those from B, until, when a quarter of a wavelength nearer A (and therefore quarter of a wavelength farther from B), they are 180° out of phase. Another quarter wavelength nearer A the phase difference is 360°, or one whole cycle; so the waves are in phase once more.

Let 16 be the line on which all points have a phase difference of one cycle relative to 14. Then the space between 14 and 16 is known as a lane. From the foregoing, the width of the lanes at their narrowest (which is where they cross a straight line drawn between the transmitters) is seen to be half a wavelength. So if the transmitters work on, say, 1,000 metres, a lane in this region is 500 metres wide.

Fig. 2 shows the interference pattern set up by the "red" and "green" pairs of transmitters in the Decca chain that was used on D-Day for guiding the leading minesweepers and landing craft accurately to their allotted positions along the French coast. A, the "Master" transmitter, is common to both pairs. For clearness on this small-scale map, only every tenth curve is shown, except near Paris; so each space between adjacent curves is 10 lanes wide. On actual navigational charts, of course, every lane is shown, and each is subdivided appropriately to the scale of the chart.

The same illustration shows also the dials of the two phase indicators or "Decometers," from the readings of which the position can be determined. The whole number of the lane is shown at the hundreds, tens and units windows seen on the upper half of each dial; and the first two decimal places are shown by the pointer moving over a 100-line scale. Taking the lane width to be 500 metres, each division on this scale represents a width of 5 metres. At greater distances from the transmitters the lanes widen out, and also the two sets of curves tend to run more parallel, making the exact points of intersection more difficult to determine. After allowing for this, however, it is clear that if the Decometer readings can be relied upon within one division, they enable positions to be fixed well within 100 yards over a wide radius from the transmitter.

It is even more clear, perhaps, that the provision of an instrument of the accuracy just stipulated is no small technical problem. Its solution is extremely interesting.

In the first place, the relative strengths of the two signals whose phases are to be compared vary enormously over the service areas of the transmitters. So the phase indicator must be practically independent of signal amplitude. To make this problem a more reasonable one, the discrepancy is first of all greatly reduced by using separate high-gain R.F. amplifiers, controlled by very effective A.G.C., for each signal. Within the narrower limits to which the signal strength ratio is thus brought, the phase indicator itself—which will be described presently—is inherently independent of amplitude.

Secondly, a stationary phase pattern can only be maintained when the two transmitters in a pair are working on exactly the same frequency; but, if they do, their signals cannot be separated at the receiver for phase comparison. This difficulty is circumvented by radiating signals which, although different in frequency, have a common harmonic frequency, which can be extracted from the outputs of the separate amplifiers in the receiver.

Taking round numbers, for example, suppose A transmits on 60 kc/s. and B on 80 kc/s. In the receiver,

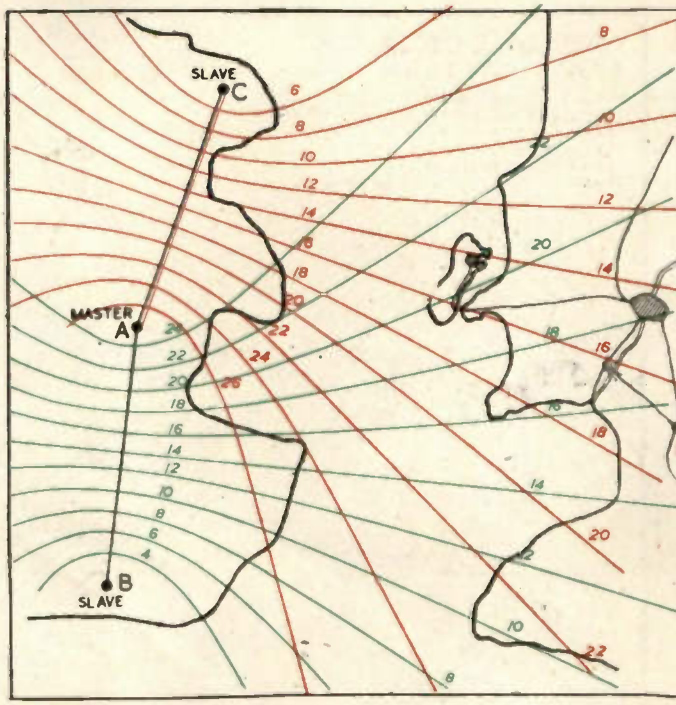


Fig. 1. Each of the red curves is such that all points on it are at a constant difference in distance from the two transmitters A and C. The green curves are similarly related to A and B. The two sets form a reference grid of the type used in both Gee and Decca systems.

after amplification and distortion of these signals, the 4th harmonic of the A signal and the 3rd harmonic of the B signal are extracted, and as both are 240 kc/s. their phases can be compared. Similarly, if C transmits on 90 kc/s., the 3rd harmonic of A and the 2nd harmonic of C are both signals of 180 kc/s., whose phases can be compared in the second indicator.*

A block diagram of the receiver (Fig. 3) shows how the sections needed to perform these functions are related. A schematic diagram of one of the indicators and its associated phase discriminators is given at Fig. 4. Each of the two discriminators consists of a pair of diodes connected so that if equal alternating voltages are applied to the two anodes the equal D.C. output voltages are in opposition and cancel out. This result is unaffected by the phase relationship of the input voltages.

---

* The actual frequencies of the transmitters referred to in Fig. 2 are :

A : 85 kc/s. × 4 }
B : 113.3 kc/s. × 3 } = 340 kc/s.
A : 85 kc/s. × 3 }
C : 127.5 kc/s. × 2 } = 255 kc/s.

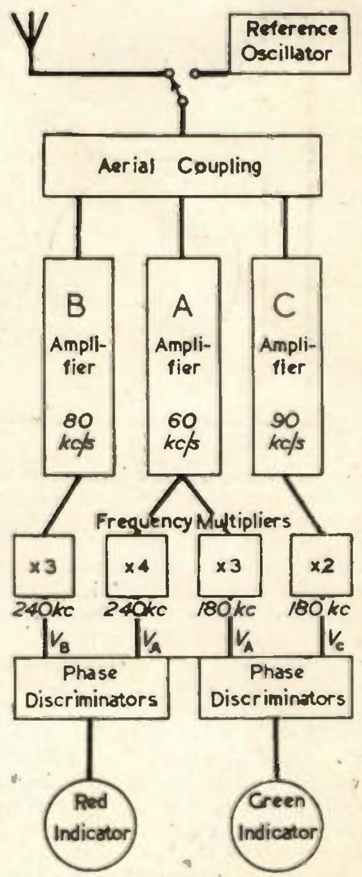


Fig. 3. Block diagram of Decca Navigator.

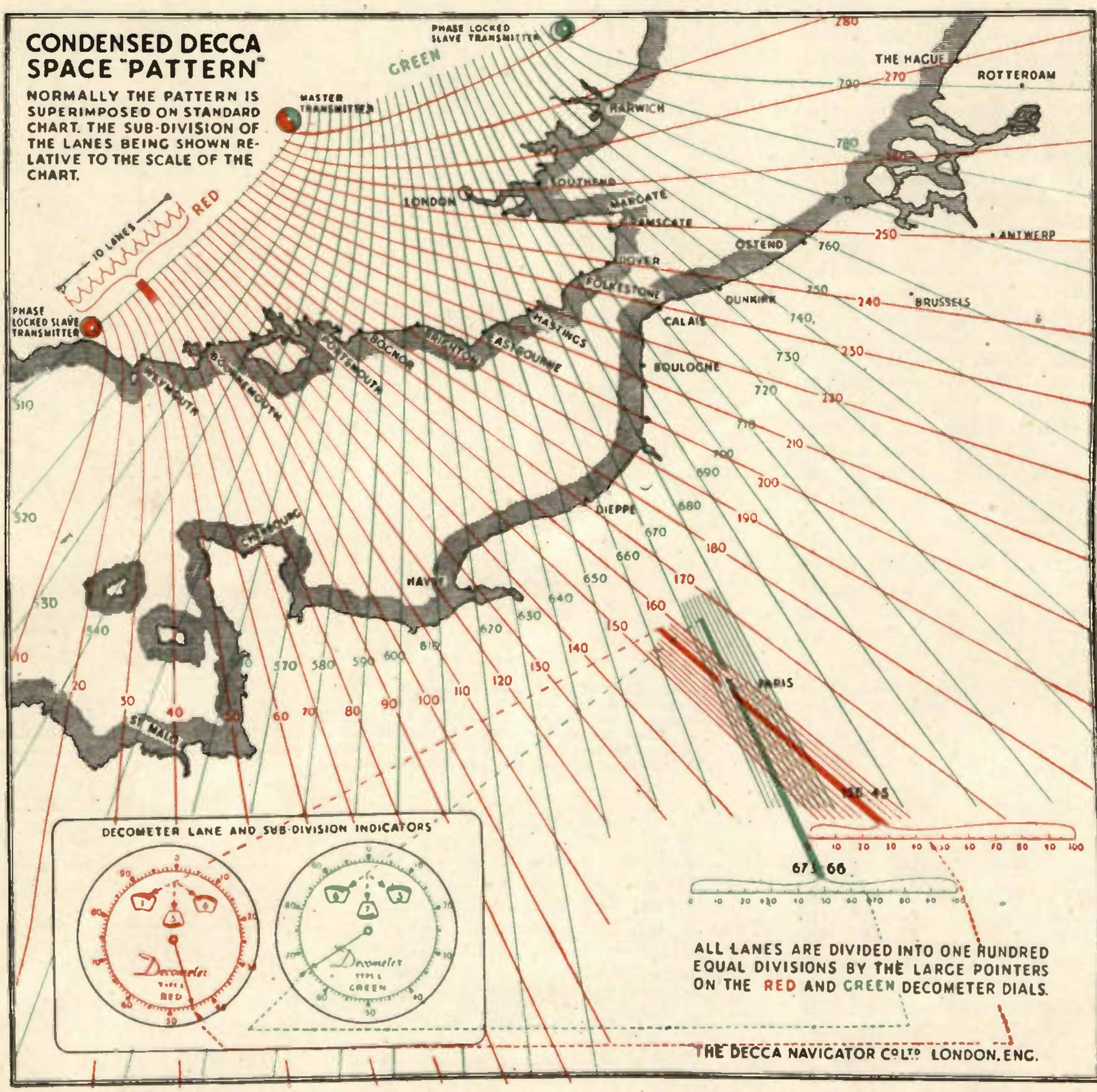


Fig. 2. Phase pattern produced by a set of three actual Decca transmitters, A, B and C, and "Decometer" receiver dials. An example of the relationship between Decometer readings and a position on the map is pointed out by the dotted lines.

The harmonic voltage V_a derived from the A signal is divided equally between the diodes of both discriminators, but in opposite phase, so by itself gives no net D.C. output from either; consequently, none of the coils of the phase indicator is energised. The harmonic voltage from the B signal is also divided into two equal parts, V_{b1} and V_{b2}, but with a 90° phase difference between them. These two voltages are applied separately to the two discriminators as shown. Suppose that the receiver happens to be in a position where V_{b1} is 90° out of phase with both halves of V_a (which can be called V_{a1} and V_{a2}), as shown in the vector diagram, Fig. 5a. Then the resultant voltages, V_{a1b1} and V_{a2b1}, applied to the anodes, are still equal, and no current flows in the related indicator field coils, F1. As V_{b2} is 90° out of phase with V_{b1}, it must be in phase with one-half of V_a and 180° out of phase with the other half, as shown in Fig. 5b. The two resultants, V_{a1b2} and V_{a2b2}, differ in magnitude to a maximum extent, and a proportionate current flows through the field coils F2.

Inside the field coils is a disk magnetised along a diameter and free to rotate about its centre; it now turns so that its magnetic axis coincides with that of the energised coils F2, and its attached pointer indicates 0 on the Decometer scale. The disk form is adopted for the moving element so that the distribution of metal in the field of the coils is unaffected by its movements, and distortion of the field, which would cause non-linearity of the scale, is thereby minimised.

Suppose next that the receiver is moved through one-eighth of a lane width, so that V_{b1} and V_{b2} shift 45° in phase relative to V_a. This condition is shown in Fig. 6, from which it is easy to see that both discriminators are unbalanced to the same extent, and equal currents flow in F1 and F2. Their resultant field is therefore at 45° to their axes, and the pointer takes up a corresponding position, indicating 12½ on the 100-line scale.

It can similarly be shown that any other phase difference is indicated. And, of course, the whole performance is duplicated for the A and C signals by the " green " indicator (*see* Fig. 4 again).

Up to the present all we know from the pointers are the phase differences of the harmonic voltages from the frequency multipliers. Two essential conditions remain to be satisfied. One is that the net phase shifts along all receiver channels from aerial to frequency multiplier outputs must be equal, so that the relative phases of the received signals are correctly indicated. The other is that the signals from the transmitters must always be locked accurately in phase.

Dealing with the first: each receiver contains a stable reference oscillator, working on a frequency which is the highest common factor of all three signal frequencies, and therefore having harmonics equal in frequency to all of them. For signal frequencies of 60, 80 and 90 kc/s., the reference oscillator frequency would be 10 kc/s. To ensure that all the harmonics are in phase and of similar amplitude, the oscillator is designed to deliver a narrow pulse waveform. The receiver can be switched over to the oscillator, as shown in Fig. 4, and the A and C amplifiers are provided with external phase adjustments for bringing the pointers of both indicators to zero. When that has been done and the amplifiers have been switched back, the indicators will read the correct phase differences in the received signals.

As each amplifier in the receiver contains a dozen or more tuned circuits, they must all be extraordinarily phase-stable if constant checking is not to be necessary in order to avoid errors due to temperature, humidity, vibration, etc., especially in aircraft, where rapid and wide variations in these conditions are liable to occur. Much detail design and testing has gone into the solution of this problem: the coils are made of enamelled wire

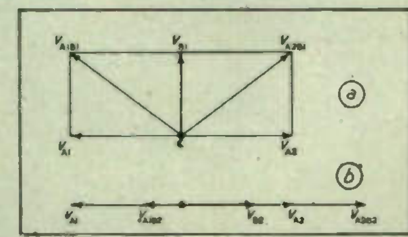


Fig. 5. Vector diagram for the phase discriminator voltages marked in Fig. 4, with V_{B1} in phase with V_{A1}. The situations in the two discriminators are shown at *a* and *b* respectively.

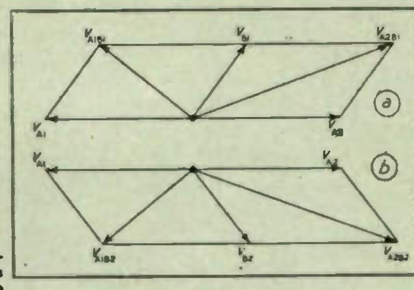


Fig. 6 (top right). Vector diagrams, corresponding to those of Fig. 5, after V_B has advanced 45° in phase relative to V_A.

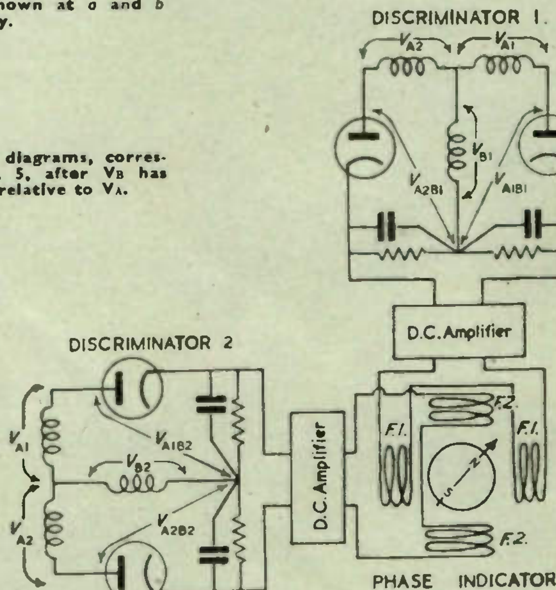
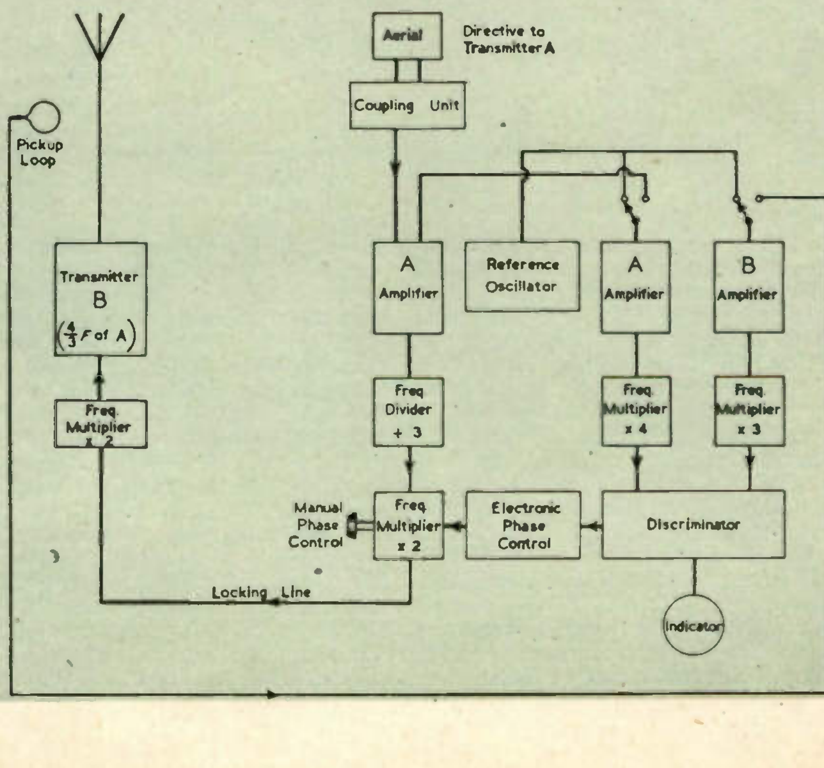


Fig. 4. Schematic diagram of phase discriminators and indicator.

Fig. 7 (below). Block diagram of phase-locking system at a slave transmitter.



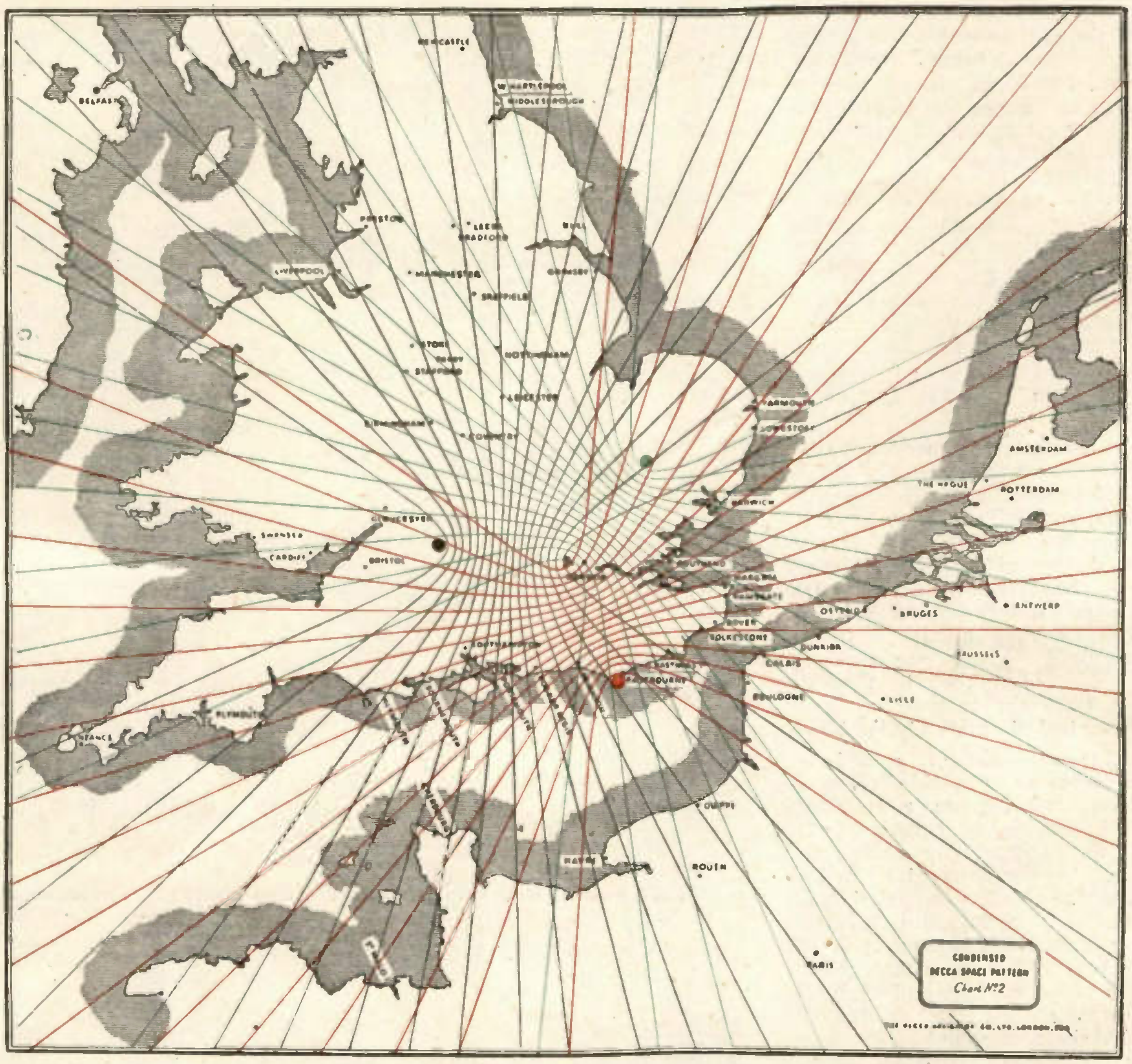


Fig. 8. Triple-slave chain now under construction.

wound on ceramic rods, and are impregnated with a special fluid and baked; the condensers are silvered by a new process and, with the coils, have extremely small temperature coefficients. The tuned circuits are designed to give constant phase/frequency ratio; the A.G.C. system is compensated as regards phase shift caused by wide variations in bias voltages; and a special aerial coupling has been developed to avoid relative phase shift due to aerial changes or movements.

