Wireless World

ELECTRONICS, RADIO, TELEVISION

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Transistors — Sliding-bias 4.5W Amplifier

The circuit shown is intended for car radio applications working from a 14V supply. The frequency response is quite suitable for this use, and distortion arising from the sliding-bias action is inaudible. The Mullard OC16 output transistor, in this circuit, produces nearly twice the output power normally obtainable in conventional Class A operation, with the same size heat sink. Because the d.c. currents vary with the signal, the circuit is exceptionally tolerant of continuous operation with speech and music, at high ambient temperatures up to 55°C. The only condition possibly dangerous to the OC16, is if the speaker is disconnected, whilst working, at high ambient temperature.

Using sliding bias, the operating point of the transistor can be altered so that the d.c. input power varies with the signal. This enables the dissipation to be halved for the same output power, or the maximum output power to be doubled for the same dissipation.

The sliding bias varies the quiescent signal in conjunction with the amplitude of the output signal, so that it is always greater than the peak signal handled. Because, with speech and music, I_q is rarely a maximum, the average current drain is appreciably less than the maximum value, and the average dissipation less than for an equivalent Class A stage.

In a conventional Class A amplifier, designed for a junction temperature T_j of 90°C (T_{amb} = 55°C), this value of T_j is reached whenever T_{amb} equals 55°C. In this sliding-bias circuit (T_{amb} = 55°C) the maximum T_j is only reached under certain conditions, these are sustained sine wave input and a combination of limit characteristics of the transistors, which are not met in practice. Operation of the transistor a maximum T_j is unlikely, so that the life of the transisto should be longer.

The sliding bias is obtained from a secondary winding on th output transformer; it is rectified by a copper oxide rectifie (R4 should be 3.9Ω), which is quite satisfactory, or a Mullar germanium diode (OA5 or OA10), which is slightly better i performance. The d.c. voltage, obtained across a capacito (C1) and a shunt resistor, is applied to the base of the OC7 by way of the secondary of the driver transformer. Tw problems not arising in conventional Class A amplifiers must be solved, the elimination of transient distortion an the provision of correct sliding-bias action.

The first requires that the charging time constant of the bia circuit must be as small as possible; this is dependent on C and the forward resistance of the diode. For a lower frequenc limit of 100 c/s, C1 must be 25µF. The discharge time constant must be chosen to avoid unnecessarily high dissipation of the OC16.

For correct sliding-bias action, the OC16 d.c. collecto current must always be slightly greater than the peak a.c collector current handled. The d.c. collector current depends on the bias at the base of the OC72. This is mostly derived from rectification of part of the a.c. collector voltage, which is directly proportional to the a.c. collector current.

The maximum collector dissipation likely is 7.2W for music drive with maximum transistor and resistor spreads.

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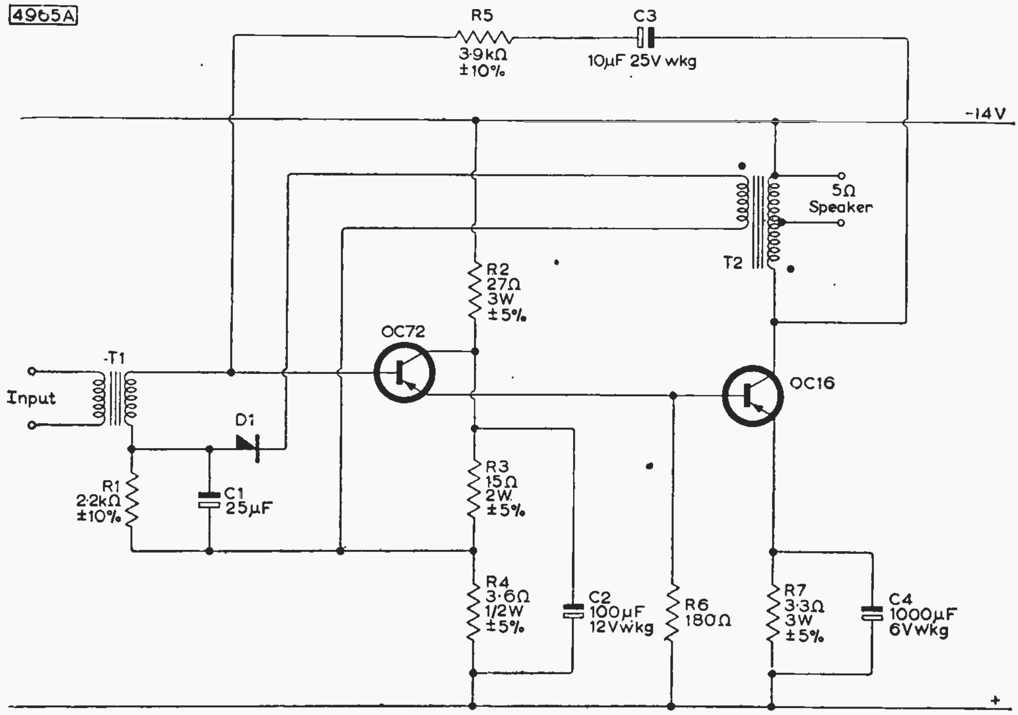

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Engineers in Association

MAN is a gregarious animal and the urge to communicate with his fellows is no less strong in engineers and technicians than it is in other members of the community. Whether it be the discovery of common interests with a complete stranger on a railway journey, participation in discussion at the local radio society or attendance at one of the Memorial Lectures of our great institutions one comes away with a sense of pleasure which is not altogether accounted for by any profit which may have been derived. Possibly the fact that engineering contains the elements of humanism and is less detached than the pure sciences may have something to do with this.

Community of interest and a willingness to impart as well as to absorb knowledge in discussion are the foundations upon which all successful associations have been built. The size of the membership will settle itself under the influence of the many factors which impel individuals to apply for and subsequently to continue membership. Inevitably there will be fluctuations which may show correlations with the external economic climate, the quality of the membership itself and the ratio of those who impart to those who merely absorb information.

The growth of knowledge and the changing pattern of industry will also result in a tendency to further specialization. This will give rise to regrouping either into cells within a larger association, or to the formation of new groups and associations. We see no cause for alarm in specialization provided that it is not pursued to the exclusion of the interchange of ideas between groups. The Royal Society of Arts sets a good example by welcoming as "institutions in union" comparatively new bodies, such as the British Sound Recording Association, which can both learn from and contribute to the traditions of skill and good taste established by the older society. Within the great engineering institutions the same object is achieved by frequent joint meetings of the specialist sections.

So far we have considered only the advantages of association for the advancement of knowledge and the individual benefit of members. Another important function is the establishment, as a condition of membership, of standards of professional competence and conduct which will be universally recognized as qualifications to practise—more particularly as independent consultants. This motive for association, which is similar to that of the ancient guilds, is one by which all the great engineering institutions are actuated. It is unthinkable that they should have separate codes of ethics, and the necessity for complete integration in this sphere seems axiomatic. On this point we are in agreement with Sir Arthur Whitaker, president of the Institution of Civil Engineers, who said at their recent annual dinner:

"Between the three major institutions we have, as always, the happiest of relations and we are going to try and see how much nearer we can get together. I am hopeful that somehow we shall find some way in which we can come extremely close together, because I believe that if we do that we shall make the engineering profession more cohesive. I believe it is a good thing. I do not like splinter groups. I do not like the suggestion that in order to cater for one particular branch of engineering you must set up a new institution. Engineering is a tremendous profession. It is a very varied profession. It covers so many things now that not even the greatest engineer can hope to be proficient in more than a moiety of it; but that is not to say that in organization we cannot get together and learn how to come under one rooof for engineering policy for the control of the profession."

We do not, however, share Sir Arthur's dislike of new splinter groups. These are apt to form and flourish with or without approval and will fully justify their separate existence if they extend the facilities for meeting and discussion and the spread of knowledge. The question of integration for other purposes can safely be left until they are as firmly established as the Institutions of Civil, Mechanical and Electrical Engineering.

Doppler Effect in Radio and Radar

I.—GENERAL PRINCIPLES

By N. M. RUST

SEVERAL articles have appeared recently in the technical press on applications of Doppler phenomena to radio and radar. Two of particular interest are "Airborne Doppler Navigation," by G. E. Beck, in *Wireless World* for May, 1957, and "Quantum's" "Fringe of the Field" article, "Son et Lumière," in the October, 1957, number of *Electronic & Radio Engineer*. The former describes a special application of Doppler to air navigation, while the latter gives a very clear exposition of the phenomenon from the point of view of relativity. The aim of this article is to draw attention to other uses of the phenomenon, and to various ways in which it comes into effect in radio and radar.