Coming now to the transmitter system, the Master, A, is crystal-controlled. The other transmitters must not only maintain their exact frequencies continuously; the relative phases of their common harmonics must be fixed within about one degree of angle. It would be impracticable to do this with independent oscillators, so the system of which a block diagram is given at Fig. 7 is used. A frame aerial near B and set to cut out the B signal picks up A's signal and (continuing to assume that A works on 60 kc/s.) frequency-divides it to 20 kc/s. This is then twice doubled to provide the drive for the slave transmitter B, on 80 kc/s. The frequency of B is thereby bound to be exactly four-thirds that of A, but the relative phase is quite fortuitous and liable to vary widely with a swinging aerial or adjustments to the tuned circuits. To prevent this, equipment similar to the A and B channels of a receiver is employed, with the addition that the discriminator voltage also operates an electronic phase control—a reactor valve associated with the drive to the transmitter B. Any tendency for the phase of B to shift brings into force a discriminator voltage which, by means of the reactor valve, corrects the tendency, in the same way as A.F.C. in a broadcast receiver pulls the heterodyne oscillator into tune.

Except for the different frequency ratios, the equipment is all duplicated at the other slave transmitter, C. To ensure that long-term phase drift does not carry the phase corrector too far off the most effective part of its working range, a manual phase control is provided to bring it back. In these circumstances, the phase is locked within about 1/1,000th of a lane, or a fraction of a degree; and the phase pattern is effectively stationary.

A further check is given by a fixed monitor receiver, sited well away from the transmitters. This can, of course, be arranged to give audible or other warning of any undue phase shift.

The system as described so far indicates lane subdivisions with great accuracy, but does not show which pair of lanes, "red" and "green," one is in. To provide this, the pointer of each Decometer is geared to units, tens and hundreds dials, showing the number of revolutions it has made. The lanes are numbered arbitrarily, and the two indicators are set by hand to read the correct lane numbers of the port or airfield of departure. Each time the receiver moves into an adjacent lane the indicator moves up or down one unit, according to the direction of travel. So long as the system as a whole is operating whenever the receiver travels from one lane to another, the indicators will read correctly. If either the receiver or any of the transmitters is not working, or the receiver is out of range, the absolute setting will be lost and will have to be reset at a known position.

To obviate this need for being in a known position in order to check the lane numbers, methods of lane identification have been developed; but the rather complex details have not yet been finalised. It is intended, however, to set up "chains" with three slave transmitters, as in Fig. 8, to provide more uniform service areas, with useful angles of intersection throughout, and to avoid ambiguity due to pairs of curves that intersect in two places. To take advantage of this arrangement, a third indicator is needed in the receiver.

For ensuring continuous service if transmitter failure occurs, duplicate sets are brought into operation sufficiently quickly to prevent any of the receivers losing their reckoning. The receivers, of which Figs. 9 and 10 are examples, are sufficiently compact for duplicates to be generally feasible, even in aircraft. Portable models with battery drive have been produced weighing as little as 27 lb. (Fig. 9). There is no difficulty in providing remote indicators (Fig. 10), if necessary in several places, so that the receiver itself can be stowed away wherever convenient.

Ranges of well over 1,000 miles have already been obtained with low-power transmitters. The number of stations needed to cover the whole globe should therefore be easily practicable. The precedure in using the Navigator is to set the indicators at the point of departure to the lane numbers belonging to the chain situated as near the destination as possible. The accuracy and reliability of the readings will then increase as the destination is approached. In most point-to-point journeys it is not even essential to refer to charts; it is sufficient to work out in advance that the correct course is steered when, say, the green indicator "loses" 3 lanes for every lane that the red indicator "gains." Navigation, even in very poor visibility, is thereby reduced to an unskilled operation.

Owing to the low radio frequencies used, the Decca system is free from the vagaries of the high frequencies such as are necessary for Gee. A good reliable range is obtainable, free from fading, skip distance, multipath propagation and such effects that impair reliability and accuracy. On the other hand, the low radio frequencies are much more liable to atmospheric and morse interference. This would be a serious drawback were it not that the characteristics of the apparatus are such that it can work reliably through interference of these types on a signal so weak as to be useless for any other purpose. The reason is that they are intermittent. While either signal is swamped, torque is removed from the indicator; but so long as this condition does not last continuously until the receiver moves through more than half a lane width, the set will not lose count of the lanes, and the pointer will take up its proper setting whenever there is the slightest break in the jamming.

R.C.A. Demonstrates Colour Television

Radio Corporation of America, which for a long time has promised colour television, early in December publicly displayed its version of such home entertainment. But General Sarnoff asseverates that neither he nor his engineers care much for the system, based on a whirling tri-coloured drum. He promises, furthermore, that an all-electronic method is under development, though he sees little hope of either method becoming commercially practicable for another five years.

Using a three-colour 525-line 20-frame system, Dr. Engstrom exhibited a television receiver in which sound was developed from a variable-width pulse with a repetition rate of 47,250 per second. Carrier frequency was 10,000 Mc/s., using a bandwidth of 12 Mc/s., with the studio located two miles distant. Transmitter output was 1/20 watt, and in addition to providing colour and sound, contained stereoscopic signals.

Colour made use of a filter-sequence system, in which a 12-segment colour drum carrying red, green and blue panels revolved the transmitter's filter at 600 r.p.m. Stereoscopic presentation was accomplished by means of two polaroid disks rotating in conjunction with the colour disk.

When applied to black-and-white video signals, pulse-width modulation yields a sound track with cut-off at 5,000 c/s. This is considered too low fidelity for television use by R.C.A. engineers. Hence, pulse-width sound channels will probably not find commercial application for black-and-white television, unless the scan system should be modified to include more than 525 lines.

—*Electronic Industries*, Jan., 1946, p. 178.

The Skiatron in Radar Displays

Extracted from a lecture by P. G. R. King given at the I.E.E. Radiolocation Convention
with additional notes from the paper by D. S. Watson

INFORMATION obtained from radar equipments is often displayed on indicators of the Plan Position type. Normally these indicators use a large-diameter cathode-ray tube with a long-after-glow fluorescent screen, and the echo from any particular target is visible on this screen until another echo is received, *i.e.*, for several seconds. The after-glow has, however, very low intensity and can be viewed only directly and under conditions of low external illumination.

It became necessary for certain applications to provide a projected large-screen P.P.I. display easily visible to a number of operators, but standard after-glow tubes could not be made with sufficient intensity for projection, and in any case the direct plotting of echoes shown by bright marks on a dark background is very difficult.

Before the war it had been suggested that the coloration of an alkali-halide crystal under electron bombardment might provide a suitable light-valve for large screen television projection, and a cathode-ray tube embodying such a material as a screen was developed under the name of the Skiatron.* The possibility of meeting the above requirements with such a tube was therefore investigated, with a considerable measure of success.

The Skiatron, or dark-trace tube, is a standard type of magnetically focused and deflected cathode-ray tube with a special screen on which a picture consisting of dark marks on a white background can be formed by electron bombardment. It should be noted that the traces are not gaps in an otherwise generally fluorescing luminous background, but appear dark merely owing to partial absorption of any incident light. The brightness of a picture therefore depends on the intensity of this incident light, and the electron beam acts solely as a control of the amount of light reflected from the screen. A magnified image of this picture can therefore be produced by episcopic projection using intense external illumination. The coloration produced decays at a slow rate dependent on the conditions of electron bombardment, illumination and temperature.

The Screen

All alkali halides are coloured by electron bombardment, each having its own characteristic colour and sensitivity. Potassium chloride is by far the most sensitive, and, in addition, gives a magenta coloration convenient for maximum contrast with illumination by green light. This means that mercury lamps, which are desirable in any case for efficient projection, can be used without loss of contrast.

The method of preparing the screen is of considerable importance. Evaporation of the material is carried out in vacuo by the eddy-current heating of a nickel cup containing the potassium chloride. The screen sensitivity was found to depend on the angle at which deposition takes place. Best results are obtained when the molecular beam from the evaporating cup strikes the glass at angles between about 30° and 60°. As exposure to air harms the screen, the evaporation is carried out during the actual pumping of the tube.

The properties of the dark-trace screen differ considerably from those of more orthodox fluorescent screens.

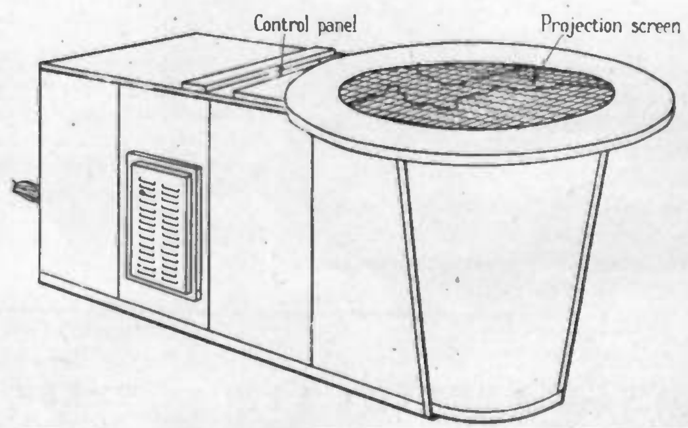
Both light and heat are necessary for any decay of the coloration to take place at all. Traces kept in the dark are therefore quite permanent. The decay rate increases with intensity of illumination from 0 to 5,000 ft.-candles, but above this figure little increase of decay rate occurs.

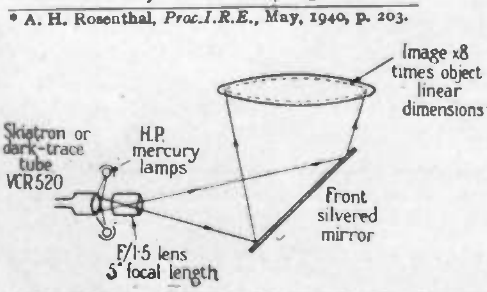
Typical decay curves of the coloration produced by a very short pulse of excitation under normal operating conditions of illumination and temperature show that the peak colour is built up almost instantaneously. It decays at a rate which is very great at first, but becomes considerably less as time increases. However, complete disappearance of traces produced under these conditions usually occurs in less than a minute. Such coloration is therefore called "transient" colour.

As the excitation is applied for an increasing length of time the decay rate becomes increasingly slow. Eventually, extremely slow decay is obtained either from bombardments extending for several seconds, or from a large number of pulse excitations, each one applied before the colour from the previous ones has had time to die away. Since the colour so formed may take several hours to disappear, it is called "persistent" colour, and this colour is the main disadvantage of the dark-trace tube. Fortunately, for radar applications, aircraft echoes correspond to pulse excitations and produce the relatively quickly decaying transient colour.

* A. H. Rosenthal, *Proc.I.R.E.*, May, 1940, p. 203.

Fig. 1. Arrangement of Skiatron projection equipment.





It is found, however, that as the temperature of the screen is raised, the decay becomes quicker and quicker. Rapid clearing of the screen is possible if it is allowed to reach a fairly high temperature and if a weak electron beam is allowed to play on the surface.

At this point it is convenient to define "contrast." The contrast is the percentage of green light reflected (in episcopic projection) from the coloration as compared with that from the background. Unfortunately, raising the temperature of the screen spoils the contrast, a loss of about 3 per cent. of the available contrast occurring for every 10° C. rise in temperature. Fig. 2 shows the relationship obtained from a single raster-type scan; the line scan is 400 c/s.; the frame scan occurs in 10 sec.; the excitation of the screen is 0.069 microcoulomb/cm.² per scan per microamp. beam current; the voltage, 10 kV; and the light intensity, 25,000 ft.-candles on the tube face. The figures relate to one typical tube only.

If 360 frames are applied in one hour, simulating the condition of a permanent echo painting in one spot, the decay of the stain is found to be very slow. (Fig. 3.) The clearing time is taken as the time for the stain to fall to 20 per cent. contrast. A single excitation at 50 mA would have faded in 10 sec. to the 20 per cent. contrast level if the temperature had been 25° C.

There are thus conflicting requirements as regards screen temperature. In order to obtain the maximum contrast it is important to keep the screen temperature low, but to keep the decay time of permanent echoes to a reasonable value a high temperature is necessary.

In the naval Skiatron equipment the practice is to keep the screen temperature as low as practicable, thus giving the maximum contrast on weak echoes. This is done by blowing 100 ft.³ of air per min. at a temperature of approximately 16° C. across the face of the tube, this low temperature being obtained in the tropics by air-cooling equipment. When it is desired to clear the face of the tube the air flow is reduced and the air circulates round a local closed system, the temperature rising rapidly owing to the heat of the lamps (1 kW). At the same time the signals are removed and a weak electron beam is allowed to play on the tube face. Using this technique, fairly satisfactory clearing of an operational Skiatron can be obtained in 10-15 min.

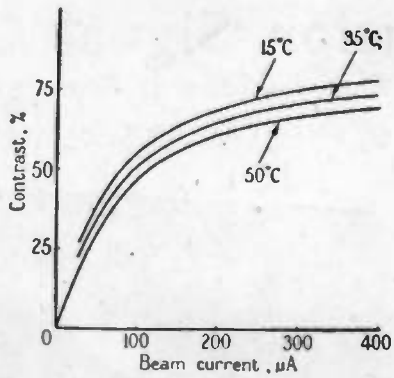


Fig. 2. Effect of temperature and beam current on contrast.

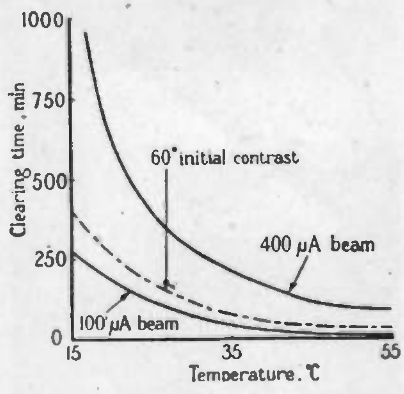


Fig. 3. Effect of temperature on clearing time

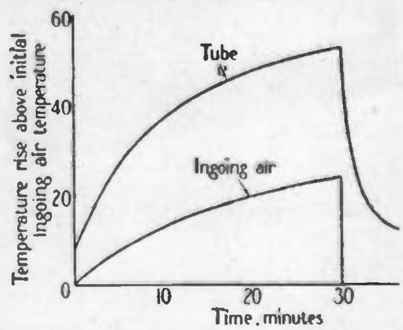


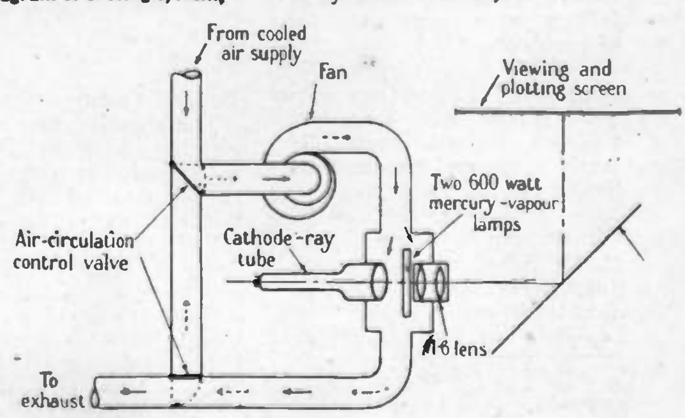
Fig. 4 (above). Heating and cooling curves and Fig. 5 (below) diagram of cooling system.

After clearing, the air flow is restored to normal and the tube rapidly returns to its normal conditions. Fig. 4 shows heating and cooling curves for a typical installation, the recirculation commencing at time 0, normal conditions being restored after 30 min. Fig. 5 shows an outline of the layout employed.

An explanation of the processes by which the colour is formed and cleared can be based on the accepted theory of ionic crystals. In an alkali-halide crystal there are imperfections due to the absence of equal numbers of halogen and metal ions. A halogen ion vacancy possesses a field such that an electron can be trapped in it, and when this occurs a colour centre is formed. Such a centre has a characteristic absorption band corresponding to transitions between its various energy levels, this absorption producing the observed coloration. The colour can be cleared only by the removal of the electrons from the colour centres, which can occur by the combined effect of heat and illumination.

In the dark-trace tube, the primary electrons in the beam eject secondaries from halogen ions, leaving uncharged halogen atoms in the crystal lattice. The secondaries are trapped by the halogen ion vacancies to form the colour centres. The simplest clearing mechanism, that of the transient colour, occurs when the electrons ejected from colour centres return direct to the nearby available halogen atoms.

Persistent colour is thought to be due to the production of local concentrations of metal ions which immobilise a corresponding number of colour centres. This coloration can therefore only clear at the slow rate set by ionic mobility.



A Television Signal Generator

Part I—General Features

By R. G. HIBBERD, B.Sc., A.M.I.E.E.*

THE excellent performance of the pre-war television receiver was remarkable when it is remembered that the designers and manufacturers had only two or three hours of B.B.C. transmission time available each day for testing purposes. Moreover, some manufacturers who were unfortunately situated outside the service area of the Alexandra Palace station had no available signals at all at their factories, and special arrangements were necessary to take receivers into the service area for test. The television signal generator to be described in this series was designed to provide manufacturers with an independent television signal conforming to the B.B.C. specification.† Such apparatus, it was felt, would be of value as a means of lining up and testing television receivers with the same fidelity as the radiated signal, but would be available whenever required and give a controlled signal level.

The development of the signal generator was started early in 1939 and the experimental equipment that will be described was almost complete at the outbreak of war. The work, of course, was then suspended; but it is continuing now that the war is over.

Brief Specification

Vision Carrier Frequency.—45 Mc/s. ± .02 per cent.

Sound Carrier Frequency.—41.5 Mc/s. ± .02 per cent.

Line Frequency.—10,125 lines per sec. (interlaced scanning).

Frame Frequency.—50 frames per sec. (interlaced scanning).

Vision Modulation.—Vision signals extend from 30 per cent. to 100 per cent. of peak carrier.

Synchronising Modulation.—Synchronising signals extend from 30 per cent. peak carrier to zero carrier.

Line Synchronising Signals.—Rectangular in shape and one-tenth of a line duration.

Frame Synchronising Signals.—Each frame synchronising impulse consists of eight pulses, occupying four line periods, two pulses per line, four-tenths of a line in duration.

* Research Laboratory, British Thomson-Houston Co., Ltd.

† See page 177.

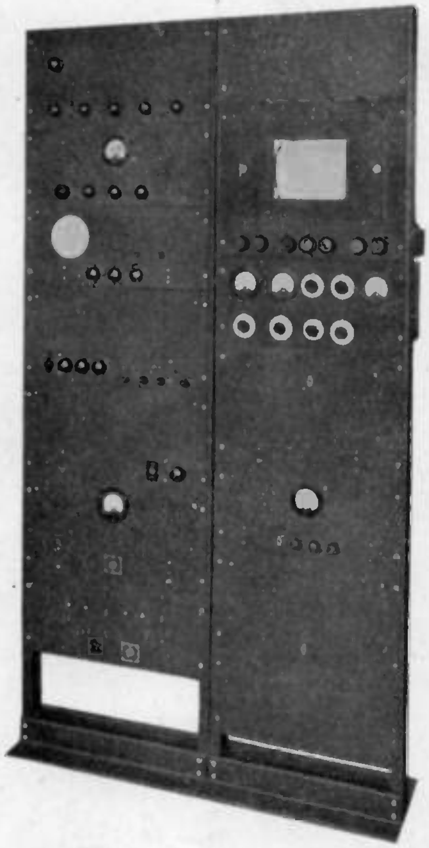


Fig. 2. Experimental television signal generator.

Residual Carrier.—During transmission of a synchronising impulse, the residual carrier shall be less than 5 per cent. peak carrier.

Sideband Transmission. — Half-power response at 2.5 Mc/s. above and below carrier.

General Features

The signal generator gives a completely modulated 45 Mc/s. signal output, designed to be within the specification of the B.B.C. transmissions as stated in the *Journ. I.E.E.*, Dec., 1938. The video modulation is obtained from a monoscope* and the synchronising impulses from a special impulse generator previously developed in the Research Laboratory.

* The actual tube used was the R.C.A. Type 1899.

The monoscope is a video signal generator tube, in which the video signal results from the scanning by an electron beam of a calibrated test pattern printed on a plate inside the tube. This tube and its test pattern will be described later.

A block layout diagram of the component parts of the signal generator is shown in Fig. 1 and a photograph of the experimental equipment in Fig. 2. The video signal is generated in the monoscope tube which is magnetically scanned. The master scanning generators feed the scanning amplifiers for the monoscope tube and also the scanning amplifiers for the picture monitor tube, which thus automatically monitors the monoscope scanning. The video output from the monoscope tube feeds a three-stage video amplifier which amplifies the signal to a suitable level for mixing in the blanking and synchronising impulses, this process being carried out in the next unit. The blanking impulses clean out the spurious signals obtained during the line and frame fly-back periods, and the synchronising impulses are then mixed into the signal, the relative amplitudes of the vision signals and the sync: pulses at this stage being approximately equal. The resulting complete signal is then amplified in the final modulation amplifier stage.

The carrier signal, at 45 Mc/s., is obtained from a 7.5 Mc/s. quartz crystal, by first trebling to 22.5 Mc/s. and then doubling to 45 Mc/s. The modulated amplifier stage uses pentode valves in push-pull, which are suppressor grid modulated. In the modulation process the ratio of the amplitudes of the vision and synchronising signals is adjusted to be correct by limiting the synchronising pulses beyond cut off. The modulated output signal is matched into a 10-ohm resistance, which feeds five output sockets at 100 ohms impedance. For each output socket is supplied a standard 100-ft. length of 100-ohm concentric cable, terminating in a pad box. The output from the pad box to the receiver under test is variable in six steps as follows: 10 mV, 3.2 mV, 1 mV, 320 μV, 100 μV, and 32 μV.

The sound carrier is obtained in a

similar manner to the vision carrier from a 6.91 Mc/s. quartz crystal. Internal sine wave modulation is provided, and provision is made for external modulation. The output from this unit is coupled into the vision output at the 10-ohm load so that a mixed vision plus sound signal is obtained at the test pad boxes.

The impulse generator consists of three units: the mixing unit, the locking unit and the power unit. It supplies :—

(1) Separate line and frame synchronising impulses for synchronising the monoscope scanning generators.

(2) Mixed line and frame blanking impulses for cleaning out the unwanted signals produced during the fly-back periods.

(3) Mixed line and frame synchronising impulses for mixing into the final video output.

A 9-in. monitor cathode-ray tube is provided for monitoring the actual picture at any point after the video head amplifier. The tube is magnetically operated, the scanning amplifiers being fed from the monoscope scanning generators, the raster thus monitoring the monoscope scan. The 45 Mc/s. output signal is monitored by amplifying and detecting the signal appearing across the 10-ohm output load. A two-stage video amplifier for feeding the C.R. tube is included in the monitor.

A 5-in. cathode-ray tube is used for monitoring the waveform of the signal at any point and for lining up the impulse generator section. This tube has a 50-cycle elliptic scan so that a complete frame can be observed. Wandering leads are used for connexion to both monitors.

The Monoscope Tube [1, 2]

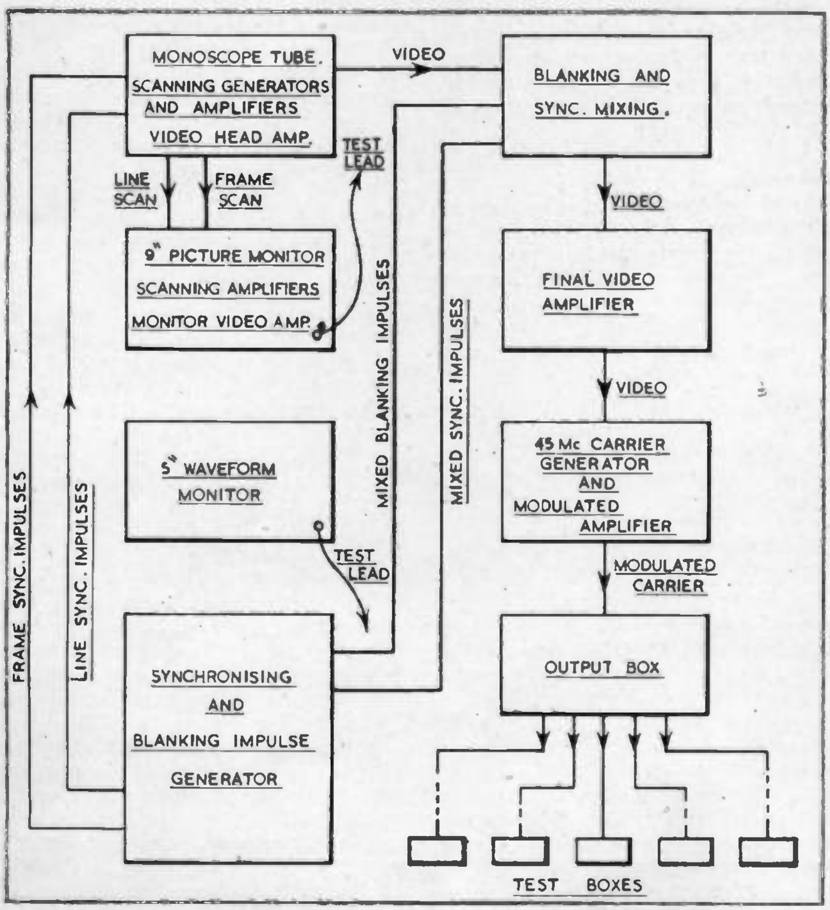
As the video signal is generated in the monoscope tube, it is necessary to have a complete understanding of the operation of the tube in order to fully interpret the results obtained. The monoscope tube is essentially a cathode-ray tube in which the fluorescent screen is replaced by an aluminium plate. The signal pattern is printed on this plate with printer's ink and is then fired in hydrogen. The aluminium has a natural coating of aluminium oxide, and the firing reduces the printer's ink to practically pure carbon. This signal plate is scanned by the beam, which is electrostatically focused and magnetically deflected. The operation of the tube depends on the fact that under bombardment by an electron beam more secondary emission current is obtained from the aluminium oxide than from the carbon. Thus a signal current representing the shading of the pattern flows in the load resistance connected to the signal plate. The collector electrode, which collects the secondary emission from the signal plate, must be maintained positive with respect to the signal plate by 50-200 volts.

The signal pattern of the R.C.A. monoscope is shown in Fig. 3. The two larger circles and the squares give a quick test of linearity. Inside the smaller circle are two methods of assessing resolution. In the centre are six concentric circles labelled 30. The radial spacing between the circles is that between the lines of a 300-line picture. Thus, if the receiver reproduces these circles separate and distinct, the receiver is said to be capable of resolving 300-line detail. The four wedges radiating from the circles are similarly calibrated, so that both the horizontal and vertical resolution may be checked by observing the point at which the lines are reproduced separate and distinct. The number of equivalent lines varies linearly along the wedges. The other two wedges in the centre circle, at 45° to the horizontal, are tone scales, to check the linearity of the receiver circuits.

Between the two larger circles on either side is a vertical row of small rectangles. The figure 50 above the top right-hand rectangle indicates that this rectangle has a width equal to 1/50 of the height of the pattern. Thus this rectangle tests the ability to reproduce 50-line detail. The rectangles progress in 25-line steps up to 575 lines. These rectangles are useful in testing for undesired transient responses which appear as "trailing."

(*Continued on p.* 178.)

Fig. 1. Block diagram of television signal generator.



The B.B.C. Television Waveform

The following specification of the radiated waveform of the B.B.C. television transmissions was issued first in 1938* and is reprinted for the benefit of those now engaged on television research. It has been revised by a member of the B.B.C. staff and minor corrections made to conform with the present practice

THE present system transmits 25 complete pictures per sec., each of 405 total lines. These lines are interlaced so that the frame and flicker frequency is 50 per sec. The transmitter will radiate signals with sidebands extending to about 2.5 Mc/s. on either side of the carrier frequency. The transmitted waveform is shown in Fig. 1.

Line Frequency

10,125 lines per sec., scanned from left to right when looking at the received picture.

Frame Frequency

50 frames per sec., scanned from top to bottom of the received picture.

Type of Scanning

The scanning is interlaced. Two frames, each of 202.5 lines, are interlaced to give a total of 405 lines with a complete picture speed of 25 per sec. The line component and the frame component of scanning are regularly recurrent, the interlace being derived from the fractional relationship between line and frame frequencies. An explanation of the method of interlacing is given at the end of this specification.

Interval between Lines

There are intervals between the vision signals of successive lines; these intervals provide time for the transmission of a line-synchronising signal and also for the return of the cathode-ray beam to the beginning of the next line. The interval between the vision signals of successive lines is 16.5 per cent. of the total line period (1/10,125 sec.); the first 0.5 per cent. of this interval corresponds in intensity to black and constitutes a short black interval separating vision signals from the beginning of the line-synchronising signal; the next 10 per cent. is occupied by the line-synchronising signal, and the remaining 5 per cent. corresponds in intensity to black and separates the end of the line-synchronising signal from successive vision signals.

Interval between Frames

There are intervals between the vision signals of successive frames. The interval between frames is 14 lines, leaving 188.5 active lines per frame, or 377 active lines per complete picture.

Picture Ratio

The picture ratio is 5 : 4, *i.e.*, the distance scanned during the active 84.5 per cent. of the total line period will be 5/4 times the distance scanned during the 188.5 active lines of the frame.

D.C. Modulation

The picture-brightness component (or the D.C. modulation component) is transmitted as an amplitude modulation, so that a definite carrier value is associated with a definite brightness. This has been called "D.C. working," and results in there being no fixed value of average carrier, since the average carrier varies with picture brightness. The radio-frequency transmitter output is specified in what follows as a percentage of the peak output. This percentage is in terms of current (or voltage) and not in terms of power.

Vision Modulation

The vision modulation is applied in such a direction that an increase in carrier represents an increase in picture brightness. Vision signals occupy values between 30 per cent. and 100 per cent. of peak carrier. The amount by which the transmitted carrier exceeds 30 per cent. represents the brightness of the point being scanned.

Synchronising Modulation

Signals below 30 per cent. of peak carrier represent synchronising signals. All synchronising signals are rectangular in shape and extend downwards from 30 per cent. peak carrier to effective zero carrier.

Line-Synchronising Signals

The line-synchronising signals are of one-tenth of a line duration and are followed by one-twentieth of a line of black (30 per cent. peak) signal.

Frame Synchronising Signals

The frame-synchronising signals comprise a train of two pulses per line, each occupying four-tenths of a line and having one-tenth of a line interval of black (30 per cent. peak) signal between them. At the end of even numbers of frames the first frame pulse starts, coincident with what would have been a line signal; and at the end of odd numbers of frames the first pulse starts half a line after the preceding line signal. Each frame signal consists of 8 pulses, occupying 4 lines. During the rest of the intervals between frames, normal line-synchronising signals will be transmitted, with black (30 per cent. peak) signals during the remaining nine-tenths of the line.

It will be noted that throughout the interval between frames (as during the whole transmission) the carrier falls from 30 per cent. to zero regularly at line frequency and in phase with the beginning of the normal line-synchronising pulses.

Variations in Transmitted Waveform

The 30 per cent. carrier is the "black level" below which no vision signals exist and above which no synchronising signals extend. The mean black level of any transmission will be (30 per cent., ± 3 per cent.) of peak carrier. The black level during any one transmission will not vary by more than 3 per cent. of peak carrier from the mean value of that transmission.

The residual carrier during the transmission of a synchronising pulse will be less than 5 per cent. of the peak carrier.

The line frequency and the frame frequency will be locked to the 50-cycle supply mains, and therefore will be subject to the frequency variations of the mains.

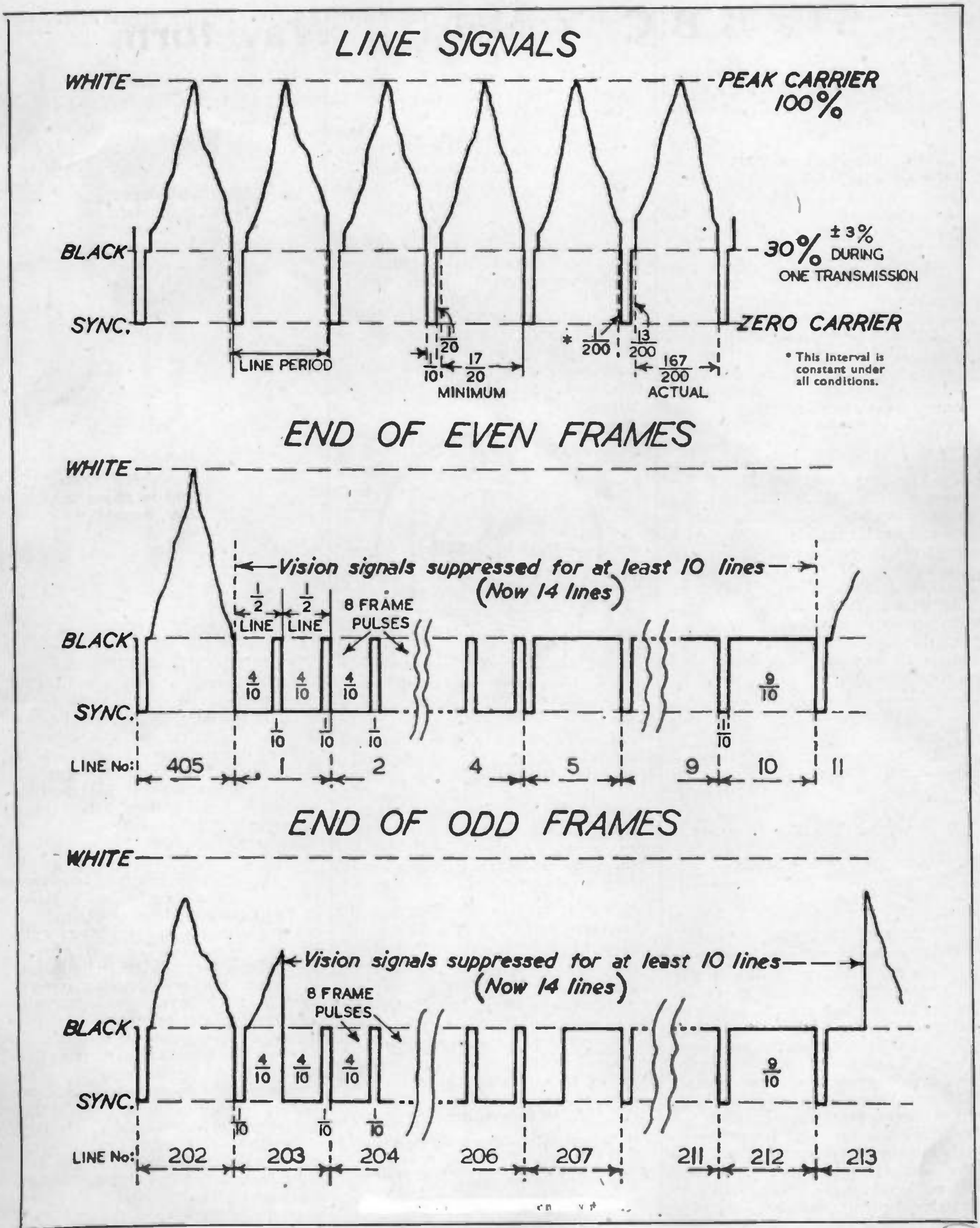
Appendix

Explanation of Method of Interlacing

The method of interlacing is demonstrated in Fig. 2 which represents the top and bottom portions on the scanned area with the distance between the lines very much enlarged. The lines show the track of the scanning spot, which moves under the influence of a regular downward motion (frame scan) with quick return and a regular left-to-right motion (line scan) with very quick return (not shown in Fig. 2). The combination of these motions pro-

(*Continued on p.* 178.)

* "The Marconi-E.M.I. Television System," Blumlein *et al*, *Jour. I.E.E.*, Dec., 1938.


LINE SIGNALS
WHITE
PEAK CARRIER 100%
BLACK
30% ±3% DURING ONE TRANSMISSION
SYNC.
ZERO CARRIER
LINE PERIOD
1/20
1/10
17/20 MINIMUM
* 1/200
13/200
167/200 ACTUAL
* This interval is constant under all conditions.
END OF EVEN FRAMES
WHITE
Vision signals suppressed for at least 10 lines
(Now 14 lines)
1/2 LINE
1/2 LINE
8 FRAME PULSES
BLACK
4/10
4/10
4/10
9/10
SYNC.
1/10
1/10
1/10
1/10
LINE No:
405
1
2
4
5
9
10
11
END OF ODD FRAMES
WHITE
Vision signals suppressed for at least 10 lines
(Now 14 lines)
8 FRAME PULSES
BLACK
4/10
4/10
4/10
9/10
SYNC.
1/10
1/10
1/10
LINE No:
202
203
204
206
207
211
212
213

The B.B.C. Television Waveform

(*Continued from p. 176.*)

duces the slightly sloping scanning lines. Starting at A, not necessarily at the beginning of the line, the spot completes the line AB, returns to the left and traverses line CD, then EF and so on down the "dotted" lines on the drawing. At the bottom of the frame the spot travels along line GH and then starts at J and travels to K. At this point the return stroke of the frame motion begins and returns the spot to L at the top of the frame. A complete frame-scan has now been made since leaving A, so that 202½ lines have been completed, and the point L is half a line away from A. The downward frame motion now starts again, causing the spot to travel along LM, completiug a single line motion JKLM. The spot then returns to the left and traces out line NO, which, owing to L being half a line ahead of A, will lie between lines AB and CD. Similarly, the next line (PQ), will lie half-way between CD and EF. The spot now traces down the chain-dotted lines to RS and finally traces out TU. At U the frame-return causes the spot to rise again to the top. When the spot reaches the top it will have completed two frames since leaving A, and as two frames occupy the time of exactly 405 complete lines the spot will return exactly to A, after which the cycle begins again.

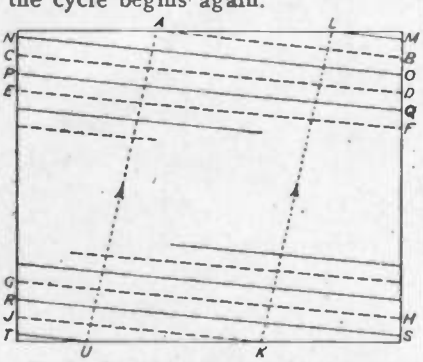


Fig. 2. Explaining method of interlacing.