As "Quantum" has pointed out, it is rather unfortunate that the Doppler effect in sound is commonly used as basis of comparison for radio and radar effects. Apart from the question of velocity with respect to a medium, which has meaning with respect to sound vibrations in air but has no meaning in relation to radio phenomena, there are other factors which lead to a completely different outlook. In sound we are concerned with the change of pitch of a note when there is relative movement between transmitting and receiving points, and we measure pitch directly. In radio we do not directly measure the frequency of the received wave. The practical application of the phenomenon for velocity determination, and position finding, leads to the comparison by interference of the frequency of radio oscillations received from a relatively moving source with that of a reference oscillation from a fixed source at the receiving point. It is the pitch of the beat note that is measured, and not the actual Doppler frequency. This beat note we term the "Doppler note," and it must be distinguished from the "Doppler frequency" that is measured in the acoustical case.

In some applications it may be desirable, in order to obtain more precise information, to compare (by direct or indirect means) the "instant-by-instant"* phase of the two sets of oscillations. An understanding of the relative phase conditions affords the best means of establishing a picture of the phenomenon in its practical application to radio.

If we understand what happens to the phase, instant-by-instant, what happens to the frequency difference, which is the thing we usually measure, will take care of itself.

Consider two oscillators that are very precisely synchronized. One is at a fixed point F, and the other at a moving point M. Initially M is placed at F, and the oscillators are brought into phase with one another. M is moved from F and its oscillations are radiated and received at F, and phase comparisons are made by means of a phase indicator. This is calibrated so that the angular position of the pointer corresponds to the phase difference between the received oscillations from M, and those of the oscillator at F.

Initially the pointer will read zero The velocity of radio waves is so very much higher than even that of a "sputnik" that it is not necessary to take account of the distance moved during the time of transmission of the signal from M to F. Any correction for such motion, although important in order to understand the phenomenon from the relativity point of view, would not effect any measurement that could be made under practical conditions. An (ideal) phase indicator pointer will therefore follow the movement of M. For every change of distance of one wavelength the pointer will make one turn and the direction of turning will depend upon the direction of motion.

If the phase indicator could be geared up to a counter so that the number of turns could be registered from the starting point, the counter would register the distance moved in wavelengths, and the fractions of a wavelength would be registered on the dial. If the rate that the needle was turning was counted in cycles per second, it would represent the radial velocity of M relative to F in wavelengths per second. The frequency of the oscillations from M received at F is the "Doppler frequency," and the difference between the frequencies of M and F, at F, is the "Doppler shift," or the "Doppler note"

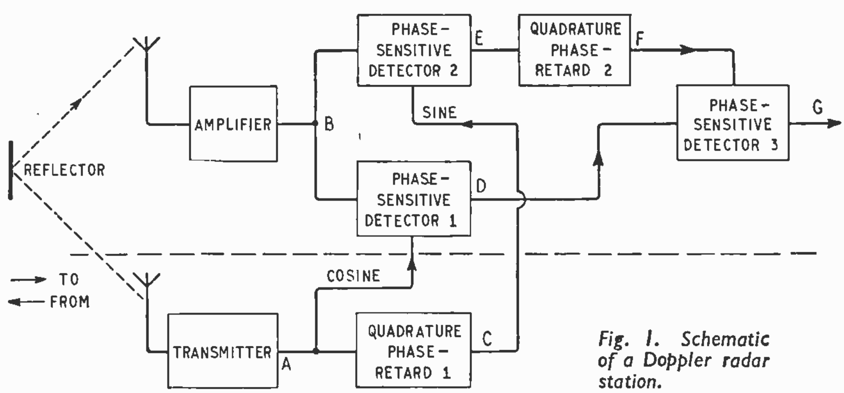


Fig. 1. Schematic of a Doppler radar station.

*The term "instant-by-instant" is preferred to "instantaneous," which conveys the impression of one event sharply defined in time. Doppler phenomena essentially concern moving objects. To understand and define them, we must think of a sequence of events sharply defined in time, and not merely of one event.

as it is usually called in radio or radar practice. Clear distinction should be made between the "Doppler frequency" and the "Doppler note."

Summarizing, then, the change in distance is represented by the total change in phase relationship, and the rate-of-change of distance (the radial velocity), by the frequency of the beat note. The scale units are defined by the wavelength of the transmitter.

Note that Doppler effect cognizes only changes in radial distance. Thus M may move in a circular path round F without causing any phase change or Doppler note. It is only the distances and velocities resolved along the radius connecting the two points, at any given instant, that are measured. If both relative bearings and relative distances are recorded instant-by-instant, the track of M relative to F is completely defined.

Perhaps the reader will say, "Although I quite understand your illustration, you have taken a hypothetical case that cannot possibly arise in practice, as you have assumed that the respective oscillators, at their positions, remain absolutely identical in frequency." The justification for this is that the more usual applications of Doppler effect are for radar purposes, in which the moving oscillator is replaced by a moving reflector illuminated from the fixed point. The difficulties of synchronization do not occur, therefore. Before considering the radar applications, however, there are several cases in which Doppler effect comes into play in ordinary radio practice, and these will be considered first.

One of the examples is in relation to single-sideband telephony from jet aircraft. If single-sideband telephony with suppressed or partially suppressed carrier is used, it is necessary to restore the carrier at the receiver by inserting a local oscillation. To obtain clear speech this must be at the right frequency. Let us consider the case of a jet aircraft flying at 600 miles per hour in the line of sight of a ground station, and transmitting on a frequency of 300Mc/s, or a wavelength of 1 metre. 600 m.p.h. is 880 ft/sec, or 278 wavelengths per second. If the aircraft is flying towards the ground station, the carrier frequency seen by this station will be raised 278 c/s above 300Mc/s. Similarly, if it is flying away on the line of sight the frequency received will be 300Mc/s − 278 c/s, and if flying transversely across the line of sight there will be no change of frequency and the carrier will remain at 300Mc/s. It will be seen, therefore, that Doppler effect presents quite a problem to the receiver designer in this case. His carrier restoring oscillator must follow these variations under all conditions to obtain clear speech.

Another important effect of Doppler in radio is in transatlantic reception of standard frequency signals, e.g., from station WWV (near Washington, U.S.A.). Ionospheric drift frequently produces quite appreciable Doppler effect, due to alterations in path lengths caused by the movement of reflecting ionospheric layers. Reference may be made to a paper "Doppler Effect in Propagation" by H. V. Griffiths of the B.B.C. in *Wireless Engineer* for June, 1947.

Perhaps, however, the most interesting application of Doppler effect in radio is that described in *Wireless World* for December, 1957, in connection with the radio observations on the Russian artificial satellites. The reader is referred to this article as it gives a very clear exposition of the way observations of Doppler changes in frequency were used, in

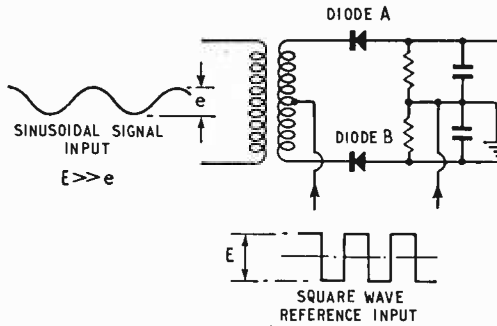


Fig. 2. Circuit of a phase-sensitive detector.

conjunction with other data, to establish the track of the satellites.

As these satellites are probably the most rapidly moving objects likely to be encountered for the present, it is interesting to check the difference in Doppler frequency derived from the Newtonian formula with that given by the Einstein type of formula derived by "Quantum." The last-mentioned provides a relativity correction factor of $(1-u^2/c^2)^{-1/2}$, where u is the velocity of the satellite, and c is that of light. The velocity of the satellite is given as 8 km/sec whilst c is 300,000 km/sec. The correction factor therefore works out as $(1-64/9\times10^{10})^{-1/2}$. This equals 1.000000000355. We are therefore, even in this extreme case, quite justified in using the ordinary formula, as the correction factor is far less than errors in measurement would be.

The illustration given above of the fixed and moving oscillators is easily adapted to radar principles. In this case we make the fixed oscillator at F radiate, and reflect the oscillations back to F by means of a moving reflector at M. This takes the place of the moving radiator. The echoes received are then compared in phase with the transmitted oscillations at F. The difference of phase is indicated by the pointer of a phase meter which makes one complete turn for every cycle change of phase The reflector M is first placed quite near to F, and adjustment is made to bring the phase meter reading to zero. We can assume that the time taken for the oscillation to complete the round trip from F to M and back is always insignificant in relation to the time taken to alter the total path length by one wavelength, or for an alteration of distance of one half wavelength. Therefore, for every change of distance of one half wavelength, the phase meter will complete one turn. The number of revolutions indicates the radial distance moved in half wavelengths, while the revolutions per second indicates the radial velocity in half wavelengths per second. Motion "to" turns the meter anti-clockwise, and motion "from" clockwise (using the same conventions as before).

M's track can be plotted by measuring instant-by-instant its Doppler phase and bearing, but there is no direct means of measuring range. Unless the radial velocity were very small, it would not be possible under practical conditions to follow the movements of a phase meter. It is therefore more practical to beat together the transmitted and received oscillations, and detect the beat note—the Doppler note. The frequency of this note gives the radial velocity directly, which can be displayed on a frequency meter.