From the foregoing it will be seen that the complete picture is scanned in two frames, but as each frame contains an integral number of lines, plus a half, the two frames will interlace. The system does not require the short return-times shown for the line and frame scans, nor need the lines begin in the position shown. Provided the line and frame traversals are regularly recurrent and have the correct frequency ratio (two frames = odd number of lines), an interlaced picture will be obtained.

A Television Signal Generator

(*Continued from p. 175.*)

Below the smaller circle is a set of horizontal lines, which provide a test of frequency response at the low-frequency end of the video band. Poor response will again produce "trailing." Above the centre circle is an Indian head, providing a test of general quality of picture reproduction.

In each of the four corners of the pattern are small circles containing resolution wedges. These wedges provide a measurement of spot defocusing by comparing the resolution in the corners with that obtained at the centre. It is normally expected that some defocusing of the cathode-ray tube spot will occur in the corners.

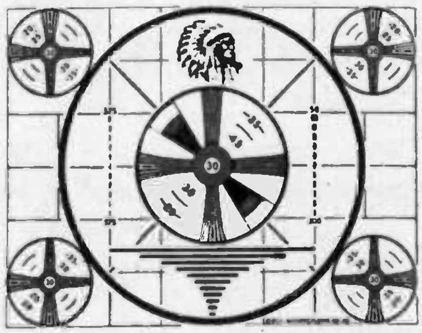


Fig. 3. R.C.A. Monoscope Type 1899 signal pattern.
—By courtesy of R.C.A.

In order to make the monoscope tube suitable for replacing the iconoscope for test purposes, the pattern is printed as a negative, so that the output is in the same phase as that of the iconoscope. Positive repreduction of the pattern will be obtained by using an odd number of video amplifier stages.

More recently, an alternative to the monoscope tube has been developed in this country by Cathodeon, Ltd. The operation of this tube is similar to that of the R.C.A. tube except that it is arranged for magnetic focusing as well as magnetic scanning. The television signal generator can be readily adapted to use this type of tube (*see adjoining column*).

References

[1] C. E. Burnett. "The Monoscope," *R.C.A. Review*, April, 1938.

[2] A. V. Bedford. "Figure of Merit for Television Performance," *R.C.A. Review*, July, 1938.

(*To be continued.*)

A New Picture Signal Generator

CATHODEON, LTD., are now producing a Picture Signal Generator Tube which will be of interest to many designers and manufacturers of television equipment.

The output current obtained by scanning the target can be applied, after amplification, to the television equipment under test; the signal output is of the order of 10 μA. The use of this tube makes available a signal of known amplitude and picture content, free from transmission and reception vagaries, at any time and in any location.

Improvements in electron gun design and a new method of producing the target plate, eliminating the use of half-tone printing screens, have resulted in a signal generator tube giving a picture equivalent to a definition of 800 lines or better.

Three standard test patterns are available, a geometric pattern for resolution and linearity tests, and two pictorial subjects for tests of overall performance and for television demonstrations.

The price of the tube is £30. Further information is obtainable from Cathodeon, Ltd., Hertford Street, Cambridge.

Complex Waveforms

The Harmonic Synthesiser (Cont.)—Wave Analysis

By HILARY MOSS, Ph.D., A.M.I.E.E.

IN the April issue we discussed the theory of symmetry in relation to complex waves, and the deductions to be drawn from certain symmetry conditions. We now turn to consider another set of principles of use in wave analysis. These are collectively termed the method of superposition.

Superposition methods are especially valuable when the complex wave contains only two or three components, the frequencies of which are small integral multiples of the fundamental. In such cases superposition is the best technique to effect a complete analysis. In the case of more complicated waveforms, superposition will generally simplify the problem.

Three Superposition Theorems

(1) *Separation of Odd and Even Harmonics.*

Divide the complete cycle into two equal parts. Denote the corresponding values of $f(\theta)$ by $f(\theta)$ and $f(\theta + \pi)$ respectively. *Then the sum of the two parts, $f(\theta) + f(\theta + \pi)$, is equal to twice the constant term in Equation (45) plus twice the sum of the even harmonics.*

Similarly, *the difference between the two parts is equal to twice the sum of the odd harmonics.*

Proof.—By Fourier's theorem:

$$f(\theta) = \tfrac{1}{2}a_0 + \sum (a_k\cos k\theta + b_k\sin k\theta) \qquad \ldots\ldots (45)$$

and

$$f(\theta + \pi) = \tfrac{1}{2}a_0 + \sum [a_k\cos k(\theta + \pi) + b_k\sin k(\theta + \pi)]$$

but by Equations (49) and (50):

$$\begin{matrix}\cos \\ \sin\end{matrix}\, k(\theta + \pi) = \begin{cases} -\begin{matrix}\cos \\ \sin\end{matrix}\, k\theta & \text{if } k \text{ is odd} \\ \begin{matrix}\cos \\ \sin\end{matrix}\, k\theta & \text{if } k \text{ is even}\end{cases}$$

Hence

$$f(\theta) + f(\theta + \pi) = a_0 + 2\sum (a_k\cos 2k\theta + b_k\sin 2k\theta)$$

and

$$f(\theta) - f(\theta + \pi) = 2\sum [a_k\cos(2k + 1)\theta + b_k\sin(2k + 1)\theta]$$

where k is any integer which proves the proposition.

(2) *Separation of Sine and Cosine Components.*

Draw any ordinate parallel to the axis of amplitude cutting the X (angle or time) axis at any point. Values of the wave to the right of this axis are denoted by $f(\theta)$, and to the left by $f(-\theta)$. Superpose the two portions by folding about the arbitrary ordinate. *Then the sum of the portions $f(\theta) + f(-\theta)$ is equal to a_0 plus twice the sum of the cosine terms* and *similarly the difference of the two portions, $f(\theta) - f(-\theta)$, is equal to twice the sum of the sine terms.*

Proof.—By Fourier's theorem:

$$f(\theta) = \tfrac{1}{2}a_0 + \sum (a_k\cos k\theta + b_k\sin k\theta) \qquad \ldots\ldots (45)$$

whence

$$f(-\theta) = \tfrac{1}{2}a_0 + \sum \left\{a_k\cos(-k\theta) + b_k\sin(-k\theta)\right\}$$

and since

$$\sin\theta = -\sin(-\theta) \text{ (odd function)}$$
$$\cos\theta = \cos(-\theta) \text{ (even function)}$$

$$f(\theta) + f(-\theta) = a_0 + 2\sum a_k\cos k\theta$$

and

$$f(\theta) - f(-\theta) = 2\sum b_k\sin k\theta$$

which proves the proposition.

(3) *Isolation of Components having Frequencies which are Multiples of some Fixed Frequency.*

We now establish the following theorem. If the basic cycle is divided into n equal parts, which are subsequently added together, then the wave so formed is due to n times the sum of those harmonics which have frequencies which are integral multiples of n.

Proof.—By Fourier's theorem the original wave may be represented by:

$$f(\theta) = \tfrac{1}{2}a_0 + \sum (a_k\cos k\theta + b_k\sin k\theta).$$

Denoting the value of $f(\theta)$ from 0 to $2\pi/n$ by the notation $f(\theta)_0^{2\pi/n}$ and so on, we obtain by addition of the n parts of the wave:

$$f(\theta)_0^{2\pi/n} + f(\theta)_{2\pi/n}^{4\pi/n} + f(\theta)_{4\pi/n}^{6\pi/n} \ldots n \text{ terms}$$

$$= \frac{n}{2}a_0 + \sum_{k=1}^{k=\infty} (a_k\cos k\theta + b_k\sin k\theta)$$
$$+ \sum\left[a_k\cos k\left(\theta + \frac{2\pi}{n}\right) + b_k\sin k\left(\theta + \frac{2\pi}{n}\right)\right]$$
$$+ \sum\left[a_k\cos k\left(\theta + \frac{4\pi}{n}\right) + b_k\sin k\left(\theta + \frac{4\pi}{n}\right)\right]$$
$$+ \ldots n \text{ terms.} \qquad \ldots\ldots\ldots\ldots (53)$$

But

$$\sum_{K=0}^{K=n-1} \begin{matrix}\cos \\ \sin\end{matrix}\, k\left(\theta + \frac{2\pi K}{n}\right) = 0$$

when k/n is non-integral

and

$$\sum_{K=0}^{K=n-1} \begin{matrix}\cos \\ \sin\end{matrix}\, k\left(\theta + \frac{2\pi K}{n}\right) = n\begin{matrix}\sin \\ \cos\end{matrix}\, k\theta$$

when $k = M.n$ where M is any positive integer.

Hence (53) may be reduced to

$$f(\theta)_0^{2\pi/n} + f(\theta)_{2\pi/n}^{4\pi/n} + f(\theta)_{4\pi/n}^{6\pi/n} + \ldots$$
$$= \frac{n}{2}a_0 + n\sum_{M=1}^{M=\infty} (a_{Mn}\cos M.n.\theta + b_{Mn}\sin M.n.\theta)$$

which proves the proposition. Notice that the first superposition theorem is merely a special case of this more general result.

The Envelope Method

There are two special but important types of complex wave, for which the method of superposition is of little value in analysis, and for which the symmetry conditions do not provide much information. Both these types are readily treated by the envelope method.

Complex Waveforms — 4th Harmonic Distortion. *(Note all waves are non-alternant)*

136

$A \sin \theta + \frac{A}{10} \sin 4\theta$

137

$A \sin \theta + \frac{A}{5} \sin 4\theta$

138

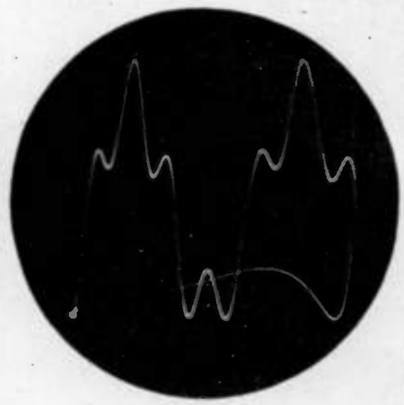
$A \sin \theta + \frac{2}{5} A \sin 4\theta$

139

$A \sin \theta + \frac{A}{10} \sin \left(4\theta + \frac{\pi}{2} \right)$

140

$A \sin \theta + \frac{A}{5} \sin \left(4\theta + \frac{\pi}{2} \right)$



141

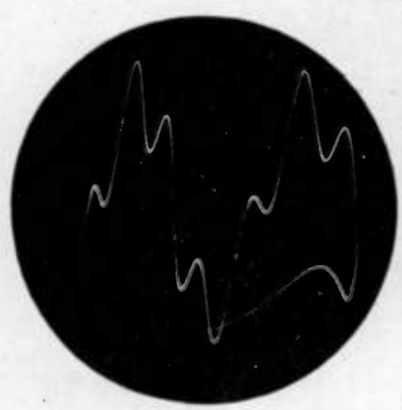
$A \sin \theta + \frac{2}{5} A \sin \left(4\theta + \frac{\pi}{2} \right)$

142

$A \sin \theta + \frac{A}{10} \sin (4\theta + \pi)$

143

$A \sin \theta + \frac{A}{5} \sin (4\theta + \pi)$



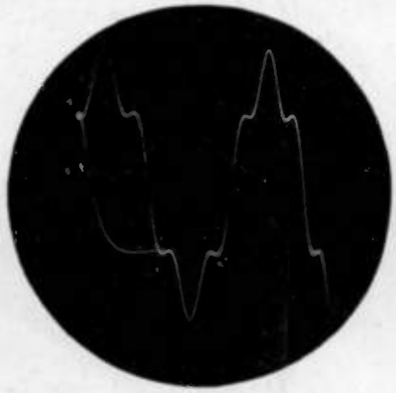
144

$A \sin \theta + \frac{2}{5} A \sin (4\theta + \pi)$

Complex Waveforms — 5th Harmonic Distortion. *(Note all waves are alternant)*

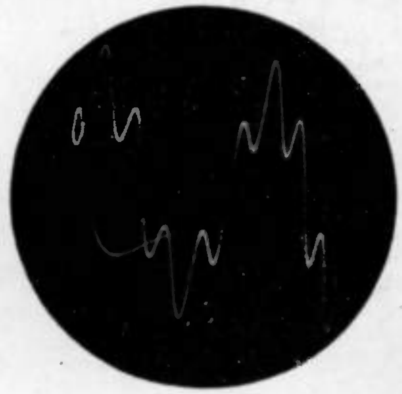
145

$A \sin\theta + \frac{A}{10}\sin 5\theta$



146

$A \sin\theta + \frac{A}{5}\sin 5\theta$



147

$A \sin\theta + \frac{2}{5} A \sin 5\theta$

148

$A \sin\theta + \frac{A}{10}\sin\left(5\theta + \frac{\pi}{2}\right)$

149

$A \sin\theta + \frac{A}{5}\sin\left(5\theta + \frac{\pi}{2}\right)$

150

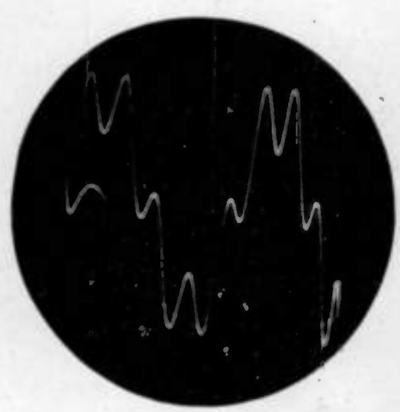
$A \sin\theta + \frac{2}{5} A \sin\left(5\theta + \frac{\pi}{2}\right)$

151

$A \sin\theta + \frac{A}{10}\sin(5\theta + \pi)$

152

$A \sin\theta + \frac{A}{5}\sin(5\theta + \pi)$



153

$A \sin\theta + 2\frac{A}{5}\sin(5\theta + \pi)$

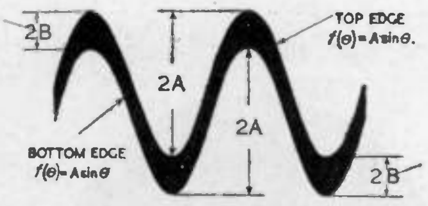


Fig. 3. Function $f(\theta) = A\sin\theta + B\sin k\theta \; (k \to \infty)$.

The two classes of complex wave are (a) that in which two major components have a rather high-frequency ratio, say five to one or more, and (b) that in which two major components have a frequency ratio which closely approaches unity. Case (b) is of special interest to the radio engineer in connexion with the theory of "beats" or heterodyning.

Case (a).—Waves of High-Frequency Ratio.

Consider the complex wave defined by:

$$f(\theta) = A.\sin\theta + B.\sin k\theta \quad \ldots\ldots\ldots \quad (54)$$

where $k >> 1$

In the limit as $k \to \infty$, the second term in (54) goes through an infinite number of oscillations as θ goes through a very small variation in relation to 2π. Hence the complex wave (54) resembles Fig. 3, from which the significance of the term "envelope" becomes apparent. *The distance between the two edges of the envelope is 2.B, and each edge of the envelope is the curve A.sinθ, i.e., the low-frequency component.* This is the basis of the envelope method of analysis. We illustrate by an example taken from this series.

Example

Analyse the wave shown in photo No. 116 (September, 1945). It is assumed that the photo shows one complete cycle.

The wave is redrawn in Fig. 4. Proceeding as above we first sketch in the envelope of the high-frequency component. Measurement shows that the width of the envelope is 8 mm. and that the amplitude of either edge of the envelope is 28 mm. Hence it follows that in (54) $A = 14$, and $B = 4$.

Again, we note that there are thirteen oscillations of the H.F. component in one complete cycle of the L.F. component, so that $k = 13$.

The phase is readily determined by drawing in the ordinate through the position of zero amplitude of the L.F. component. This cuts the H.F. wave at approximately the commencement of it cycle, so the phase angle is zero.

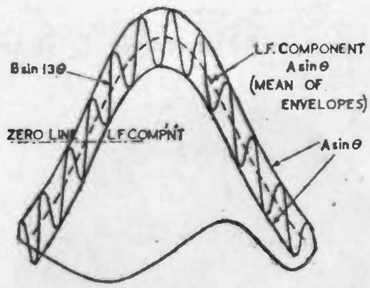


Fig. 4. Function $f(\theta) = 14\sin\theta + 4\sin 13\theta$.

Hence the wave or photo No. 116 may be expressed as

$$f(\theta) = 14\sin\theta + 4\sin 13\theta$$

Case (b).—Waves of Frequency Ratio tending to Unity—"beats."

A rigorous general treatment of the complex wave was formed by the addition of two sinusoids of nearly equal frequency is quite involved. In actual practice such a treatment is rather unnecessary and it is usually sufficient to employ approximations which suffice for most purposes. It is, however, important to be clear when and where such approximations are introduced.

Such a complex wave may be represented quite generally by:

$$f(t) = A\sin(\omega t + \phi) + B\sin(\omega + \delta\omega).t \quad (55)$$

where $\theta = \omega t$. ϕ is the arbitrary phase angle. We are most interested in the case when $\omega/\delta\omega$ is large. *We commence by considering the case when $\omega/\delta\omega = k$ where k is integral.* In this case the periodicity of (55) is given by $t = 2.\pi/\delta\omega$ and is thus *equal to the difference between the frequencies of the component waves.* This is the result usually quoted, but it is not always made clear that it obtains only when $\omega/\delta\omega$ is integral. A "beat" *is* obtained when this condition does not hold, but each "beat" is not then one complete cycle of (55). *When $\omega/\delta\omega$ is integral, the result that the periodicity of* (55) *is given by* $t = 2.\pi/\delta\omega$ is exact, regardless of the *phase angle ϕ or the relative amplitudes A and B.*

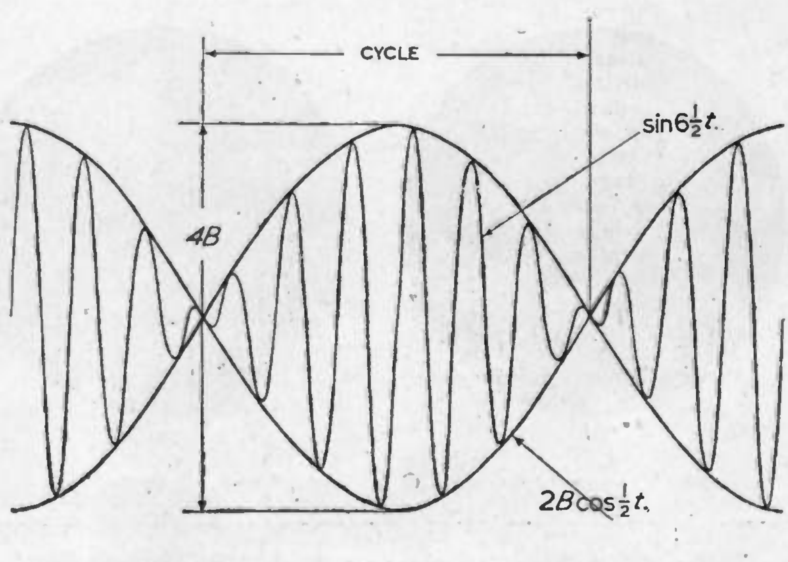
For many purposes it is convenient to re-express (55) in the form:

$$f(t) = (A - B)\sin(\omega t + \phi) + B\sin(\omega t + \phi) + B\sin(\omega + \delta\omega).t$$

$$= (A - B)\sin(\omega t + \phi) + 2.B\sin\left\{\left(\omega + \frac{\delta\omega}{2}\right).t + \frac{\phi}{2}\right\}\cos\left(\frac{\delta\omega}{2}.t - \frac{\phi}{2}\right) \quad (55A)$$

In the simplest case, when $A = B$ (*i.e.*, the amplitudes of the two components are equal), then $f(t)$ is merely the second term of (55A). This function has been plotted in Fig. 5 for the special case when $\omega = 6$, $\delta\omega = 1$, and $\phi = 0$. Since $A = B$, the curve is enclosed in the double envelope $f(t) = \pm\, 2.B\cos\left(\frac{\delta\omega}{2}.t - \frac{\phi}{2}\right)$. The curve itself tends to a true sinusoid as $\omega/\delta\omega \to \infty$. The period of the curve is given by $t = 2.\pi/\left(\omega + \frac{\delta\omega}{2}\right)$ except just at the nodes where the effect of the cosine term is dominant and introduces an extra zero. The apparent frequency is thus the mean of the component frequencies, but this result holds only as long as $A = B$.

Fig. 5. Function $f(t) = 2B\sin 6\tfrac{1}{2}t\cos\tfrac{1}{2}t$



A Visual Tuning Indicator Employing a Thyratron

By L. S. JOYCE*

THE usual tuning indicators such as the electronic " Magic Eye " and the milliammeter inserted in the anode lead of one or more of the A.V.C. controlled valves, while quite efficient, are not satisfactory if a reasonably accurate estimate of the relative signal strengths of various stations is required. The possibilities of employing a thyratron, or gas-filled relay, for the above purpose and also for operating an ordinary low-voltage metal filament lamp as the actual indicator were investigated.

Theoretical Details

With an A.C. voltage applied to the anode of a thyratron two common methods of controlling the average anode current are available.†

(1) By applying a suitable negative D.C. bias to the grid of the thyratron. This provides continuous control over the range lying within the limits corresponding to half-wave rectification and half this value. With this method it is, however, impossible to make the anode current continuously variable from zero to its maximum value.

(2) Phase control of the thyratron. In this method the control is effected by altering the phase of an A.C. voltage applied in the grid circuit. The average anode current can be made continuously variable from zero to its maximum value, the latter occurring when the thyratron is conducting during practically the whole of the positive half-cycle of the applied anode voltage.

For a tuning indicator, the most convenient "triggering voltage" suitable for controlling the thyratron current is the D.C. component of the rectified signal—obtained from either the signal diode or a separate A.V.C. diode. Unfortunately this D.C. component would not produce continuous control of the average anode current from zero to its maximum

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† H. J. Reich, "Theory and Application of Electron Tubes." McGraw-Hill Book Co., pp. 441-45.

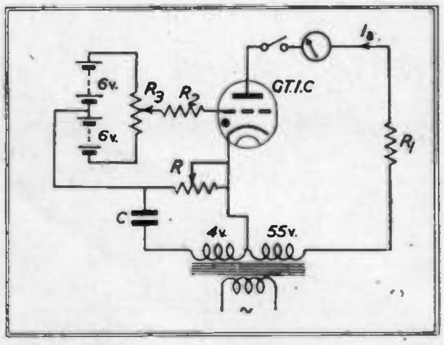

Fig. 1. Basic circuit to illustrate the principle of the tuning indicator.

value, if it alone were applied to the grid of the thyratron. One method of overcoming this difficulty is illustrated by the circuit of Fig. 1. In this circuit the bias applied to the grid of the thyratron consists of a D.C. component and an A.C. component connected in series between the grid and the cathode. R_1 and R_2 are the usual anode and grid current limiting resistances. By suitable adjustment of the values of R and C, the phase of the A.C. voltage applied to the grid can be varied and made to lag by any value between approximately 90° and 180° behind the anode voltage. With this method of phase control it is well to bear in mind that the amplitude of the A.C. voltage developed across R also depends upon the values of R and C. If this is very objectionable a method of varying the phase without varying the amplitude can be employed.* If θ is the angle by which the A.C. potential of the grid lags behind the anode voltage then

$$\theta = \left(180^\circ - \tan^{-1}\frac{1}{C\omega R}\right)$$

and the amplitude of the A.C. voltage applied in the grid circuit can also be calculated if required. Using 50 cycle A.C. and with $C = 0.1\ \mu F$, θ is approximately 135° when R is 30,000 ohms. By means of the potentiometer R_3 the D.C. bias or potential applied to the grid can be varied from −6 to +6 volts and in the following discussion this D.C. bias is denoted by e volts.

* O. S. Puckle, "Time Bases." Chapman and Hall, p. 120.

The graphs of Fig. 2 indicate the general principle of the method by which the control is effected. The solid curve marked V represents the applied anode voltage supply, while the graph marked V_c represents the corresponding critical or firing voltage. The graph of V_c can, of course, be obtained directly from the control characteristic of the thyratron. In the graphs of Fig. 2 the anode and grid voltages are not drawn to the same scale. If the anode voltage supply is 55 volts r.m.s., this gives a peak value of 78 volts, and from the control characteristic of the GT1C it is found that the corresponding value of V_c is −3.8 volts. Thus, if no A.C. is applied in the grid circuit and the D.C. potential of the grid is −4 volts, the thyratron will never conduct. If, however, the D.C. bias is altered to −3.8 volts, the thyratron will start to conduct at the moment in each positive half-cycle of V when the latter has its peak value and continue to conduct until the anode potential falls below the ionisation potential, this being about 16 volts for the GT1C. When the D.C. bias is altered to −2 volts, the point at which conduction begins in each positive half-cycle of V will occur earlier in the cycle. On the graphs the D.C. component of the grid voltage is represented by the line AB, its distance from the datum line O—O being equal to e volts. The solid curve V_g represents the actual grid voltage applied to the thyratron when the bias consists of both A.C. and D.C. components. Alteration of R in Fig. 1 affects the angle θ by which this voltage lags behind V, and in the graphs of Fig. 2 this angle of lag, θ, is approximately 135°. An increase in θ would be indicated in Fig. 2 by a displacement of the curve of V_g to the right, and *vice versa*. Since OA represents e, the D.C. component of the grid voltage, an alteration in e would be indicated on the graphs by a displacement of the curve of V_g up or down with reference to the line O—O. The thyratron will "fire" or commence to conduct from the moment in each positive half-cycle of V when the curve of V_g *first* intersects or touches the curve of V_e, and will continue to conduct until the anode potential falls to the ionisation potential of 16 volts.

By suitable adjustment of the angle of lag, θ, and the value of e, it is quite a simple process to make the curve of V_g be just on the point of touching the curve of V_e at the point where the latter curve starts to become vertical. In this condition, represented in Fig. 2a, the thyratron is just failing to conduct. If now, as in Fig. 2b, the value of e, the D.C. component of the grid voltage, is made less negative, the effect is to raise the curve V_g slowly and a point of intersection of V_g and V_c occurs earlier in the cycle. It is at the moment corresponding to the *first* point of intersection that the thyratron starts to conduct—or fires—and it continues to do so until the anode potential falls to 16 volts. The period during which conduction occurs is shown shaded in the diagrams of Fig. 2. With a resistive load in the anode circuit, the anode current is approximately of the same waveform as the shaded portion. An inductive load would tend to smooth out the abruptness of the commencement and termination of the conducting period. In Fig. 2c the process is carried a stage further, since here the D.C. component has passed through zero and now has a positive value. The point of intersection of V_g and V_c now occurs at almost the commencement of the positive half-cycle of anode voltage, and thus we have practically half-wave rectification. The general effect is that, as e is made less negative, the graph of V_g is gradually raised, the point of intersection of V_g and V_c occurs earlier in the cycle, and so the period during which conduction occurs can be increased from zero to its maximum value by alteration of e alone. The graphs of Fig. 2 are drawn on the assumption that no complications are created by the flow of grid current.

The initial adjustment of the circuit to the condition represented by Fig. 2a is quickly achieved in practice. For example, referring to Fig. 1, if R is made approximately 30,000 ohms and C is 0.1 μF, then θ is 135°. Now, starting with e, the D.C. potential at −6 volts, this D.C. potential is gradually made less negative, or more positive, until anode current just starts to flow. If the adjustment is correct there will be a *gradual increase in anode current from zero* as e is made even more positive. Slight adjustments of R will usually enable satisfactory results to be obtained.

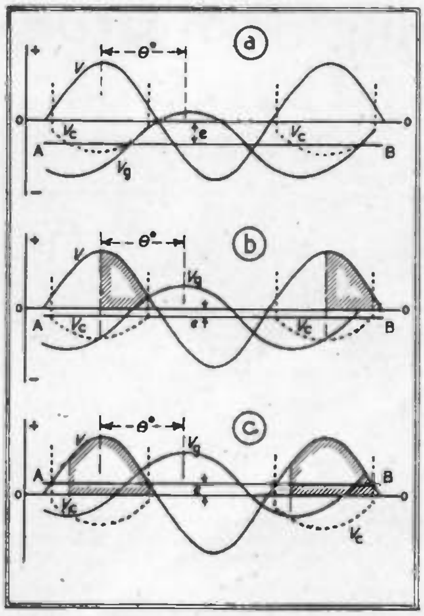

Fig. 2. Graphs showing how variation of D.C. bias can produce continuous control of thyratron current.

The choice of the supply voltages is a matter of considerable interest. The curve of V_c is very similar to a sine curve. Thus *the* A.C. *component of V_g must have an amplitude or peak value greater than the maximum value of V_c*. This is essential, since otherwise it is impossible to adjust θ or e so that the curve of V_g is just touching the curve of V_c at the point where the latter starts to become vertical. Fig. 3 illustrates the case where the amplitude of the A.C. component of V_g is less than the maximum value of V_c. The curve of V_g is then adjusted to be on the point of touching V_c, but it is clear that if e is now made less negative there will be a *sudden increase* in anode current from zero, since the initial point of contact of V_g and V_c does not occur at the point where the latter starts to become vertical. A little consideration will show that if the amplitude of the A.C. component of V_g is not much greater than the maximum value of V_c, then a slight alteration in e will cause a relatively large movement of the point of intersection of V_g and V_c. Thus the anode current will be sensitive to small changes in e. A very clear insight into the method of control can be obtained by drawing the graphs of V and V_c and then drawing the graph of V_g on tracing paper. By moving the tracing paper it is then possible to see at a glance the effect of altering e or θ.

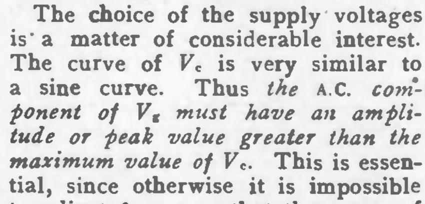

Fig. 3. Graph illustrating a case when the method fails.

The thyratron GT1C, being Argon filled, has a practically constant characteristic under all variations of room temperature. To calculate the relation between e and the average anode current I_a, as measured by a D.C. ammeter, is difficult unless several approximations are made. The relation can, however, be quickly investigated experimentally and is almost linear. It is interesting to note that if the phase of the A.C. voltage in the grid circuit is arranged to *lead* the anode voltage by almost 180°, then "on-off" control can also be obtained. In this case, when e is made slightly less negative the thyratron will suddenly start to conduct during almost the whole of the positive half-cycle of V.

Practical Details

The application of the above method of thyratron control to a practical form of tuning indicator involves only slight modifications of the circuit of Fig. 1. Suppose that with the circuit of Fig. 1 the D.C. component e is adjusted so that the thyratron is just on the point of conducting, *i.e.*, in the condition represented by Fig. 2a. If now the D.C. component of the rectified signal, obtained from the radio receiver, is inserted in the grid circuit of the thyratron in such a manner as to make the grid potential of the thyratron more positive, then anode current will flow and any fluctuations of the former will affect the latter. Moreover, if no signal is being received, or the radio receiver is detuned, the anode current of the thyratron will be zero.

The circuit diagram of an actual tuning indicator is illustrated in Fig. 4. If the anode voltage is supplied directly from the 250-V main supply, then the A.C. voltage required in the grid circuit is also comparatively large. In practice, it was found most convenient to utilise

4-V windings on a mains transformer to provide the heater current, the A.C. voltage in the grid circuit, and, after rectification, the steady D.C. grid bias. Finally, a special 50-V or 55-V winding was wound on the mains transformer to provide the anode voltage supply. If a larger anode voltage supply is used, a suitable value for the A.C. voltage required in the grid circuit can easily be calculated since the latter must have an amplitude greater than the maximum value of V_c.

The indicating device may be either a metal filament lamp or a suitable ammeter, and in the original instrument both were included in the anode circuit. The ammeter used was a D.C. moving-coil milliammeter with a range of 0-50 mA, suitably shunted to read 0-0.125 amp. The switch in the anode lead was a precautionary measure installed while carrying out the initial adjustments, because the thyratron filament should be allowed to heat up for at least 30 sec. before anode current is allowed to flow. If the lamp is omitted from the anode circuit it is essential to replace it by a resistance of 50 or 60 ohms to prevent the average anode current ever exceeding a value of 0.3 amp. for the GT1C. It is, in fact, a wise precaution to insert this protecting resistance in any case, and it is included in the anode circuit of Fig. 4. The anode current of the GT1C must never be allowed to exceed a peak value of 1.0 amp. The 12-V 0.25-amp. lamp has a resistance of 48 ohms when carrying a steady current of 0.25 amp., but when the filament is cold its resistance may be as low as 5 ohms. Thus, without the protecting resistance in series with it, there is a grave danger of instantaneous values of anode current considerably exceeding the rated value of 1.0 amp.

To provide a steady negative D.C. bias in the grid circuit, the 4-V A.C. from one of the transformer windings was rectified by means of a metal rectifier, Westector Type W4, a simple resistance capacity filter or smoothing circuit being quite suitable. The smoothing condenser was an 8 μF electrolytic condenser. For reasons of economy, the 4-V winding which provided the rectified grid voltage was also employed to heat the filament. The resistors R_1 and R_2 were small pre-set type radio potentiometers with a maximum value of 100,000 ohms, and R_3 was a 1-megohm resistor serving to limit

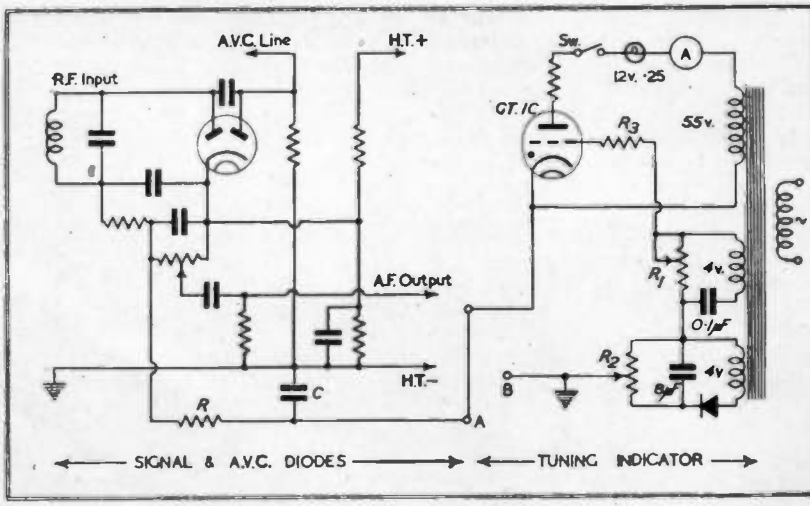

Fig. 4. Practical form of tuning indicator.

the grid current. The latter resistance could be considerably smaller, or even omitted in this case, since the resistance in the grid circuit is, even without it, quite considerable.

The tuning indicator was tested on a normal mains superheterodyne receiver consisting of band-pass tuning circuit, H.F. amplifier, triode hextrode mixer valve, single-stage I.F. amplifier, double-diode detector and A.V.C. valve and a two-stage L.F. amplifier. The tuning indicator may be operated from either the signal or A.V.C. diode and in the initial tests the signal diode was employed. For convenience, the double-diode portion of the receiver is shown in Fig. 4 with the indicator being fed from the signal diode. The maximum D.C. voltage developed across the diode load when receiving was 5 or 6 V. With the conventional double-diode circuit indicated, the A.V.C. line is at a negative potential with respect to the earth line of the radio receiver. If the D.C. component is obtained directly from the signal diode, the point A is also at a negative potential with respect to the earth line of the radio receiver. Since it was not desirable to alter the circuit of the radio receiver and the D.C. component obtained must be applied to the thyratron in such a sense as to make the grid more positive, the cathode of the thyratron was connected to the point A. The terminal B was connected to earth. With this arrangement the point B is at a higher potential than A when a signal is being received, and the grid of the thyratron is driven more positive with respect to the cathode.

The initial adjustment of the indicator is quite simple with the values indicated in Fig. 4. It is, of course, important at this stage to leave the switch in the anode lead of the thyratron open for at least 30 sec. after switching on the heater current. First, with the radio receiver receiving no signal R_1 and R_2 are adjusted so that the thyratron is just on the point of conducting. When correctly adjusted a very slight decrease in the effective portion of R_2 will cause the thyratron to start conducting. If any difficulty is encountered, the leads from the 4-V winding supplying the A.C. component of the grid voltage probably need reversing. If the set is now tuned to receive an incoming signal, then the D.C. voltage developed across the diode load increases as the correct tuning point is approached, and thus an increasingly less negative (or, in the final stages, more positive) D.C. potential is applied to the grid of the thyratron and thus, as indicated in Fig. 2, the average anode current of the thyratron is gradually increased. Tuning by watching the brilliance of the lamp only, and not the ammeter reading, was remarkably accurate, and at one time the lamp was used to illuminate one side of a Joly paraffin wax photometer with very pleasant results.

The ammeter indicates the average value of the anode current, whereas the lamp depends for its brilliance on the r.m.s. value of the anode current. (This latter value should not be allowed to exceed 0.5 amp. for the GT1C.) It can easily be verified that the ratio of the r.m.s. value to the average value of the current depends upon the magnitude of the portion of the positive half-cycle of V during which conduction occurs. Apart from small values of anode current, it is reasonable to assume that the r.m.s. value of the anode current is approximately twice the value of the average anode current as recorded by the D.C. ammeter.

Once the initial adjustments were made it was found that the switch in the anode lead of the thyratron could be dispensed with if the indicator and superhet were switched on simultaneously, since the delay due to the time required for the valves in the set to warm up was itself sufficient to prevent anode current flowing in the thyratron for 30 sec. As an extra precaution the superhet could, of course, be detuned before switching on the battery supplies. With an indirectly heated mains rectifier in the receiver the delay in heating up would, of course, be greater.

With the components chosen, the thyratron only conducted during approximately half of the positive half-cycle of anode supply voltage even when the strongest station was being received. In order to test the indicator's suitability for measuring signal strengths, the A.V.C. control of the radio receiver was removed and a 1,000-kc/s. signal modulated at 400 c/s. was injected into the set by means of an Avo oscillator. The set was then carefully tuned by means of the tuning indicator and, finally, the input to the set was varied and the readings of the ammeter in the anode circuit of the thyratron noted. Typical results were as follows:

Input in μV	0	1,000	2,000	3,000	4,000
Ammeter reading	0	10	22	35	47

For practical purposes the linearity is quite good and the ammeter reading can be considered as directly proportional to the signal strength. If a linear relation is required, the initial adjustment of R_1 and R_2 must be done very carefully so that even a very weak signal will cause the thyratron to "fire." The results quoted are, however, quite typical and were obtained without difficulty.

The sensitivity of the indicator can, to some extent, be controlled by adjustment of the values of R_1 and R_2, since the former, besides controlling the phase of the A.C. component of the grid voltage, also controls its amplitude. With a very powerful receiver it would be necessary to either attenuate the triggering voltage before applying it to the indicator, or to choose more suitable values for V_g and V. The indicator works quite well when operated from the A.V.C. portion of the double diode, but will not indicate the presence of weak signals when operated from a delayed A.V.C. circuit. The values of R and C, forming the filter circuit, will depend upon circumstances, but in the case shown in Fig. 4 the signal diode load was 500,000 ohms and R was 2 megohms, while C was 0.1 μF.

The distortion produced by the use of the indicator is, with reasonable care, not severe even with the manual volume control in its maximum position. One difficulty, however, does arise from the point of view of distortion with the arrangement shown in Fig. 4. At the commencement of each firing period, which occurs once per cycle of anode voltage supply, there is an abrupt increase in the instantaneous values of the anode and grid currents. This sudden change, combined with the fact that the grid circuit is coupled to the anode circuit via the supply transformer, tends to produce transients which may be heard as a slightly objectionable "crackle" in the loudspeaker when the manual control is in its maximum position. This effect, while not entirely eliminated, is considerably reduced by connecting a 4-μF condenser across the 55-V winding of the transformer.

Some Novel Projection Type Television Tubes

THE problem of producing satisfactory large screen television pictures has already received much attention, and will no doubt take on even greater importance in the future. Broadly, there are two ways of tackling it; by providing at the receiver a local source of illumination and interposing between this and the projection screen some form of "light valve" controlled by the received picture signals; or by using a cathode-ray tube having a luminescent screen of generally well-known type, operating at high intensity and in combination with an optical projection system.