This method of displaying the Doppler information, which is usually the only practical one for fast-moving objects, introduces a difficulty. How can motion "to" be distinguished from motion "from," or vice versa? To the ear, or to the display, a note of 1,000 c/s may represent motion "to," or "from," of equal velocities; there is no means of distinguishing between them. If we had an electronic counter that would count either forwards or backwards, and register both positive and negative, the problem would be solved. Such a method is possible, but might prove complicated. The usual method of discriminating direction of motion will be described, therefore, especially as it affords an opportunity of bringing out some important features.

The problem is essentially that of distinguishing whether the beat note obtained by mixing a signal with a reference oscillator is due to a lower or a higher frequency than that of the reference oscillator. This has been successfully solved by a technique used for sideband cancellation in single-sideband telephony.

A Doppler radar station is shown schematically in Fig. 1. The receiver is shown at the top, and the transmitter just below it. The dotted line between them indicates that the receiving circuits are adequately isolated from the transmitter, so that they are not "swamped" by the transmitted signals. This may be accomplished, either by screening and separation, using separate transmitting and receiving aerials arranged so that the receiving aerial is placed on a null of the transmitting aerial, or by circular polarization methods. In the last-mentioned case it is possible to use a common aerial. Direct reception is indicated, but in practice special heterodyne methods would be used in order to obtain good signal-to-noise ratios.

The amplified signals are passed to two special detectors which, for want of a better name, have been called "phase sensitive detectors." Similar circuits have been called "synchronous" and "homodyne" detectors, but both these terms refer to the detection of signals of the same frequency and obviously do not apply when they are used as beat frequency detectors, as in the present case. Whilst not essential for the purpose, they are preferred because of special properties which are illustrated in Figs. 2 and 3. Fig. 2 shows one of the many forms of the phase sensitive detector that has been chosen for simplicity of illustration. Two diodes, A and B, are fed push-pull from the signal source, and push-push from a square-wave reference voltage derived from the transmitter. Fig. 3 shows that, choosing the received signal applied to A as the phase reference, when the signal and the square-wave reference voltage are in phase, charge is added to the high-frequency bypass capacitor connected to A and subtracted from that connected to B. An output voltage of one sign, say positive, is obtained. When the signal and reference waveform are in quadrature they do not change the charge on either capacitor, as they add and subtract for equal times. In anti-phase conditions, A now subtracts and B adds, resulting in a negative voltage equal to the positive "in-phase" voltage.

It is very simple to show that when the square-wave reference voltage E is big compared to the signal voltage e, the output bears a sinusoidal relation to relative phase in the way shown at the bottom of Fig. 3. It is clear, then, that if the phase detection process is carried out carefully the detected Doppler beats (the "Doppler note") will be sinusoidal.

Referring again to Fig. 1, as has been mentioned above, the square-wave reference source for the phase sensitive detectors is obtained from the transmitter. Phase sensitive detector 1 is fed in with in-phase reference oscillations (marked cosine), and phase sensitive detector 2 with quadrature phase retarded oscillations (marked sine). Beat note outputs are present at points D and E. That from phase sensitive detector 2 is quadrature phase retarded and acts

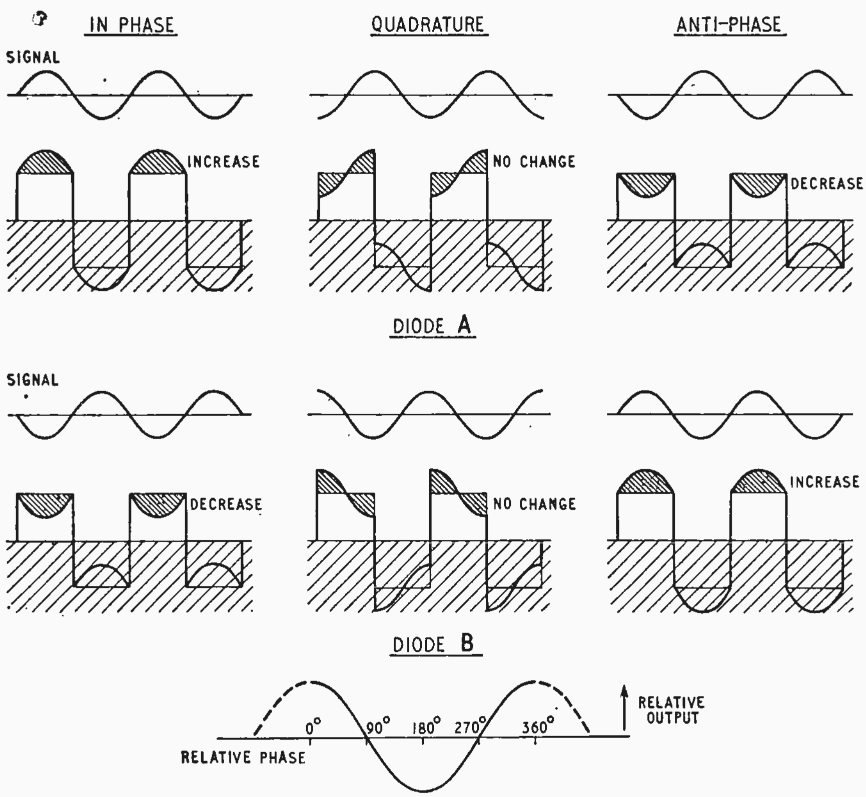
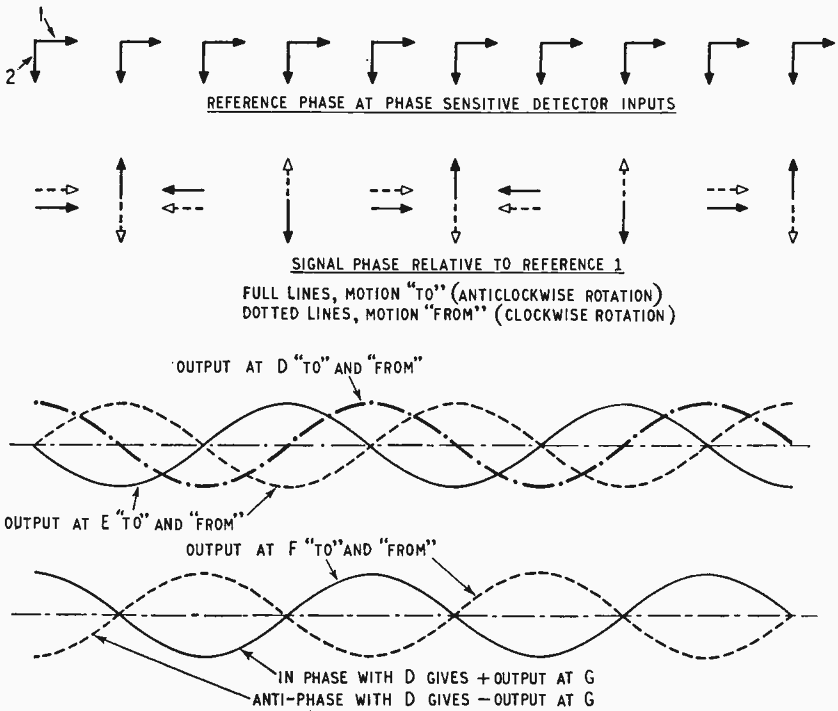


Fig. 3. Addition of the signal and reference waveform in Fig. 2 with different phase relationships. The lower shaded portions represent the non-conducting condition.

Fig. 4. Phase relationships of the signal and reference waveforms in Fig. 1.



as the reference oscillator to phase sensitive detector 3, the other input of which is fed from the cosine source, phase sensitive detector 1. Phase sensitive detector 3 has a d.c. output that changes in sign with the direction of motion of the reflector. By inserting limiting circuits and differentiating networks in the appropriate places, the amplitude of the output can be made proportional to the radial velocity. The radial velocity can, therefore, be displayed in convenient units as positive for one direction and negative for the other.

Fig. 4 shows how directional discrimination is carried out. Phases are indicated every 90°, starting from an instant at which the received signal at B in Fig. 1 is in phase with the cosine transmitter feed at A. All phases are referred to the last-mentioned. These relative phases define the envelope curve of the interfering high-frequency oscillations, and hence the beat note. Thus, when the signals are in phase with the reference oscillation, there is maximum beat note output from the phase sensitive detector, when in anti-phase this is reversed, and quadrature conditions give no beat frequency output. "To" signals are shown by full lines, producing anti-clockwise rotation of the relative phase vector, and "from" signals are shown by dotted lines with clockwise rotation. The amplitudes of the outputs of phase sensitive detectors 1 and 2 at D and E are obtained by comparing the relative phases of the signal inputs with the corresponding reference oscillations. It will be seen that they are in quadrature, and that the sine output reverses in phase with the direction of motion, whereas the cosine output does not. The result of subjecting the sine output to a 90° phase retardation is shown at the bottom of the diagram. It will be seen that it has pulled the beat note signals for "to" into phase with the output from D, whilst the "from" signals are thrown into anti-phase. The phase sensitive detector 3, in which comparison is made between the signals from D and F, cognizes this and a positive potential is registered at the output G for "to" signals, and a negative potential for "from" signals.