Systems are now well known in which the televised image traced on the fluorescent screen of the c.r.t. is projected by means of a spherical mirror on to a suitable separate viewing screen where the enlarged image is produced. In such systems it is essential to include an appropriately figured correcting plate, to correct for spherical aberration introduced by the mirror. The accompanying illustrations, Figs. 1 and 2, show a convenient manner of combining the various optical elements of the system, the correcting plate forming, or being externally attached to, the end wall of the tube on the inner surface of which the fluorescent screen is deposited. For the rest, the tube is of ordinary bottle shape, with a neck in which the electron gun is housed, and a shoulder having a spherical curvaure and being silvered or otherwise treated to render it serviceable as the mirror of the optical system.

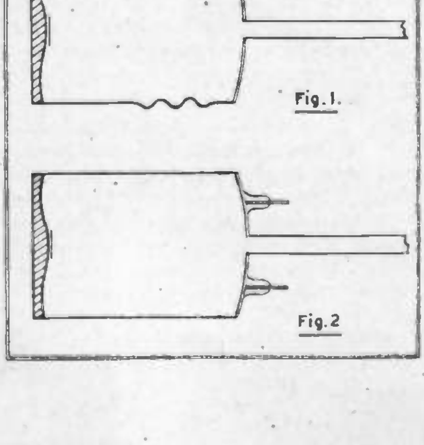

Fig. 1.

Fig. 2

Where it is necessary to allow for adjustment of the distance between mirror and correcting plate, as for focusing, this may be done by incorporating a bellows section, of say copper, in the tube wall (*see* Fig. 1). Alternatively, the spherical mirror may be formed on a separate support closely adjacent to, but not actually part of, the tube wall and there may be attached to this support rods extending through elongated external pips on the tube shoulder; in this case a limited amount of focusing adjustment may be made after softening these pips (*see* Fig. 2).

Good contrast is obtained with the arrangement as a result of using in the image forming system the light emanating from the front (*i.e.*, the bombarded) side of the fluorescent screen; and cooling of the latter, if found necessary, can be easily provided without disturbing the optics.

—*Communication from E.M.I. Laboratories.*

A Reference Library for Radio Engineers

By G. J. HUNT, A.M.I.E.E.

READERS may be interested in the following notes concerning a Radio Technical Reference Library run during the war years. The need for the library arose when a section of a large organisation was removed from the parent body by the needs of war. As it was no longer possible to have access to the main works' library, it was decided to create a purely private library on behalf of the radio engineers concerned.

The membership of approximately twenty was on the basis of a weekly subscription of 1s. This subscription covered the cost of British and American periodicals, while technical books, B.S.S., and other relevant literature were purchased as funds permitted.

Considerable discrimination was used, particularly in the early days, in selecting periodicals and books in order that this library should be of the greatest possible use. Readers interested in the purchase of technical literature may therefore glean ideas from Tables I and II, in which are listed respectively the periodicals and books acquired by the library.

A card index was maintained, covering all articles in the periodicals, thus enabling immediate reference to be made to articles on any given subject. Table III gives a list of the headings finally evolved from experience of indexing needs. This list will no doubt be of interest to those readers who may be considering indexing the radio periodicals to which they subscribe, since these are the headings which have survived the prunings and alterations dictated by experience of indexing ten periodicals over a period of three years. The title cards were filed in alphabetical order, the card entries giving the title of article, author, periodical, page and date. The card entries automatically fell into approximately chronological order. Subdivisions of the sixty-one headings given in Table III were not found necessary, apart from keeping on separate cards entries falling into the classification of "Inventions and References." These cards were filed behind the appropriate title card, but at the back of the other cards. The information given in such extracts is small and is indexed for the purpose of covering those occasions when it is necessary to explore every possible approach to a given problem.

TABLE I

List of Journals

Bell System Technical Journal.
Communications.
Electronics.
Electronic Engineering.
F.M. and Television.
Journal of the Institute of Electrical Engineers (Part 3—Radio).
Proc. I.R.E.
Q.S.T.
Wireless Engineer.
Wireless World.

The task of indexing periodicals is made easier by numbering the list of headings to be used, *e.g.*, in the case of Table III from 1 to 61. In looking through each periodical it is then only necessary to put the appropriate number in pencil against the heading of each article, or the number with the suffix I.R. in the case of extracts. The entry in the card index can be made at a later date, and recorded in the periodical by putting a ring round the pencilled number. (There are occasions when an article must be entered under two or three headings, but this does not, of course, affect the procedure.) This simple system allows the actual card entries to be made by a person without technical knowledge, while the indexing can be interrupted as convenience indicates without causing confusion in the records.

When founding the library, it was laid down that when the time should arrive for liquidation, the books and periodicals would be sold by auction to the members of the library and the proceeds distributed in proportion to subscriptions paid. The choice of the books and periodicals which had been purchased was amply vindicated by the success of this auction, at which the books realised 102 per cent. of list price, while the overall figure, including periodicals, was 84 per cent. of list price.

TABLE III

Headings for Reference Index

Acoustics.
Aerials, Radiating Systems and Wave Propagation.
Amplifiers.
Attenuators and Transmission Lines.

Bridges.

Cathode-Ray Oscillography.
Component Testing.
Components.
Condensers.
Coupled Circuits.
Crystal Technique.

Data Sheets.
Direction Finding.

Electric Motors and Rotary Transformers.
Electron Microscope.
Electronic Devices.
Electronic Equipment for Medical Purposes.
Electronic Organ Design.

Facsimile.
Filters.
Frequency and Phase Modulation.
Frequency Measurement.

Harmonic Analysis.
H.T. Units.

Inductance Design.
Induction Heating and R.F. Heating.
Industrial X-Ray Equipment.
Insulation Measurements and Insulating Materials.
Interference Suppression.
Ionosphere and Cosmic Rays..

Loudspeakers.

Magnet Design.
Mathematics.
Meters.
Microphones.
Microwave Technique and Wave Guides.
Miscellaneous.

New Books and Literature.

Oscillators.

Photo-Electric Equipment and Photo-Cells.
Plastics.
Pulses, Generation and Use.

Receivers.
Rectifier Circuits.
Relays.

Sound Recording and Sound Reproduction

Television.
Temperature Recording and Control.
Test Gear.
Time Bases.
Transformer, Choke Design and Magnetism.
Transmitters.
Transreceivers, Communication Systems and Equipment.
Tropicalisation.

Valves and C.R. Tubes, Calculations, Measurements and Construction.
Valves and C.R. Tubes Data.
V.H.F. Technique.
Voltage Stabilisation.

Welding.

TABLE II **List of Books in Library**

Title	*Author*	*Publisher*
Measurements in Radio Engineering	Terman	McGraw-Hill Publishing Co.
Radio Engineering	Terman	„
Radio Engineers' Handbook	Terman	„
Frequency Modulation	Hund	„
High Frequency Measurements	Hund	
Phenomena in High Frequency Systems	Hund	„
Radio Engineering Handbook	Henney	„
Engineering Electronics	Fink	„
Electric Oscillations and Electric Waves	Pierce	„
Communication Engineering	Everitt	„
Physics of Electron Tubes	Koller	„
Principles of Aeronautical Radio Engineering	Sandretto	„
Higher Mathematics for Engineers and Physicists	Sokolnikoff	„
Graphical Construction for Vacuum Tube Circuits	Preisman	„
Industrial Electronic Control	Cockrell	„
Microwave Transmission	Slater	„
The Calculation and Design of Electrical Apparatus	Wilson	Chapman & Hall.
Time Bases	Puckle	„
Temperature Control	Ansley	„
Radio Frequency Measurements	Hartshorn	„
Ultra-High Frequency Techniques	Brainerd, Reich, *et al.*	„
Technique of Radio Design	Zepler	„
Short-Wave Wireless Communication	Ladner and Stoner	„
Theory and Design of Valve Oscillators	Thomas	„
Radio Receiver Design, Parts 1 and 2	Sturley	„
High Vacuum Technique	Yarwood	„
High Frequency Thermionic Tubes	Harvey	„
Wave Filters	Jackson	Methuen.
Wave Guides	Lamont	„
High Voltage Physics	Jacob	„
Physical Principles of Wireless	Ratcliffe	„
The Cyclotron	Mann	„
Electromagnetic Waves	White	„
Alternating Current Measurements	Owen	„
Thermionic Vacuum Tubes	Appleton	„
Thermionic Emission	Jones	„
High Frequency Transmission Lines	Willis Jackson	„
Wireless Direction Finding	Keen	Iliffe.
Radio Designer's Handbook	Langford-Smith	„
Radio Data Charts	Beatty	„
Electromagnets and Windings	Windred	Newnes.
Electric Relays	Rosslyn	„
Physics for Engineers	Sir Ambrose Fleming	„
A Dictionary of Metals and their Alloys	Camm	„
Transmission Networks and Wave Filters	Shea	D. Van Nostrand.
Electromagnetic Waves	Schelkunoff	„
Dynamic Analogies	Olson	
Communication Circuits	Ware and Reed	John Wiley.
Control of Electric Motors	Harwood	„
Hyper and Ultra High Frequency Engineering	Sarbacher and Edson	„
Fields and Waves in Modern Radio	Ramo and Whinnery	„
Alternating Current Electrical Engineering	Kemp	Macmillan.
Precision Echo Sounding and Surveying	Macmillan	Henry Hughes.
The Electron Microscope	Burton and Kohl	Reinbold Publishing Co.
Infra-Red Spectroscopy	Barnes	„
X-Rays in Research and Industry	H. Hirst	Tait Publishing Co.
The Radio Amateur's Handbook	...	A.R.R.L.
Plastics	Dubois	American Technical Society.
An Introduction to the Operational Calculus	Seeley	International Textbook Co.
Electrical Counting	Lewis	Cambridge University Press.
The Simple Calculation of Electrical Transients	Carter	„
Electrotherapy with Direct and Low Frequency Currents	Clayton	Bailliere Tindall & Cox.
American Standard Definitions of Electrical Terms	A.I.E.E.	A.I.E.E.
Admiralty Handbook of Wireless Telegraphy	H.M. Stationery Office	H.M. Stationery Office.
Applications of the Cathode-Ray Oscillograph in Radio Research	Watson Watt	„
Electrical Measurements and Measuring Instruments	Golding	Pitman.
Electric Circuits and Wave Filters	Starr	„
The Telephone Handbook	Poole	„
Thermionic Valves in Modern Radio Receivers	Witts	„
Maintenance and Servicing of Electrical Instruments	Spencer	Instruments Publishing Co.
Fundamentals of Radio Communications	Frey	Longmans, Green & Co.

NOTE: Details of some standard handbooks, data books, and monographs have been omitted for lack of space.—Ed.

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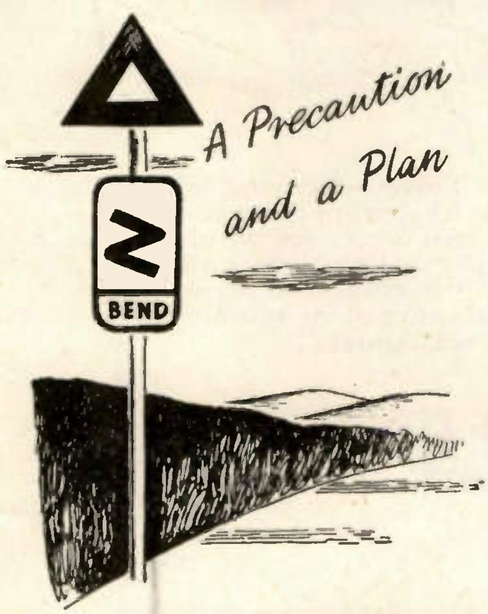

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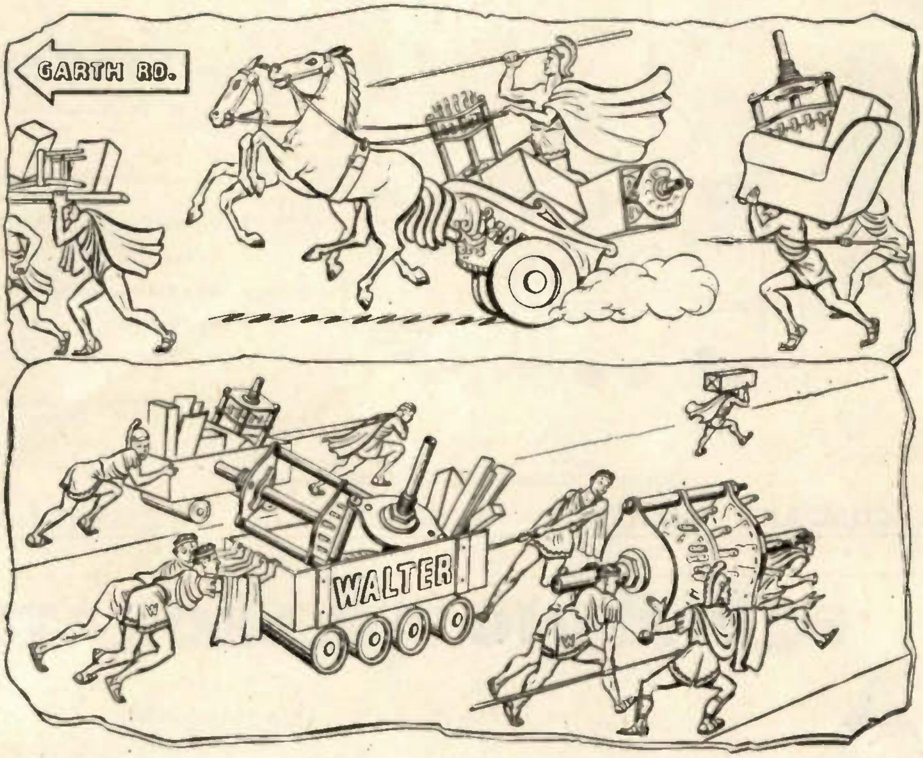

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A KNOWN amplifier capable of developing a stable balanced output free, to a considerable degree, from unbalanced components, despite conditions of unbalance and possibly changing conditions of unbalance in its input circuit, employs a pair of amplifier valves having in their cathode circuit a common impedance. This impedance is normally a pure resistance connected at one end to the negative terminal of high tension supply and at the other directly to each cathode. Input signals may be applied to each of the control electrodes of the two valves and the control exerted upon the two valves is then determined by the signal variations present at the control electrodes and by such potential variations as may be developed at the connected cathodes. The latter variations depend upon the current variations in the two valves and upon the magnitude of the resistance forming the common cathode circuit. If the variations of cathode current are equal and opposite so that balanced currents are set up in the valves, then it is evident that the potential developed at the cathodes of the valves remains constant. If, however, the valve currents tend for any reason to depart from a condition of balance, the difference of these currents flowing in the common cathode resistance results in variations of the potential at the cathode, so setting up a differential control of the valves that tends to equalise their currents. An amplifier of this kind will produce a satisfactory balanced output even when only one of its pair of control grids is excited. This requires a value of common cathode resistance equal at least to the reciprocal of the mutual conductance of the valves and with a resistance of such magnitude the essential characteristic of the amplifier is its notable insensitivity to so-called push-push components of variation present in its input circuit.

It will be clear from these remarks that the desirable properties of the circuit depend upon the use of a common cathode resistance of large magnitude. It will also be appreciated that the use of such a resistance can make demands upon the source of high tension which are at least inconvenient, even if the waste of power can be tolerated. This is so, particularly if the valves take large currents, for then the inevitable drop of potential in the cathode resistance becomes very large.

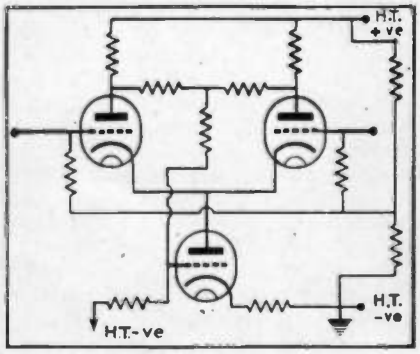


Fig. 1.

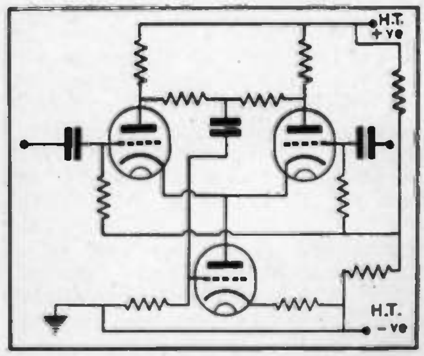


Fig. 2.

It has accordingly been proposed to replace the common cathode resistance by a valve, and not merely to do this, but also to control this valve from a point on a potential divider connected between the output circuits of the pair of valves. Thus, with similar valves and equal output resistances connected in their anode circuits the potential divider may be connected directly between the anodes and the control taken from the midpoint of the divider. With such an arrangement the stabilising effect of potential variations set up at the cathodes and resulting from an unbalanced condition in the output of the amplifier can be increased to a degree vastly in excess of that obtainable from an arrangement using simply a resistance for the common cathode circuit and not incurring a greater drop of potential in its cathode circuit. The amplifier may be worked either with a balanced input circuit or with an unbalanced input circuit in which one of the two control electrodes of the pair of valves is effectively grounded. Fig. 1 illustrates a circuit for balanced input operation and A.C. conditions. Fig. 2 shows a similar circuit only arranged for D.C. working.

The improved form of amplifier has one advantage in particular over the normal form in which the cathodes are coupled only by a passive impedance, and this advantage consists in the ability to compensate automatically for load circuit changes that would otherwise upset the balance of the output, as would happen if, for example, by a change in load one of the anode circuit impedances of the pair of valves were effectively halved.

The amplifier may be employed to deliver an output in a predetermined unbalanced ratio if desired, and in such an instance the tap on the potential divider will not be a mid tap, but will be appropriately displaced, so that when the output is exactly in the required ratio no control is exerted on the common cathode valve. In the Figures it will be noticed that the common cathode valve is provided with a cathode-load resistance. This is not merely to provide conveniently a bias for the valve, but also to render its operation less dependent on changes in its characteristics, and is simply a part of well known technique.

—Communication from E.M.I. Laboratories.

Helium Leak Detector

The use of helium in mass spectrography as a means of locating leaks in vacuum systems has been developed by engineers of the Westinghouse Manufacturing Co. (Pittsburg).

A jet of helium is sprayed over the suspected leak or over the entire system, and its presence inside the vacuum is shown by the mass spectrometer indication. The advantage is in the stability and inertness of the helium compared with other possible gases in the system.

Microphones

Part III—Pressure-operated Microphones

By S. W. AMOS, B.Sc.,* and F. C. BROOKER, A.M.I.E.E.*

Carbon Microphones

TELEPHONE Type.—The earliest types of microphone which were designed for use in telephone systems were all, consciously or unconsciously, made to operate on the pressure principle. Sectional views of both an early and modern telephone-type transmitter are shown in Fig. 1 a and b. The original microphone consisted of a shallow metal "box," the back of which had a concentrically corrugated carbon block inset, carbon granules filling the remainder of the space, and a thin carbon diaphragm covering these, but insulated from the rim of the metal box by a ring of cotton wool. This latter served the dual purpose of insulation and of providing a certain amount of damping against large resonances. One of the main defects of this version was the extreme brittleness of the carbon diaphragm which, when it broke, would allow all the granules to escape. This was overcome in a later model by the use of a carbon-coated rubber diaphragm (and even by a metal one), but this was not as satisfactory as the later type illustrated in Fig. 1b, which shows the inside of a modern telephone handset. It consists of a shallow, conical-shaped diaphragm, 2½ in. dia., connected to a "piston" of solid carbon which is in contact with the carbon granules contained in the "button." At the back of the button is the fixed electrode, also carbon, and the remaining space is loosely packed with finely powdered carbon, about 3,000 granules being a normal figure. The granules are insulated from the sides of the metal box by coating the metal with an insulating varnish and the electrical path is thus only between the two carbon blocks, via the granules.