(To be concluded.)

BOOKS RECEIVED

Calculus for Electronics by A. E. Richmond. Working textbook, illustrated by upwards of 450 problems in electronics which can best be solved by the use of the calculus. Early chapters deal with basic functions and operations and lead to the use of Maclaurin, Taylor and Fourier series and the solution of differential equations. There is a useful appendix of tables of functions. Pp. 409; Figs. 146. Price 46s 6d. McGraw-Hill Publishing Co., Ltd., 59, Farringdon Street, London, E.C.4.

Pulse and Time-Base Generators by D. A. Levell, M.Sc., A.M.I.E.E. Concise survey, supported by an extensive bibliography, of linear and non-linear circuits, pulse modulators for radar, trigger circuits, electromagnetic time-bases and transistor circuits. Pp. 175; Figs. 166. Price 25s. Sir Isaac Pitman & Sons, Ltd., Parker Street, London, W.C.2.

An Approach to Audio Frequency Amplifier Design. Discussion of considerations leading to the design of seventeen amplifiers and pre-amplifiers for outputs from 5 to 1,100 watts which have been built and tested by the G.E.C. Valve and Electronics Department. Pp. 125; Figs. 75. Price 10s 6d. The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

The B.B.C. Colour Television Tests: An Appraisal of Results by W. N. Sproson, M.A., S. N. Watson, A.M.I.E.E., and M. Campbell, B.Sc.(Econ.). B.B.C. Engineering Monograph No. 18. Description of transmitting and receiving equipment used in field trials, and a statistical analysis of observers' reports. Pp. 39; Figs. 4 and 24 tables. Price 5s. B.B.C. Publications, 35, Marylebone High Street, London, W.1.

Hi Fi Year Book, 1958. Directory of pickups, amplifiers, radio tuners, microphones, tape recorders and loudspeakers with introductory articles by well-known authorities. A separate section is devoted to recent developments in stereo sound. Pp. 208; Figs. 340. Price 10s 6d. Miles Henslow Publications, Ltd., 99, Mortimer Street, London, W.1.

Tape Position Indicator

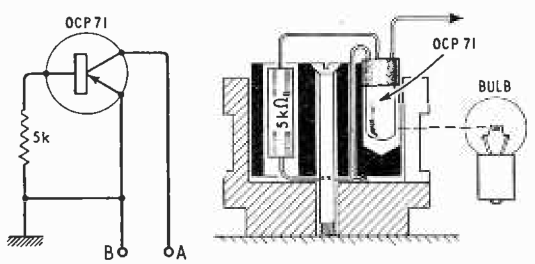
By B. H. PARKS

Light Operated Relay System Giving Accurate Location

THE need for a satisfactory device for accurate tape marking in domestic recorders was shown by correspondence* from readers of *Wireless World* following an editorial in August, 1955, and an article by Price and Frewer the previous April. Tape thickening, low frequency recording, and metallic contact have been used, there being advantages and disadvantages with each method. Most tape deck manufacturers fit some form of counter or clock-face indicator, this being usually operated from the take-up mechanism. This method is only approximate as the requirements of positive drive, i.e., independence of tape stretch or slip on the spool, are rarely met. Also it depends on correct zero resetting at the beginning of each tape. For stage sound effects, it must be possible to find the required place on the tape quickly and accurately. The device described here was designed for such stage use, and is accurate to within a few milliseconds irrespective of changes in the tape length or spooling. It can, if required, be used while fast winding or rewinding.

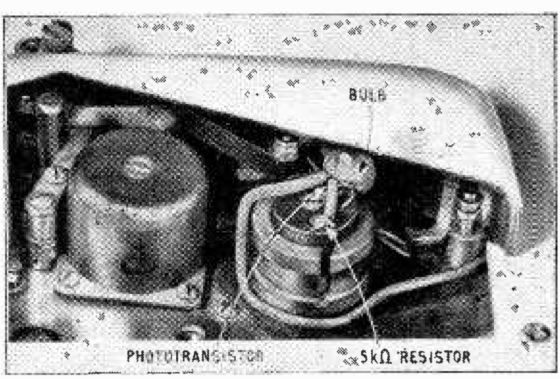
For use at playing speeds up to $7\frac{1}{2}$ in/sec, a required position on the tape is marked by removing a strip of the oxide coating about $\frac{1}{32}$in wide across half the width of the tape; a wider gap being required for higher speeds. A low power lamp and a phototransistor are mounted on the deck on opposite sides of the tape. The gap in the oxide coating allows sufficient light to pass to the phototransistor so that it bottoms (conducts fully), allowing a current of 4 to 5mA to pass to operate a relay. This can then be used to operate a lamp indicator; or a stepping switch to count the gaps and then stop the tape where required or mute the amplifier.

* September and October 1955, pp. 427, 497.



(a) (b)

Fig. 1. (a) Circuit of head unit. (b) Arrangement of head unit. Below: Mounting of head unit on tape deck.



Head Unit.—This consists of a 6.3V, 2W torch bulb on one side of the tape; and on the other side an OCP71 phototransistor and, for convenience, its associated 5kΩ resistor connected as in Fig. 1 (a). The bulb is underrun at 4V to prevent too much stray light reaching the phototransistor. On the Wearite deck which was used, the pressure arm of the automatic stop must be removed. This may readily be replaced if required, but, in any case, the present device performs the same function of stopping the deck at the end of the tape. The phototransistor is mounted with its connecting wires uppermost together with the 5KΩ resistor in a block of insulating material in the circular autostop tape guide. The sensitive area of the phototransistor is carefully positioned opposite the slot in the tape guide and behind the upper half of the tape, as shown in Fig. 1 (b) and the photograph.

The illuminating lamp was mounted under the front cover, directly opposite the slot in the tape guide but at least $\frac{1}{8}$in away from it to allow the tape to be dropped into place without hindrance. The lamp was connected through a 6Ω resistor to the existing 6.3V supply on the deck.

Associated Circuits.—Fig. 2 gives the circuit of a simple unit with lamp indication only; while Figs. 3(a) and 3(b) show the circuit and layout of a selector unit with 11 positions, neon lamp indicators, and facilities for stopping the tape or muting the amplifier at any of the 11 positions. Either unit can be operated from a −50V supply.

Either a relay or a transistor may be used for muting; but if a transistor gate (for example, see *Wireless World*, March, 1958, p. 109) is used, it should be applied to one of the later amplifier stages, or additional noise may be introduced.

Indicator Unit.—This is shown in Fig. 2. It con-

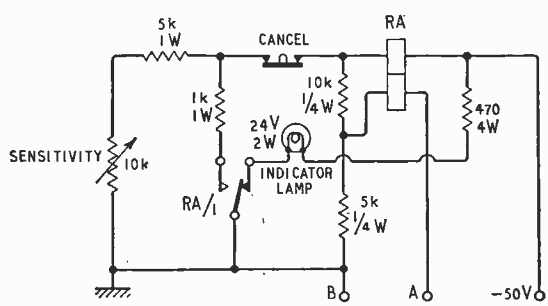


Fig. 2. Indicator unit.

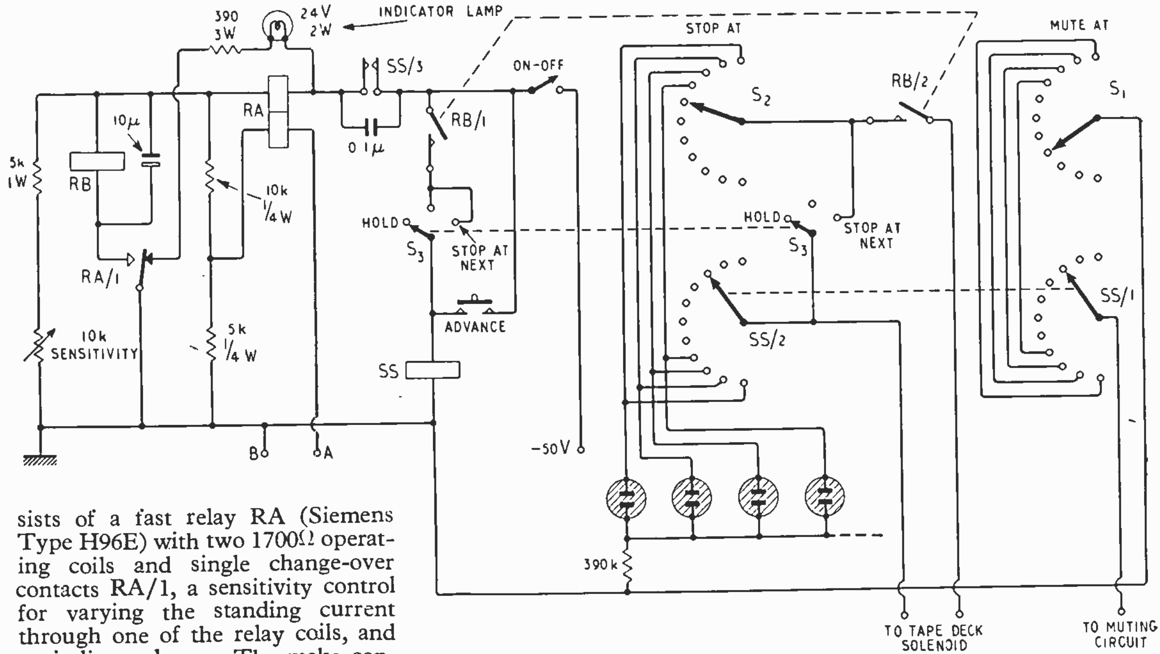
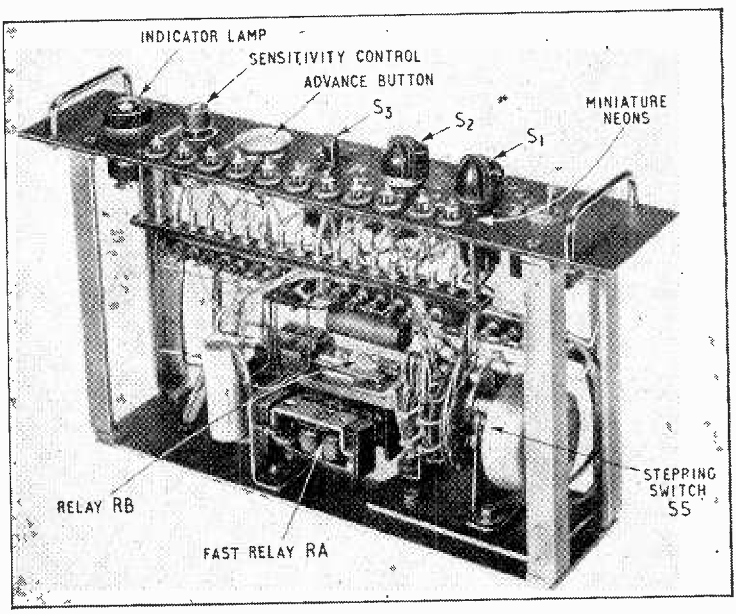


Fig. 3. (a) Circuit of selector unit. (b) Layout of selector unit.



sists of a fast relay RA (Siemens Type H96E) with two 1700Ω operating coils and single change-over contacts RA/1, a sensitivity control for varying the standing current through one of the relay coils, and an indicator lamp. The make contact is used to hold on the relay, and the break contact is used in the lamp circuit. Operation is signified by the lamp going out. It is necessary for the relay to hold on when it makes, otherwise it would operate so quickly as to escape observation. A push button to reset the relay is thus required.

An additional current of 4mA through both coils for approximately 20msec will operate the relay, the standing current of about 9mA through one coil being insufficient for this purpose. The circuit is arranged so that at no time can the potential across the transistor rise above 20V, nor can the current through it exceed 5mA. A point to note is that the sensitivity control cannot be directly in parallel with the transistor, as the current through this control would then fall almost to zero when the transistor bottomed, and nearly the full relay current would have to be carried by the transistor.

Selector Unit.—The circuit shown in Fig. 3 (a) is just one of many possible arrangements. It can be used for counting up to 11 positions at one time, and stopping the deck or muting the amplifier at any of these positions. For simplicity, connections for only 4 of the 11 positions are shown. The input circuit is the same as in the indicator unit, except that a second relay RB (Post Office Type 3000) is connected in the hold-on circuit of the first relay. This second relay has a 10μF capacitor across its single 2000Ω coil to hold it in sufficiently long to allow the deck solenoid to release when required. A slugged relay could equally well be used. This second relay has two pairs of heavy duty make contacts. One pair of contacts (RB/1) is used to operate a 50V N.S.F. stepping switch SS; the function of the second pair will be mentioned later. Each operation of this relay moves the stepping switch forward one position. This switch carries two wafers, each with 11 positions. One of these wafers (SS/1) is used with a manually set single pole 11-position switch S_1 to provide an earth contact for muting an amplifier. The other (SS/2) is used with another manually set 11-position switch S_2 for shorting the tape deck solenoid, and so stopping the tape transport mechanism. The h.t. voltage on the solenoid is used to illuminate one of 11 miniature neon lamps, so indicating the position of the stepping switch. To prevent the manual 11-way switch S_2 from illuminating the neon lamp corresponding to the position to which it is set, the second pair of contacts (RB/2) on the second relay keep this circuit open, except during operation. With this arrangement, the neon lamp on the position to which the manual stop switch is set lights momentarily at each operation. Resetting of the two relays is carried out by a pair of contacts SS/3 on the stepping switch which open each time it operates. An "advance" push button can be used to manually shift the stepping switch to any required position (without shorting the tape deck solenoid). A 2-pole 3-way switch (S_3) is provided to stop the deck at the next mark or to prevent the stepping switch from operating, the third position allowing normal operation as described previously.

On reaching the end of the tape, the phototransistor is continually illuminated, and the stepping switch moves round at intervals of about $\frac{3}{4}$ sec per step until it reaches the position at which the stop switch is set. The tape transport then stops, and a microswitch on the deck can be used to cut off the 50V power supply from the unit.

Sensitivity.—A gap of $\frac{1}{32}$in corresponds to just over 4msec at $7\frac{1}{2}$ in/sec, or over 8msec at $3\frac{3}{4}$ in/sec. This will cause the relay to operate at either speed. The gap is in "view" of the phototransistor for about $\frac{1}{8}$in of travel; or 17msec at $7\frac{1}{2}$ in/sec. The narrowness of the gap is not limited by the sensitivity of the instrument, but the difficulty of making a narrower gap.

For locating individual items in a tape at a full wind-on speed of about 800 feet per minute a gap approximately $\frac{1}{4}$in long is required. It may be possible to reduce this length by using narrow staggered or sloping gaps, but this has not been tried.

Removing the Oxide Coating.—This can usually be done using acetone on a small paint brush. However, with some tapes the backing is affected by acetone, so it is always best to initially test a sample of each make and type of tape. Where acetone softens the tape backing, it has always proved possible to remove the oxide with cellulose enamel thinner. Paper-backed tapes have not been tried.

It is advisable, where possible, to make gaps before recording, since they are then extremely difficult to detect. If gaps are made in a recorded tape without subsequent erasure, some oxide is always disturbed and causes a faint "tick."

Re-use of Tape.—When the tape comes to be re-used, the gaps cause no noticeable effect in the normal way. However for re-use with this device, the gaps must first be blacked out, and black enamel can be used for this purpose. The $\frac{1}{4}$in wide gaps should only be used with recordings of a permanent nature.

Microwave Valves

POINTERS FROM THE I.E.E. CONVENTION

THE great variety of methods now used to generate microwaves, and the big differences between these methods and those used in valves for lower frequencies were well exemplified in more than one hundred papers given at the Convention organized recently by the Institution of Electrical Engineers.

Parametric Amplifiers—This type of amplifier, which has recently been applied to microwaves, is based simply on varying the inductance or capacity in a tuned circuit, i.e., on varying a circuit parameter.

The tuned circuit is made resonant at the signal frequency, f_s say, and the capacity, say, is varied at another frequency known as the pump frequency, f_p say. For suitable phase differences between f_p and f_s, power at f_p is converted into power at f_s, and may be used to produce amplification or oscillation.

Parametric amplifiers have some similarities to modulators with gain such as magnetic or dielectric amplifiers. However, with these latter, the amplified power is obtained in the sidebands at $f_p \pm f_s$ rather than directly at f_s.

In one simple type of parametric amplifier, the tuned circuit capacity is increased when there is a signal voltage across it, and decreased when, twice every signal cycle, there is not. In the former case the energy stored in the capacity is increased; in the latter it remains unchanged. Thus the energy needed to vary the capacity is transferred to the signal circuit.

Since in this simple type of amplifier the capacity is decreased twice every signal cycle, the pump frequency f_p is twice the signal frequency f_s. If f_p is made slightly different from $2f_s$, it may be regarded as a frequency of $2f_s$ whose phase varies at $2\pi(f_p - 2f_s)$. This phase will then be correct for amplification for part of the time, and f_p need not be synchronized to f_s. (It is difficult to synchronize two different microwave frequencies.) This type of parametric amplifier gives the maximum gain for a given bandwidth (or *vice versa*).