The action of all types of carbon-granule microphones depends on the variation of the electrical resistance of powdered carbon when subjected to variations of mechanical pressure. The diaphragm, which behaves as an acoustical-mechanical transformer, provides the pressure variations and the carbon-granule button achieves the mechanical-electrical conversion. Telephone circuits are nowadays quite complicated, due to the introduction of other components, such as the receiver and bell, but the basic circuit could be simplified to either of those shown in Fig. 2 a and b, where it will be seen that either the transformer or choke-capacitance performs the function of removing the wanted A.C. component from the mixture of A.C. and D.C. which constitutes the output of the instrument. The resistance of this type of microphone is about 100 ohms and the average output (for normal speech input) is about 1 mW. It is interesting to note that the electrical power output actually exceeds the acoustical power put in. This paradox does not, of course, indicate greater than 100 per cent. efficiency because the battery supplies power to the circuit, and the whole circuit can be looked upon as an amplifier. A typical frequency response curve of an early type of telephone microphone is given in Fig. 3, which shows a useful range only between 300 and 3,000 c/s. and even this is far from flat, a sharp peak, due to the mechanical resonance of the diaphragm, occurring between 1,000 and 1,500 c/s. While this limited range is adequate for telephone purposes the response is not good enough for broadcasting or film recording purposes. In addition to this frequency distortion, this type of microphone gives fairly acute harmonic distortion. There are two main reasons for this. Firstly, the displacement-resistance relationship is not linear, particularly for large amplitudes. Even if it were, the expression for the A.C. component is found to contain terms with frequencies which are multiples of the applied frequency. Secondly, the asymmetrical mechanical loading of the stretched diaphragm means that there is greater resistance to motion for excursions in one direction than the other, which also results in harmonic distortion. Attempts made to cure both types of distortion resulted in the "double-button" microphone.

Double - Button Microphone.—In this instrument, in order to obtain an extended (and flatter) frequency response, the diaphragm is made of duralumin (to give a combination of lightness and strength) and is mounted under great tension so as to push up the resonant frequency to

* Engineering Training Department, B.B.C.

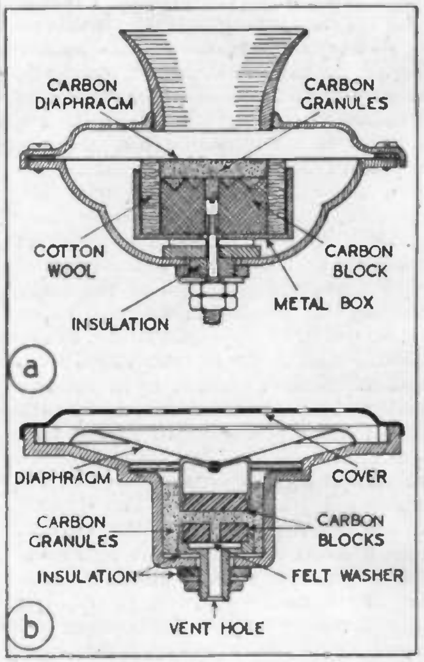


Fig. 1. Sectional views of telephone microphones.

(a) Early telephone microphone.
(b) Modern telephone inset.

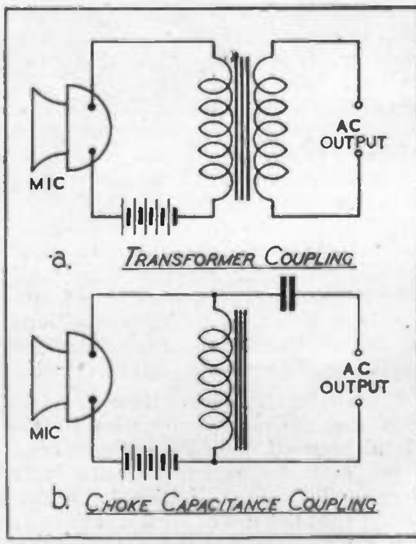


Fig. 2. Simplified circuits for carbon microphones.

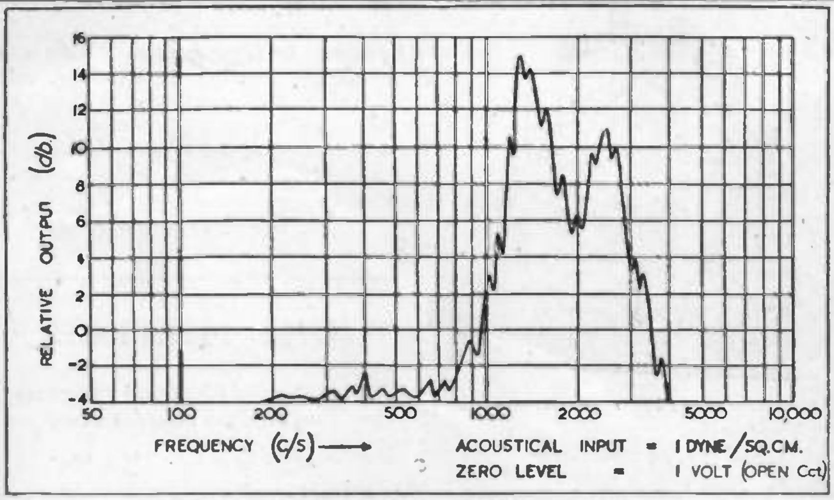


Fig. 3. Frequency response of early telephone microphone.

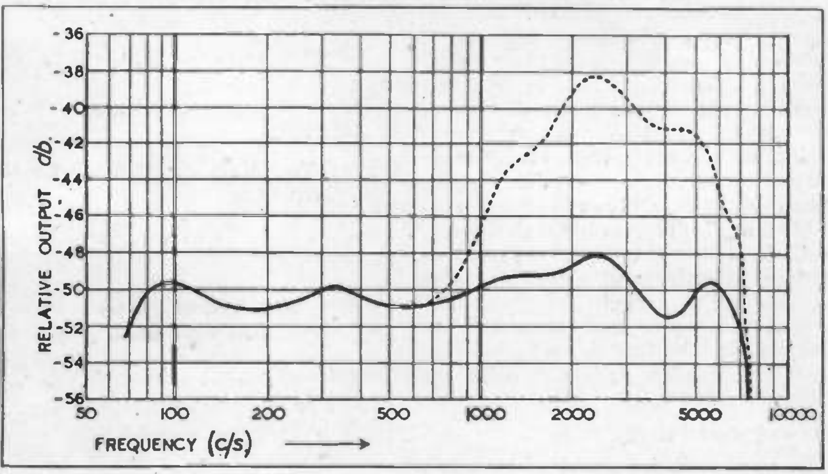


Fig. 4(b). Frequency response of double-button microphone.

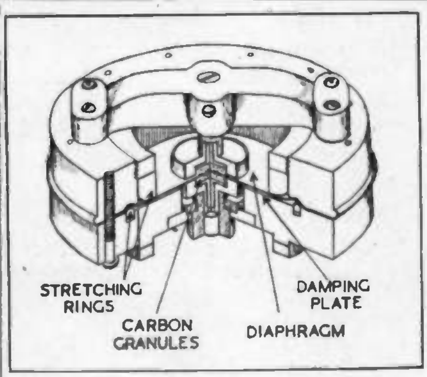


Fig. 4(a) (left). Part-sectional view of double-button microphone.

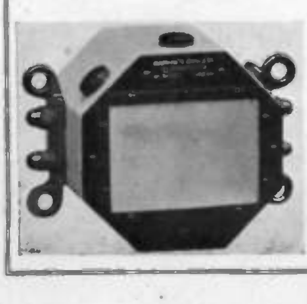
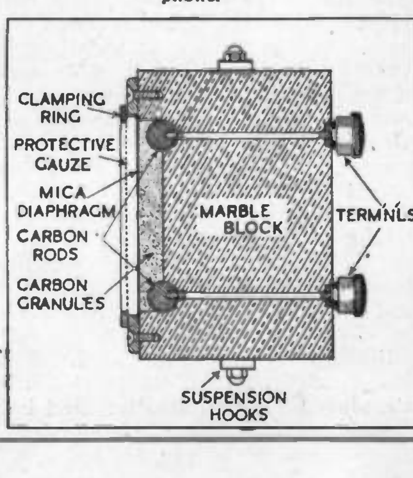


Fig. 5(a). Marconi carbon granule microphone (Reisz) type.

Fig. 5(b). Sectional view of Reisz microphone.



some value between 5,000 and 8,000 c/s. Over most of its range the diaphragm is thus under elastic control, which means that the velocity of movement is directly proportional to frequency for constant pressure on the diaphragm. Since, for a given velocity, displacement is inversely proportional to frequency, the two characteristics are complementary and the displacement for a given pressure on the diaphragm is therefore independent of frequency up to a point near resonance. The mechanical construction is shown in Fig. 4a where it is seen that the two buttons are in "push-pull." This arrangement is used to lessen the second harmonic distortion which was a feature of the single-button type. The duralumin diaphragm was gold-plated so as to make good contact with the carbon granules. One side only of the diaphragm was open to sound waves, the other being closed in by a backing plate placed very close to it in order to provide a high degree of acoustical damping. Thus, although the microphone *looks* double-sided it is, in fact, a pressure-operated device. By acoustical damping is meant that the thin "cushion" of air trapped between the diaphragm and plate has to be displaced from the centre to the sides when the diaphragm is pressed in. In so doing, energy is dissipated in frictional resistance, and the net effect is to even out any large resonant peaks in the response. The very great tension of the diaphragm, necessary to keep the resonant peak high in the A.F. spectrum lowers the sensitivity considerably. The average output is some 10 db. lower than the single-button type. Fig. 4b shows the response curve obtained by direct-pressure methods.

It must be remembered (Part II) that, due to both cavity resonance and pressure doubling effects, the free-air calibration will be quite different from this pressure calibration. An attempt to forecast the probable frequency response under these conditions is made in the dotted curve added to Fig. 4b, the rise of 12 db. at 3,000 to 4,000 c/s. being quite common for this type of microphone. There will also be some frequency distortion of a directional nature, as the sound source is moved round to the side of the microphone. This microphone, while considerably better than the telephone instrument, was still not up to the standard required for high-quality broadcasting purposes.

The Reisz Microphone.—This type of microphone, which was used by the B.B.C. up to about 1930, was also the outcome of an attempt to produce a high-grade instrument working on the carbon-granule principle. The granules are contained in a shallow cavity hollowed out of one face of a solid block of marble. The reason for using such a massive body (it weighed some 3½ lb.) was to avoid mechanical resonance of the casing which might affect the frequency response. Figs. 5a and b illustrate the microphone in general view and section. The fact that the current passes *across* the carbon between the two carbon rods has led to the name "transverse-current" type often associated with it. The diaphragm was originally of thin sheet mica, but this was found to have an unpleasant mechanical resonance at about 4,500 c/s. and an impregnated rice-paper was tried with superior results. Though there is hardly any cavity resonance (the diaphragm is stuck on, flush, to the face of the marble) the size of this type of microphone (4 in. across) causes appreciable diffraction effects and so there is frequency distortion in the form of top lift when the sound is coming from the front, and top cut for sounds arriving at oblique angles. It so happens that there is one angle of incidence—actually about 45°—where these two effects are almost self-compensating and produce a fairly level response. Announcers made use of this fact by developing (without any knowledge of acoustics!) a special "sideways" technique when speaking into the microphone so as to minimise any tendency to sibilance. The sensitivity of the Reisz microphone is roughly that of the double-button type, having a slightly improved response in the bass, and not such a pronounced peak in the higher frequencies.

Disadvantages of Carbon-Granule Microphones. — All carbon-granule microphones suffer from several defects associated with the carbon granules themselves. These have a tendency to become "packed" into a more or less solid mass. The microphone then draws an excessive current and its sensitivity falls. A slight tap will usually put matters right, but while this procedure is admissible in telephone instruments it is hardly practicable in broadcasting! Probably the worst fault is the high background noise—a continual hiss—which may be attributed to the fact that the operation of the microphone really depends upon bad contacts. It is sometimes maintained that the hiss is due to the large number of minute arcs occurring between neighbouring granules. Apart from a certain amount of harmonic distortion, already referred to, for normal amplitudes, the microphone is easily overloaded on larger amplitudes, a condition commonly referred to as "blasting." This is because there is a limit to the "compressibility" of carbon granules and saturation may be reached for high pressures. A similar curvature is evident for the low-pressure half cycle, where a cut-off point is reached, below which the current cannot go.

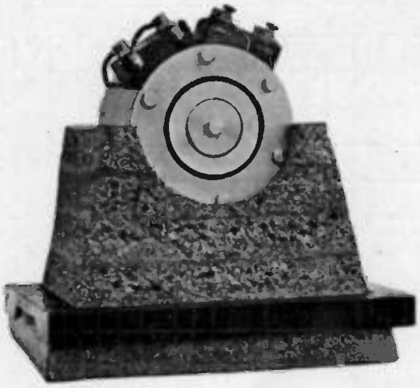


Fig. 6. The Round-Sykes "Magnetophone."
—*By courtesy of Marconi's Wireless Telegraph Co., Ltd.*

Moving Coil Microphones

General Principles and early types. —The idea of using Faraday's principle of electromagnetic induction in the construction of a microphone is a very attractive one since it eliminates at once the disadvantages associated with the use of carbon granules (although, of course, the diffraction effects of a large diaphragm remain). The B.B.C. used a microphone employing this principle as early as 1923. It was known as the Round-Sykes "Magnetophone," and consisted of a flat spiral of wire (which presents a large enough surface to act also as a diaphragm) which was placed in the annular gap of an energised magnet system not unlike the very large "pot" magnet of a loudspeaker. The method of securing the diaphragm was crude, to say the least, it being merely stuck against a pad of cotton wool smeared with vaseline. Needless to say, the coil fell clean out of the gap on more than one occasion! This type was abandoned as other smaller, and improved, types became available. The Round-Sykes microphone weighed a quarter of a hundredweight, and needed polarising batteries in addition; whereas modern moving coil microphones, using permanent magnets, weigh about 2 lb. A photograph of the "Magnetophone" is shown in Fig. 6.

(*To be continued*)

JUNE MEETINGS

Institution of Electrical Engineers

Repeat of the Faraday Lecture

Date: June 5. Time 6 p.m.

Held at:
The Central Hall, Westminster.

Lecture:
"Atoms, Electrons and Engineers."

By:
Dr. T. E. Allibone, Ph.D., M.I.E.E.

Note: No tickets are required for this Lecture.

Institute of Physics

Electronics Group

Summer Meeting.

Date: June 15. Time: 2.30 p.m.

Held at:
Research Laboratories, G.E.C., Wembley.

Discussion on:
"The Physics of Luminescence."

Opening Papers:
"Electronic Motion of Crystals—a General Survey."

By:
Professor N. F. Mott, F.R.S.

"Recent Advances in the Study of Electron Traps in Luminescent Solids."

By:
Dr. G. F. J. Garlick.

"Examination of the mechanism of build-up and decay of Phosphorescent Screens."

By:
L. C. Jesty, B.Sc., M.I.E.E.

Group Secretary:
A. J. Maddock, M.Sc., F.Inst.P., Messrs. Standard Telephones and Cables, Ltd., Oakleigh Road, London, N.11.

BOOK REVIEWS

Television—The Eyes of Tomorrow

W. C. Eddy. 319+8 pp. (Prentice-Hall Inc.) 1945.

This book, dealing as it does with the problems of the television service rather than the technical details of the apparatus comprising the television station, brings to the reader a new field of study.

The first two chapters covering the history and development of television up to the present time give a good picture of the state of the art in America.

Then follows a non-technical description of the Iconoscope camera and its associated control signals, and a little space is devoted to the Orthicon and similar types. It is perhaps unfortunate that in an attempt to use simple language for the benefit of the layman the descriptions get somewhat wordy and consequently confusing.

A short section is devoted to the various types of receiver, including those giving large screen protection, the subject-matter being chiefly concerned with the cathode-ray tube.

Chapter 6 deals with the control room and the controversial subjects of its location with respect to the studio, extent of the monitoring facilities, and to what extent intercommunication is necessary between the personnel of the station during a production. Here a good general picture is given of the various layouts and methods tried and of the modern trend in these matters.

The chapter on studio lighting is perhaps the best in the book and should prove valuable to technicians in this country as a resumé of methods tried and of the results of these trials. Considerable detail is given of the use of various light sources, not only as a method of just getting light on the stage but of using that light to its best advantage from an artistic and scenic point of view and of assisting the control engineers.

On the other hand, the treatment of colour television is somewhat disappointing, the difficulties of picture and lighting control being glossed over, and the part played by cine film is dealt with but is hardly given the attention that it deserves.

Studio design is well covered, the problems of the present and proposals for the future being handled in such a way as to prove a useful guide to the designer and a help to the producer. The advice on staging a production and the rôle of the actor, read with an earlier section on the colour response of the camera, should be of help to both artist and technician.

A glossary of terms, together with some notes to student producers and a complex index, conclude the book, which is illustrated with lavish photographs of apparatus and studio layout.

An undoubtedly useful publication covering an aspect of television up to now only sparsely reported.

D. O. WALTER.

Radar—Radiolocation Simply Explained

R. W. Hallows. 136 pp. 59 figs., 8 plates. (Chapman & Hall, 7s. 6d. net.)

This book can be read with interest and enjoyment not only by the non-technical reader for whom it is intended, but also by engineers whose work lies outside the orbit of radar developments.

Major Hallows has the attributes of a successful popular writer. He is lucid, fluent, and his illustrations are apt and well drawn. The book covers the preliminary theory of range measuring and electronics of the cathode-ray tube, leading to the requirements of precision radar, and the trend of peace-time developments.

General Sir F. A. Pile, speaking of early radar training in the introduction, sums it up correctly by saying, "Every instructor in radar would have been glad to pay large sums to have had this book at that time."

G. PARR.

CORRESPONDENCE

Determination of Sense of Rotation of Circular Time Bases

DEAR SIR,—

Mr. Hilary Moss (ELECTRONIC ENGINEERING, Oct., 1945, page 725, and Sept., 1944, page 15) refers to methods for determining the direction of spot traverse by pulse injection.

Your readers may be interested in a simple method in use about fifteen years ago at the Radio Research Station, Slough.

The observer looks *quickly* from *left to right* across the screen. The movement of the spot will appear to describe a sort of cycloid, owing to the combination of the movements of the spot and eyes.

If the cusps or loops point *upwards* the motion of the spot is *clockwise*; if they point *downwards* the motion is *anti-clockwise*.

The explanation of the effect is that the cusps will appear on the part of the screen where the spot and eyes are moving in the same direction.

L. BAINBRIDGE-BELL.

Single Stroke Time Base

DEAR SIR,—We have been interested to read the description of a single stroke time base, by D. McMullen, in your January issue. This circuit which combines an Eccles-Jordan trigger circuit with a Puckle time base, is the same in all important respects as one we have developed. Our interest in such a time base arose during the construction of an instrument for testing camera shutters. This instrument, of which it is hoped to publish an account shortly, has been in use for a considerable time now, and we can confirm that the time base in question operates very satisfactorily.

In order to avoid the provision of a negative bias supply for the trigger circuit valves we connect their cathodes to a point on a bleeder resistance across the H.T. supply. We have also found it preferable to transpose the rôle of the suppressor and control grids of the trigger valves, applying the input signal to the suppressor grid, and interlocking the two valves on their control grids.

A further useful feature is that by breaking the cathode connexion to the first trigger valve, the circuit becomes an ordinary free-running Puckle time base.

Yours faithfully,

H. M. ROSS,

D. T. R. DIGHTON,

Kodak Research Laboratories.

NOTES FROM THE INDUSTRY

Standards for Radio Components BS/RC Series

The following specifications in the BS/RC series for radio components, prepared by the Inter-Service Components Technical Committee and published on their behalf by the British Standards Institution, have recently been issued.

BS/RC. G2. Guide on Batching and Sampling.

BS/RC. S/141.1. Test Schedule for Air Dielectric Rotary Variable Capacitors.

BS/RC. S/165m. Group Test-specification for Miniature Relays.

These are additional to the 24 specifications in this series previously issued. Copies of all these specifications may be obtained from the Publications Department, British Standards Institution, 28 Victoria Street, London, S.W.1.

Code of Practice for Valves

The British Standards Institution has recently issued a Code of Practice which should be read by all users and designers of electronic equipment. It embodies the recommendations of the Electrical Industry Committee on the operating conditions of valves in apparatus to secure optimum performance and life, and is a revision of B.S.1106 of 1943 in the light of more recent experience.

Copies can be obtained from the British Standards Institution, 28 Victoria Street, S.W.1, at 2s. post free.

Reports on German Industry

The public relations department of the Board of Trade has issued a further list of reports on German industry. The reports cover every branch of industry, and many of them are of special interest to readers of this journal. They are available at libraries in most of the large towns in this country, and in London can be seen at the Patent Office Library.

The Decca Navigator Co., Ltd.

The Decca Navigator Company, Ltd., announce that Mr. H. F. Schwarz has been elected deputy-chairman of the company. Group Captain E. Fennessy, O.B.E., the chief engineer of the R.A.F. Radar Group, has been released from the Services and has been appointed to an executive position and made a director of the company.

Standard Telecommunication Laboratories, Ltd.

Mr. T. R. Scott, D.F.C., B.Sc., M.I.E.E., has been appointed assistant director of research to Standard Telecommunication Laboratories, Ltd., the recently formed subsidiary of Standard Telephones and Cables, Ltd.

Mr. A. T. Starr, M.A., Ph.D., has also taken up an important appointment with this company. For the greater part of the war, Dr. Starr was with the Telecommunications Research Establishment, and is also known in the industry as the author of a number of books and papers on the subject of telecommunications.

Cinema-Television, Ltd., and Rauland's (U.S.A.)

It is announced that an agreement has been signed between Cinema-Television, Ltd., and the Rauland Corporation of Chicago, Illinois. The agreement places at the disposal of Cinema-Television the very advanced television technique of Rauland's and covers the marketing by Cinema-Television of the Rauland product in the U.K., Dominions and Europe.

A new trade mark, consisting of the word "Cintel" prominently displayed in an ornamental circle on a squared screen, has been adopted by Cinema-Television, Ltd., and will in future appear on all their products, including photo-electric cells.

McElroy-Adams Group

This company, with offices at Imperial Buildings, Kingsway, London, W.C.2, was recently formed by H. R. Adams (with Webbs Radio before the war) and T. R. McElroy, of America. Mr. McElroy is well known on both sides of the Atlantic as a manufacturer of telegraphic equipment, and this Anglo-American company has been created to design and produce a full range of communication equipment in this country. Some models are nearly ready for marketing, including an amateur band exciter-transmitter, covering the 28 and 56 Mc. bands, a VHF converter and a range of power packs. The McElroy-Adams Group holds the sole U.K. concessions for Hallicrafters.

Wayne Kerr Laboratories, Ltd.

This is a new company of electronic engineers which will specialise in the production of a range of precision electronic measuring instruments, and the design and manufacture of apparatus to meet special requirements in industry. The directors of the company are all well-known in the industry; two are Mr. Richard Foxwell, who will lead the electrical design group, and Mr. Raymond Calvert (from the B.B.C. Research Department) who will be in charge of the mechanical design group. Within the next few weeks the first instruments in the range of measuring equipment will be introduced. In due course this range will include R.F. and A.F. Bridges, A.F. and Video Oscillators, Waveform and Spectrum Analysers, radio and audio frequency measuring apparatus, etc. The address of the company is Sycamore Grove, New Malden, Surrey. Telephone: Malden 0600.

British Rola and Celestion

British Rola, Ltd., announces that it has acquired 97 per cent of the Share Capital of Celestion, Ltd. The manufacturing and selling policies of the two companies will continue to operate independently insofar as models and prices are concerned, and research and technical development will also proceed along independent lines, although provision is made for an exchange of technical data which will ultimately be of benefit to both products.

Delco-Remy and Hyatt, Ltd.

This company announces that since May 6, all departments of the organisation, both in London and Dunstable, have been working a five-day week. The regular business hours are 8.45 a.m. to 5.30 p.m. Mondays to Fridays. The head office of the company is at 111 Grosvenor Road, London, S.W.1.

Marketing Radar Equipment

Metropolitan-Vickers Electrical Co., Ltd., and Siemens Bros. & Co., Ltd., announce that an agreement has been concluded between them in connexion with the marketing, hire maintenance and servicing of radar and associated audio-type equipment for marine navigational purposes. Marine radar equipment designed by Metropolitan-Vickers will continue to be manufactured by them, whilst the design and manufacture of equipment on the audio side will be handled by Siemens Bros. Marketing of both types of equipment on an outright sale basis will be done by both firms, and Siemens Bros. will handle hire maintenance and servicing contracts.

Recordomat Co., Ltd.

The Recordomat Co., Ltd., 19 Exmouth Market, Rosebery Avenue, London, E.C.1, announce the production of several amplifiers, including a portable type U.15 which has an output at 230 V of 15 watts at 2 per cent. total harmonic distortion, and an impedance of 7½ ohms. The microphone input impedance is 15 ohms and any standard moving coil microphone can be used. The gramophone unit impedance is 50,000 ohms and will admit all standard pickups. Frequency response is flat within ½ db. from 50-10,000 cycles. The amplifier operates on either D.C. or A.C., 40-60 cycles, 200-250 V. Other products of this company include slow moving volume indicators, microphone amplifiers, amplifiers for projectors, mixing desks and loudspeakers. Amplifiers can be built to specification.

New Name for Philco

The name of the existing public company of Philco is being changed to Radio and Television Trust, Ltd., and under new agreements made with the Philco Corporation of Philadelphia, the British company is now free to export radio and television receivers under the trade mark "Airmec," or any other name except Philco. These products will still be sold in the British Isles under the name Philco.

The Radio Industries Club

Mr. Leslie Gamage, joint managing director and vice-chairman of the General Electric Co., Ltd., has been elected president of the club for 1946/47 in succession to Sir Robert Renwick, Bt., K.B.E.

Amateur Radio Society

The Ilford and District Radio Society is now functioning again, and meetings are held fortnightly at the St. Albans Church Hall, Albert Road, Ilford, Essex, at 8 p.m. A full programme is being arranged, including discussion evenings and lectures from representatives of well-known organisations. Prospective attendees should communicate with the Hon. Secretary, Mr. C. E. Largen, at 44 Trelawney Road, Barkingside, Essex (Hainault 126). The Chairman and Press Officer of this society is Mr. H. T. Stott, of A. F. Bulgin & Co., Ltd.

Data on New Products

Wright and Weaire Coil Pack

Wright and Weaire, Ltd., announce the production of a compact, highly efficient unit, comprising coils, switch, trimmers, padders, etc., for aerial and oscillator tuning. This coil pack is completely assembled, wired and tested, and is suitable for use with any of the standard frequency changers of the triode-hexode type. Further details may be obtained from the technical department of the company at 740 High Road, Tottenham, London, N.17.

Londex, Ltd.

Two interesting leaflets have been issued by Londex, Ltd., 207 Anerley Road, London, S.E.20. One deals with a high-speed contactor, type BB, a heavy duty type for A.C. or D.C. noiseless working, with 4 VA coil consumption. This has been designed for high-speed welding, motor control and signalling. The other refers to a unit for the remote control of street lighting with a master switch.

Geiger-Muller Counter Set

The Cyclotron Specialities Co., of Moraga, California, have sent us details of their G.-M. counter set, Geiger tube, and impulse register. This equipment makes a complete apparatus for determination of radio-activity. The impulse register is recommended as a separate item for work requiring quick and accurate counting, and will register up to 60 impulses per second. Full particulars are obtainable from the company at the address given.

Paper Insulated Cables

W. T. Henley's Telegraph Works Company, Limited, recently issued a new catalogue "C" which covers the range of Henley Paper Insulated Cables, standardised in accordance with B.S. 480-1942.

G.E.C., Ltd.

A folder which gives in tabular form the characteristics of more than 80 types of valve, tube and photo-cell, together with tables and diagrams which form a useful valve base and valve pin connexion chart, is available on request from the publicity organisation of the G.E.C. Each class of valve is clearly indicated by "streamer" side headings so that easy reference is facilitated.

ABSTRACTS OF ELECTRONIC LITERATURE

THEORY

The Self-Inductance of a Toroidal Coil without Iron

(*H. B. Dwight*)

The author derives formulae for the inductance of a toroidal coil with a rectangular section and comparatively thick winding, as distinct from the case where the toroidal coil comprises a single layer of wire wound around a non-magnetic ring. For the latter, comparatively simple expressions have already been derived for the two cases where the sections of the non-magnetic ring are rectangular and circular respectively. An example is included of a coil, the inductance of which is calculated by means of the author's formulae, for which it is claimed that the measured value of inductance agrees within 1 per cent. with the calculated value.

—*Trans. A.I.E.E.*, November, 1945, p. 805.*

Micro-Electromagnetic Waves

(*M. G. Kellner and E. T. S. Walton*)

A description is given of a reliable, sensitive and fairly selective detector for the micro-electromagnetic waves produced by sparking between short tungsten rods under oil. It has usually been assumed that the radiation produced in this way consists of a damped train of waves emitted every 0.01 sec., if the transformer used to produce the sparks is run on 50 c/s. A.C. The present experiments show that about 20 to 30 wave trains are emitted every 0.01 sec. and that these trains show very much smaller damping than is predicted by theory. It is suggested that some mechanism may be present tending to maintain the oscillations.

—*Wireless Eng.*, Feb., 1946, p.46.*

Loop-Antenna Coupling Transformer Design

(*W. S. Bachman*)

The low-impedance loop coupling transformer circuit is analysed, the transformer parameters being expressed in terms of the circuit and transformer coupling coefficients. Equations are developed which yield optimum design values for the transformer. It is shown that an ideal transformer-coupled loop has 38.4 per cent. of the gain realisable from a direct-connected loop of the same area, assuming the same Q in the transformer secondary as in the direct-connected loop.

—*Proc. I.R.E.*, Dec., 1945, p.865.*

MEASUREMENT

Radio-Frequency Spectrum Analysers

(*E. M. Williams*)

The resolving power of radio-frequency spectrum analysers of the continuously tuned type is defined as the width in frequency, at points 3 db. down from the peak value, of the trace of a continuous wave signal. The optimum resolving power is $1.3\sqrt{F/T}$, in which F is the frequency band scanned and T the period of one scan. Traces of pulse-modulated, frequency-modulated and amplitude-modulated signals are illustrated to show the effect of resolving power.

—*Proc. I.R.E., Jan.*, 1946, p. 18.*

A Standard of Frequency and its Applications

(*C. F. Booth and F. J. M. Laver*)

The paper discusses the importance of frequency standardisation to the telecommunication engineer, and outlines the work which the Post Office has carried out in this field. As published information on the subject is scanty, the historical development of frequency standards is reviewed, a bibliography is included and the factors affecting the design of a standard are briefly analysed. The design, performance and application of the Post Office standard are considered in some detail. In particular, the absolute calibration of the group of crystal-controlled oscillators comprising the standard is discussed, details are given of equipment designed for the precise intercomparison of the frequencies of the individual oscillators. A specialised form of frequency standard, known as a "quartz clock," which is now being used by astronomers in addition to the older type of pendulum clock, is briefly described.

The methods available for the comparison of frequency standards, both nationally and internationally, are analysed, and a résumé of international comparisons reveals the advances achieved in frequency standardisation during the past two decades. At present, it is considered that the absolute value of the Post Office standard of frequency is known to $\pm 1 \times 10^{-8}$. Finally, the development work now being carried out to improve the stability and reliability of the standard is outlined.

—*Jour. I.E.E.* (to be published).

INDUSTRY

Stabilised D.C. High-Voltage Supply

(*A. M. Gurewitsch and P. C. Noble*)

The D.C. power supply equipment described is capable of delivering 60 watts at 60 kV. An oscillator drives a power amplifier at a frequency of about 35 kc. The tank circuit of the amplifier is a tuned high-frequency voltage step-up transformer followed by a voltage quadrupling and rectifying circuit, the ripple of the quadrupler circuit being reduced by a filter. Across the output of the quadrupler circuit is placed a high-voltage divider. The oscillator output is controlled by means of a voltage obtained from the divider and an amplifier which ultimately determines the screen voltage of the oscillator tube and a dry-cell battery provides the reference voltage for the regulation. An analysis of the circuit operation and the application of the mathematical analysis is given.

—*Gen. Elec. Rev.*, Dec., 1945, p. 46.*

THERMIONIC DEVICES

Cavity Magnetrons

This article gives the first published information on microwave pulse generators which are capable of producing four million watts peak power at 3,000 Mc/s. A cavity magnetron consists of a cylindrical unipotential-heater cathode surrounded by a massive copper anode having cut into it several resonant cavities. From a modulating pulse input of 1,150 kW (24 kV at 43 amperes) a radio-frequency peak power of 490 kW is developed by the type 4J36-4J41 series of tubes, at an efficiency of 47.5 per cent. Output frequency and undesired modes, magnetic aspects, the Reike diagram and mechanical design, in addition to general characteristics, are features discussed in this article.

—*Electronics*, Jan., 1946, p. 126.*

* Abstracts supplied by the courtesy of Metropolitan Vickers Electrical Co. Ltd., Trafford Park, Manchester

The Amateur of the Future

"FIRST, let us examine the fundamental requirements of an ideal amateur station. The primary question confronting the average ham is: Does he want his station *on* or does he want it *off*? Reference to the literature will confirm that an 'on-off' switch is the most practical solution to this problem. Having established this component as a prerequisite, let us delve into the less interesting sub-assemblies to be tied into the on-off switch. The best way to cover this is to describe the sequence of operations occurring when this switch is thrown from the 'off' to the 'on' position.

"Joe Blow strolls into his shack, turns on the aforementioned switch, lights a cigarette, and starts reading the latest copy of *Esquire*. Rotating beam antennas on all amateur bands start scanning the horizon, feeding in signals to appropriate receivers, which are scanning the bands in frequency, looking for a CQ. Let us suppose that the receiver system on band A finds a CQ first. The audio signal, having passed through the CQ-pass filters, operates relays which de-energise the other receivers, switch off the scanning function of antenna A, and automatically points the beam at the originating transmitter by means of an appropriate servo system. Simultaneously, Joe's own transmitter is automatically tuned to the frequency of the incoming signal, and held in readiness to transmit. As soon as the received signal stops, the transmitter sends out a call automatically prepared on a magnetic wire recorder from the call sent by the other station and including Joe's call.

"Whenever the other station breaks in, Joe's transmitter stands by and his receiving system comes into its own. Basically, the signal is fed into three channels, the Log channel, the QSL channel and the Miscellaneous channel. The Log channel uses information contained in the signal relating to the signal strength and the time the QSO started, and prints it on the Log sheet. The QSL channel, in a similar manner, prints part of the QSL card. The Miscellaneous channel accumulates the non-essential information passed out by the other station and feeds it into the waste basket.

"When the victim stands by, Joe's station automatically goes to the transmit position, sends out 'Good Morning,' 'Good Evening,' or 'Good Afternoon,' as determined by a suitably connected clock, transmits the other fellow's RST report complete with fudge factor, gives the weather as measured by a barometer and thermometer on the roof, states the QTH (not a variable, making this part simpler), adds 73 and signs.

"After the other station signs, the Log and QSL machines finish printing their respective cards. When this is complete and the QSL card has been automatically shot out to the nearest mail box, a siren is energised to distract OM Blow from his *Esquire*. He is then faced with a decision. Should he let things take their course and have another QSO, or should he throw the switch to 'off' and delve further into the printed pulchritude?"

—*Carl C. Stotz*, W3EPJ/2, "QST," February, 1946.

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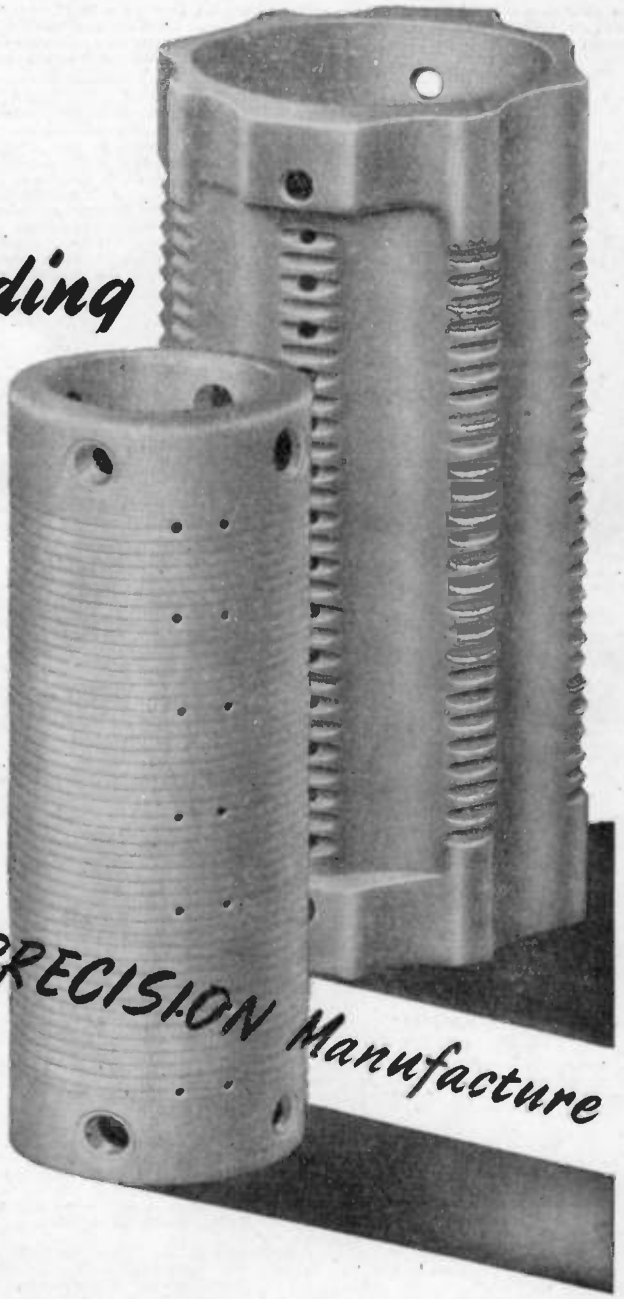

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Manchester Office: 196, Deansgate, Manchester

CLASSIFIED ANNOUNCEMENTS

The charge for miscellaneous advertisements on this page is 12 words or less, 4/- and 4d. for every additional word. Box numbers count as four words, plus 1/- extra for replies. Remittance should accompany advertisement. Cheques and P.O.'s payable to Hulton Press, Ltd., 43 Shoe Lane, E.C.4. Replies to box numbers should be addressed as above, marked "Elec. Engg." Press date: 15th of month for following issue.

FOR SALE

PHOTO-ELECTRIC CELLS, SeTe on gold-alloy, super-sensitive to light, gasfilled, permanent, operate relay direct or with valve amplifier, perfect reproduction of speech and music, etc., from sound track of films; large tube 3½ in. from glass top to valve pin base, 1 in. dia., 38/-; same type, 2½ in. long, 35/-; small tube, 2 in. from top to terminal base, ¾ in. dia., 30/-; miniature cell, 1 in. overall glass top to cap base, ½ in. dia., thin flex leads, 28/-; all cells operate on 40 to 100 volts. Connections diagrams free.

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LATEST SOUND Equipment available from stock. Portable dance band amplifiers. 12 watt A.C./D.C., £8 10s. Cinema models 50 watt, 45 gns. Guitar contact mikes, 4 gns. Speakers from 3 in. to 18 in. in stock, also microphones and radio tuners. Communication receivers and mobile equipment for 6-28 v, also 100 v D.C. Catalogues on request. United Electronics Ltd., 156 North End Road, West Kensington, W.14. FULham 5577/8.

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LOUDSPEAKERS—We carry on. Sinclair Speakers, 12, Pembroke Street, N.1.

LOUDSPEAKER repairs, British, American, any make, moderate prices.—Sinclair Speakers, 12, Pembroke Street, N.1.

MISCELLANEOUS

WE WILL BUY at your price used radios, amplifiers, converters, test meters, motors, pick-ups, speakers, etc., radio and electrical accessories. Write, phone or call, University Radio, Ltd., 22, Lisle Street, London, W.C.2. GER. 4447.

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RESEARCH AND DEVELOPMENT Engineers and Technical Assistants required for Laboratories of large Group of Companies. Must have academical and practical knowledge of radio. Persons with experience of Government receivers and transmitters preferred. Salaries ranging up to £800 p.a. according to age, experience, and qualifications. Write giving full details to Box 841, "Elec. Engg."

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