Practical Microwave Parametric Amplifiers.—In the first of these, the precession (motion like a wobbling top) of the magnetic moment of spinning electrons in a ferrite about the direction of an external field was used to give variably inductive coupling between the pump circuit at 9 kMc/s and the signal circuit at 4.5 kMc/s.[1]

Such spin states have also been used in masers.[2] Unlike masers (microwave amplification by stimulated emission of radiation), parametric amplifiers are not restricted to use with atomic or molecular quantum energy levels. Other advantages of parametric amplifiers over masers are a much greater maximum output power, and the very small amounts of extra noise introduced by the amplifier even at normal temperatures. Low temperature operation is generally necessary with masers to secure long enough relaxation times.

The use of reversed bias p-n junction diodes as variable capacities in parametric amplifiers was discussed in a paper by Chang and Bloom, who used a pump frequency less than the signal frequency; and also by Uhlir, who reported operation up to 9000 Mc/s with noise figures from 1.0 to 1.5dB at room temperatures.

Capacitive or inductive coupling using modulated electron beams in cavities was discussed in a paper by Ashkin, Bridges, Louisell and Quate.[3] In such beams there are two space charge density waves at the signal frequency—one wave having a lesser and the other a greater velocity than the electrons themselves. The faster wave corresponds to electron energies greater than the d.c. energy of the beam, and the slower wave to electron energies less than the d.c. energy of the beam. Thus, where the only power source is the d.c. energy, as in conventional microwave valves, only the slower wave can be amplified. With the additional pump power source of parametric amplifiers, the faster wave can be amplified. In this case, the noise contributed by the beam is very much less, and a possible disadvantage of electron beam parametric amplifiers is avoided. In an experimental valve, the beam first passed through a cavity tuned to the f_p of 8300 Mc/s and into which pump power was fed, next through a cavity tuned to the f_s of 4,150 Mc/s and into which the input signal was fed, and then through a second suitably spaced cavity tuned to f_s from which the amplified signal output was obtained. The distance between the two cavities was different from that in a normal two-cavity klystron. In such a klystron this distance would correspond to a transit phase difference between the cavities of $(2n + 3/2)\pi$. Actually it corresponds to $(2n + 2)\pi$ or $(2n + 1)\pi$ for capacitive or inductive coupling respectively (n is any whole number). With inductive coupling, if the drift space is also short compared to the plasma wavelength, the noise currents in the two gaps are equal and opposite. These currents can then be cancelled out.

Several authors discussed the possibilities of increasing the at present narrow bandwidth of parametric amplifiers and masers by using long broadband structures embedded in material with a high density of effective electron spins and along which an electromagnetic travelling wave can be propagated. As is unfortunately often the case, increased bandwidth can only be obtained at the expense of decreased gain. Calculations suggest that, for useful gains in a reasonable length, the bandwidth can only be increased up to a few per cent of the centre frequency.

Doppler Effect Frequency Multiplier—In the type discussed by R-Shersby-Harvie[4], the input signal at the fundamental frequency f is propagated in the opposite direction to a beam of electrons bunched at a frequency f_o. A signal at a frequency of $nf_o + f$ (where n is a whole number) and travelling in the same direction as the beam can then be induced if the velocity of the electrons is suitable. This velocity must be chosen so that, due to the Doppler effect, to the electron the fundamental and induced signals have the same frequency. These signals can then interact through the electrons.

In microwave valves, interaction is usually with electromagnetic waves travelling much slower than the velocity of light. Such waves, which are known as slow waves, can only be propagated in special slow-wave structures such as the helix. If the operating frequency is increased, such structures must be decreased in size. They are then more difficult to make, and also cannot dissipate so much power.

In this use of the Doppler effect, for frequency multiplication by up to about ten both signals can travel fast enough to propagate in ordinary smooth-walled waveguides, and no slow-wave structures are necessary. The electrons' kinetic energy can also be less than the rest energy.

M-J Valve—This modification of the M-type valve was described by Johnson and Birdsall. The best known example of an ordinary M-valve is the magnetron. In M-valves the electrons move mainly at right angles to and under the influence of both electrostatic and magnetic fields which are at right angles to each other. The electrons also drift in the direction of the electrostatic field from the negative cathode to the positive anode or collector, i.e. at right angles to their main motion. The anode is usually also made the slow-wave structure, and the electron motion is confined to one plane by end plates.

In the M-J valve the electrodes are rotated through 90° about the main direction of electron motion, the electrostatic and magnetic fields being left unchanged. The electrons then go to an electrode separate from the slow-wave structure. Power dissipation problems in small slow-wave structures at high frequencies are thus avoided. The use of j to denote 90° rotation explains the choice of name (for which the authors apologized!).

The electron motion in M-J valves is in three directions at right angles instead of two as in M-valves. M-J valves should give a higher gain than M-valves without any reduction in efficiency.

E-type valves[5]—A Russian paper by Tchernov reported recent developments. In such valves, the electrons describe circular or spiral orbits, the centrifugal force being balanced by a radial electrostatic field. The first variety was called a magnet-less magnetron.

In the Russian anti-klystron, the electrons move inside a hollow ring describing spiral orbits about a circular electrode placed centrally inside the ring. The electrons can interact with an electromagnetic wave travelling at right angles to the plane of the ring and passing through its centre. The operating frequency is fixed only by the rotational velocity of the electrons, and the electromagnetic wave can be synchronized with a harmonic of this velocity. Slow-wave structures may thus not be necessary, and operation at very short wavelengths should be easy.

Travelling-wave Klystron Amplifier—A new variety was described by Heathcote, Lindsay, Barraclough and Newby[6]. Here the electrons can interact with fast waves in smooth-walled waveguides because they travel at right angles to these waves. The input and output signals travel one in each of two parallel waveguides. Ideally, the electrons should form a sheet beam passing first through the input and next through the output waveguide through slits along the guide lengths[7]. In practice, however, it has proved difficult to produce satisfactorily focused sheet beams in these conditions.

In the authors' modification, the sheet beam is replaced by a number of separate cylindrical beams passing through the guides in the same direction as the sheet. The waveguides are also periodically loaded with inductive irises placed across their widths midway between each beam and its two neighbours. While this loading increases the power output and efficiency, it reduces the bandwidth to about 10%. This valve is similar to a number of two-cavity klystrons connected in parallel side by side, the cavities being joined to form the two waveguides.

REFERENCES

1 H. Suhl, *Phys. Rev.*, April 1957, p. 384, and M. T. Weiss, *Phys. Rev.*, July 1957, p. 317.

2 See for example *Wireless World*, May 1957, p. 212, or J. P. Wittke, *Proc. I.R.E.*, March 1957, p. 291.

3 See also T. J. Bridges, *Proc. I.R.E.*, Feb. 1958, p. 494, and W. H. Louisell and C. F. Quate, *Proc. I.R.E.*, April 1958, p. 707.

4 I.E.E. Paper No. R2646.

5 See for example A. Versnel and J. L. H. Jonker, *Philips Research Reports*, Vol. 9, Dec. 1954, p. 458, and H. Heffner and D. A. Watkins, *Proc. I.R.E.*, Vol. 43, Aug. 1955, p. 1008.

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7 T. G. Mihran, *Proc. I.R.E.*, Vol. 40, March 1952, p. 308.

The "Cathoguard"

By L. G. WHITE

Wideband Amplifier of Improved Rise Time

DESIGNING wide-band pulse amplifiers is a problem which revolves round the types of valves currently available. The only circuit improvements which have increased the ratio of bandwidth to gain are the use of suitable filter sections to reduce the effects of stray capacitances and the application of small amounts of voltage negative feedback.

The design of filter sections for pulse amplifiers is limited by the overshoot which occurs if the full bandwidth for the steady sine wave condition is used. Most pulse amplifiers use simple series peaking as being the best compromise. The more involved filters are more difficult to adjust and are very dependent on valve capacitances for their performance. By using voltage negative feedback some improvement can be made but the delay time of the amplifier itself prevents more than a small gain in performance. It is useless to apply large amounts of negative feedback because it does not act until the signal has reached the output of the amplifier, by which time it is too late to apply feedback to the leading edge of the pulse! This results in overshoot of the leading edge of the pulse and little improvement in the rise time. To reduce this undesirable effect to a minimum an individual feedback loop is connected round each amplifier stage. Speaking generally, negative feedback gives little improvement in the pulse rise time.

TABLE I

Inter-electrode Capacitances for EF91
EF91 with normal holder (valve cold)
g_1 to all others 9.5 pF
a to all others 3.5 pF
Using a three terminal bridge (Wayne Kerr B 221)
a to all others g_3 neutralized 1.3 pF
g_1 to all others g_2 neutralized 7pF
g_1 to g_3, all others neutralized 1 pF

TABLE II

Inter-electrode Capacitances for EF80
EF80 with normal holder (valve cold)
g_1 to all others 9 pF
a to all others 5.5 pF
a to all others g_3 neutralized 4 pF
g_1 to all others g_2 neutralized 3 pF
g_3 and a to g_1 all others neutralized 0.15 pF

With the above points in mind, work was started to find some other means of improving amplifier pulse rise time. As the valve capacitances seemed to be the limiting factor, measurements were made on an EF91 valve to find how the capacitances were made up. Table I gives the results.

This shows that 2.2 pF of the output capacitance is due to the suppressor grid and 2.5 pF of the input capacitance to the screen grid. The output capacitance would be very much reduced if the suppressor grid were driven from a generator giving it the same potential as the anode. There would be no voltage difference between the electrodes, therefore no energy would be stored in the capacitance. This is, in effect, similar to the use of "guard-ring" measuring techniques. A suitable circuit to put into practice this capacitance removing effect is shown in Fig. 1.

The normal amplifying stage (V1) feeds a cathode follower (V2). The output could be taken in the normal way from the anode of V1, but as the cathode follower gives a lower output impedance it is better to take it from the cathode of V2.

The suppressor grid base of V1 is about 35V for a 10% drop in mutual conductance so the feedback voltage will have little effect on the normal operation of V1. However, it will "remove" nearly all the anode to suppressor grid capacitances.

Further Improvements

As it stands, the circuit has several disadvantages—the most important is the Miller capacitance due to the 1 pF control grid to suppressor grid and anode capacitance of V1 and the grid to anode capacitance of V2. The control grid to anode capacitance can be effectively removed in V2 by the circuit of Fig. 2. The screen-grid of V2 is now at nearly the same a.c. potential as V2 control grid—so removing, in effect, the input capacitance The Miller capacitance due to the 1 pF control grid to suppressor grid and anode of V1 can be overcome by using a valve in which

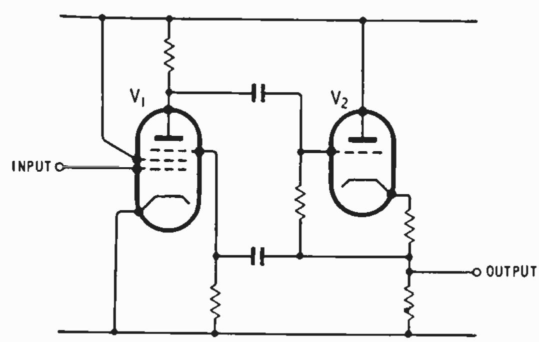


Fig. 1. Reducing effective output capacitance.

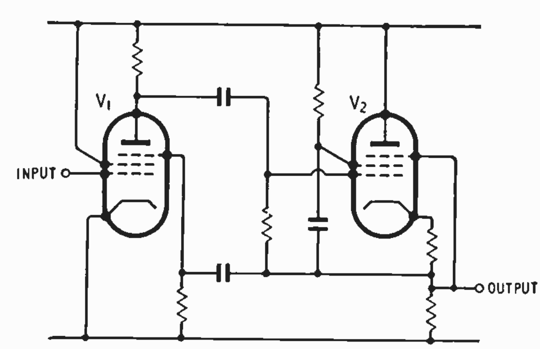


Fig. 2. Reducing input capacitance of cathode follower.

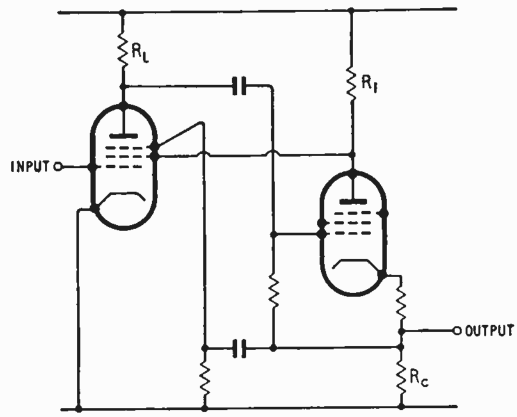


Fig. 3. Another modification reduces V1 input capacitance and produces the "Cathoguard".

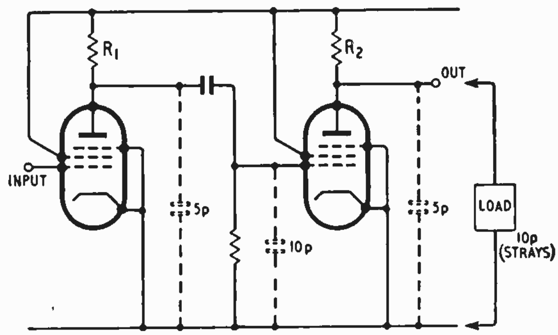


Fig. 4. Skeleton circuit of a conventional pulse amplifier.

the internal screen is not connected to the suppressor grid. The EF80 was found to be a more suitable valve and Table II gives the capacitances measured.

The anode and suppressor grid to control grid capacitance is now only 0.15 pF and the Miller effect is no longer important. The rest of the output capacitance is to the internal screen—no doubt other valves are available which would give better screening of the anode by the suppressor grid.

The circuit of Fig. 2 can still further be improved by feeding the screen grid of V1 with a voltage of the same phase and amplitude as that on the control grid. This will effectively remove the control grid to screen grid capacitance. Fig. 3 shows a simple way of doing this.

The value of R_1, the cathode follower anode load, to give the correct voltage is approximately:—

$$\frac{10R_c}{9g_m\,R_L}$$

where R_a is in kΩ, R_c and R_1 in identical units. In a typical case where $g_m = 10$mA/V, $R_a = 10$KΩ, $R_c = 1000\Omega$, $R_1 \simeq 11\Omega$.

From the economic point of view it looks at first sight as if no improvement is obtained in the "Cathoguard" which could not be obtained from two conventional stages of amplification in cascade. To compare the two systems the example of a typical two-valve amplifier is taken and gain/bandwidth product is determined (Fig. 4).

Considering one stage in Fig. 4, for a response -1.5dB at 10Mc/s, $fCR^* = 100$

$$C = 15\text{pF}, f = 10\text{Mc/s}$$
$$\therefore R_1 = 0.66\text{k}\Omega$$

The nearest standard value is 680Ω.

$\therefore R_1 = R_2 = 680\Omega$ for a response 3dB down at 10Mc/s.

$$\text{Voltage gain (A)} = g_m R_L,$$
$$g_m = 10\text{mA/V}, R_L = 680\Omega$$
$$\therefore A = 6.8 \text{ per stage}$$
$$\text{i.e. stage gain} \simeq 17\text{dB}$$

Thus over the complete amplifier gain is 34dB; 3dB down at 10Mc/s, falling at 12dB/octave. For a standing anode current of 8mA the output amplitude is limited to roughly seven or eight volts, peak-to-peak.

*W. T. Cocking, "Television Receiving Equipment", (Iliffe) 4th Edition, page 213, Fig. 15. 3.

Comparing the "Cathoguard" of Fig. 3 with 5 pF stray capacity across R_a for 3dB down at 01Mc/s, R_a can be increased to 3kΩ and the gain becomes 30dB for a g_m of 10. This compares very favourably with Fig. 4 gain of 34dB. But the "Cathoguard" only falls off at 6dB/octave, until the cathode follower fails, which need not occur until the frequency is raised to about 30Mc/s.

The main advantages of the "Cathoguard" are:—

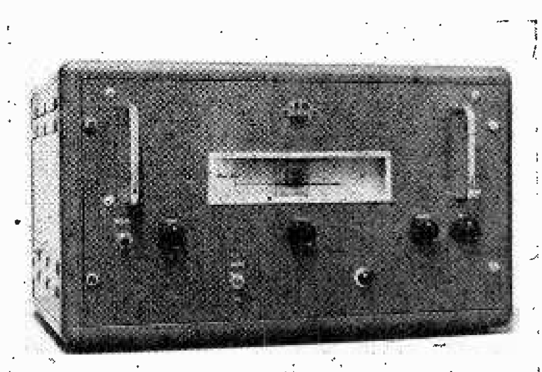
(1) The input capacitance is reduced.

(2) The output impedance is lower (on pulse rise time only).

(3) Due to the response dropping at only 6dB per octave, pulse rise time is improved without increasing the frequency of the 3dB-down point.

(4) Voltage negative feedback could be used to improve gain stability, due to the good phase response. Negative feedback is not of much use on the circuit shown in Fig. 4.

Even with valves available at present the "Cathoguard" would seem to be an improvement on the normal pulse amplifier, and with special valves and valveholders very much improved pulse amplifiers could be built. The ideal valve would have a screen round both the control grid and anode. Both screens would be brought out to separate pins and the valveholder would continue this screening.



Combined v.h.f./f.m. tuner, gramophone and microphone pre-amplifier and 25-watt amplifier designed for factory entertainment and announcements. Units with other power outputs from 6 to 100 watts are available, and the amplifiers (with pre-amplifiers) may also be obtained separately. The makers are Hadley Telephone and Sound Systems, Ltd., 72, Cape Hill, Smethwick, Staffs.

WORLD OF WIRELESS

Electronic Forum for Industry

IN an endeavour to provide a clearing-house for the exchange of information as a step towards co-ordinating technical committee work, research, development and application of data processing techniques in industry, nine industrial organizations have formed what is to be known as the Electronic Forum for Industry (E.F.F.I.).

It is also hoped it will provide a channel for the presentation of the British industry's point of view in international discussions concerned with electronic automation and computation.

Organizations taking part, so far, in addition to the Electronic Engineering Association (formerly R.C.E.E.A.), who were the conveners, are:—

British Radio and Electronic Manufacturers' Association.
British Radio Valve Manufacturers' Association.
Machine Tool Traders' Association.
Office Appliance and Business Equipment Trades Association.
Radio and Electronic Component Manufacturers' Federation.
Society of British Aircraft Constructors.
Scientific Instrument Manufacturers' Association.
Telecommunication Engineering and Manufacturing Association.

C. Metcalfe, chairman of the Data Processing Section of E.E.A., who presided at the first meeting said, "The E.F.F.I. will not assume the work or responsibilities of the individual associations, nor will there be any impingement on the work of the professional institutions. The Forum will be a co-ordinating body to help to guide industry through the growing complexity of electronics."

The E.E.A. is acting as secretariat for the Forum.

Tax on Reconditioned C.R. Tubes

TO help to clarify the intentions of H.M. Customs and Excise to levy purchase tax on certain types of reconditioned television tubes the following has been issued:—

"Under the law Purchase Tax becomes due on all goods of a class chargeable with tax when they are sold or appropriated by a registered or registrable person under taxable conditions. The fact that the goods may be reconditioned goods does not affect the position. As a concession, however, the Commissioners do not require tax to be paid on secondhand goods even if they are sold or appropriated under taxable conditions provided that the goods have been subjected to no more than minor repairs and are kept segregated from new goods both physically and in the trader's accounts.

"The general position in respect of reconditioned cathode-ray tubes is as follows:—

(1) Where only a *minor* reconditioning process has been carried out (i.e., where the tube has only been treated externally) the concession referred to above is applicable.

(2) A registered or registrable person carrying out *extensive* reconditioning work (i.e., work involving the opening of the tube) incurs liability to payment of tax where—

(a) the work is such as to amount to the manufacture of a virtually fresh tube (e.g., where the original electron gun is replaced by a fresh, not necessarily new, gun); or

(b) the tube is sold or appropriated under taxable conditions.

"If the processor does not ensure that a tube sent to him by a customer for extensive reconditioning is returned to that same customer, the transaction is a sale and tax liability is incurred under (b) above, whether or not liability is incurred under (a).

(3) A registered or registrable person having his own tubes extensively reconditioned by another person incurs liability to payment of tax when the tubes are sold or appropriated under taxable conditions.

"A person becomes registrable when his gross takings from sales of chargeable goods which he has manufactured (including virtually fresh cathode-ray tubes) and/or sales by wholesale of extensively reconditioned tubes and other chargeable goods exceed or are likely to exceed £500 a year, on average. Any person who becomes liable to registration is under legal obligation to apply for registration through his local Officer of Customs and Excise within 14 days."

From section 2(a) it seems clear that if the original gun is reconditioned and replaced in the same tube there will be no liability to purchase tax provided that the transaction does not in other respects amount to "sale or appropriation under taxable conditions."

Birthday Honours

SOME well-known names in the world of wireless appear in the Queen's Birthday Honours List.

Dr. Willis Jackson, Metropolitan-Vickers' director of research and education since 1953, who for some years before that occupied the chair of electrical engineering at Imperial College, London, is appointed a Knight Bachelor.

Among those appointed Commanders of the Order of the British Empire are P. A. T. Bevan, chief engineer of I.T.A., who was for 20 years with the B.B.C. and was on the editorial advisory board of our sister journal *Electronic & Radio Engineer;* and E. K. Cole, chairman and managing director of Ekco.

Appointments of O.B.E.s include W. T. Ash, secretary of the Radio and Electronic Component Manufacturers' Federation; Wing Cdr. R. C. Lawes, senior overseas liaison officer, International Aeradio; and D. S. Watson, senior principal scientific officer, Admiralty Signal and Radar Establishment.

H. V. Griffiths, engineer-in-charge of the B.B.C.'s Tatsfield Receiving Station, is appointed M.B.E.

Computer Exhibition

ALL available space at the Electronic Computer Exhibition to be held in the National Hall, Olympia, London, from November 28th to December 4th, has been taken by the forty-five firms exhibiting. During the exhibition, of which H.R.H. The Duke of Edinburgh is patron, a symposium on computer applications and operation will be held.

The exhibition and business computer symposium are being organised, at the instigation of the National Research Development Corporation, by the Electronic Engineering Association and the Office Appliance and Business Equipment Trades Association. The exhibition organizer is Mrs. S. S. Elliot (O.A.B.E.T.A., 11-13, Dowgate Hill, London, E.C.4). Immediately preceding the exhibition there is to be an associated scientific symposium organized by the National Physical Laboratory at Teddington, Middlesex, from November 24th to 27th.

Radio in the U.S.

FACTS and figures from the annual report of the Federal Communications Commission of America, quoted by *Electronic News*, show that about 1.25M fixed and mobile transmitters are in use in the U.S.A. For every broadcasting transmitter in operation there are about 50 other transmitters in use.

About a quarter of the fixed and mobile stations are for land transport, including 105,500 for taxis and 51,300 for railways. Another 25% are for industrial mobile radio and some 20% for public safety services—police, fire, etc.

There are approximately 3,300 a.m. broadcasting stations, some 800 television stations and over 700 f.m. transmitters. For the first time for nine years the number of f.m. stations has increased.

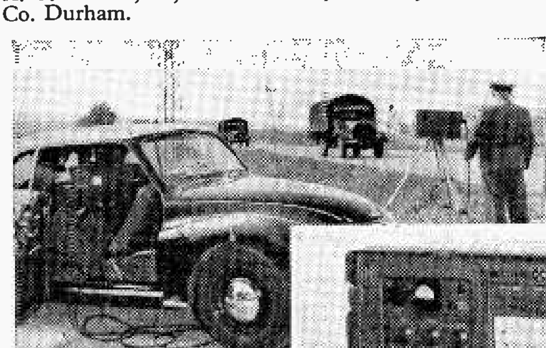
Over 90% of the population is within the service area of at least one TV transmitter and about 80% of all American homes now have a television set. Of the 44.5M sets in use, the Report states that 160,000 are colour receivers. Some 250 stations are equipped to transmit colour.

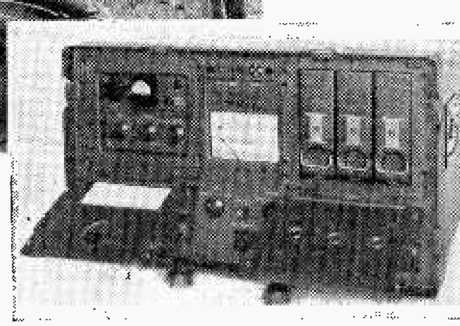
U.H.F. Mobile Radio.—What is understood to be the first British equipment for u.h.f. mobile radio to receive the P.M.G.'s approval has been designed by Elliot Brothers (London), Ltd., for operation in the 460-470 Mc/s band.

East-Anglian TV station at Tacolneston, near Norwich, which has been working on reduced power since its opening in 1956 to avoid interference with the Belgian station at Liège, is now operating on full power. The Liège transmitter, which shares the same channel, is now using a higher power transmitter. Tacolneston's directional aerial gives an e.r.p. of 1.3 to 15kW depending upon direction.

Manchester Electronics Show.—The 13th annual exhibition and convention organized by the Institution of Electronics will be held at the Manchester College of Science and Technology from July 10th-16th (excluding Sunday). Some 75 manufacturers, including some from abroad, will be exhibiting and there will also be displays by a number of scientific and industrial research organizations. Complimentary admission tickets for the exhibition and convention are obtainable from W. Birtwistle, 78, Shaw Road, Rochdale, Lancs., from whom the catalogue (price 2s 9d) is also obtainable.

Radio-Controlled Models.—The annual contest for radio-controlled model boats organized by the International Radio Controlled Models Society will be held on August 3rd and 4th, on the Model Yacht Pond, East Park, Kingston upon Hull. Particulars of the contest, which is open to non-members, are obtainable from A. S. Wilson, 14, Biddick Lane, Fatfield, Washington, Co. Durham.





GERMAN POLICE RADAR
Extensive tests of Telefunken radar speed measuring equipment are being carried out by the Hamburg and Frankfurt traffic control police with a view to its use not only for speed limit enforcement but also for statistical purposes. The linear speed scale is calibrated in km/hour and an overall accuracy of ± 3% is claimed. There is provision for recording, in conjunction with an automatic camera, the speed and identity of any vehicle which exceeds a given limit.

Two new laboratories were officially opened at the Royal Radar Establishment, Malvern, by the Minister of Supply on May 27th. One of the labs is devoted to research work on the physics of solids and the other houses the greater part of the guided weapons department of the establishment.

I.E.E. annual report for 1957/58 records that of its 43,231 members, 5,765 are members of the Radio and Telecommunication Section. This section held more meetings (24) during the year ended in March than any of the other three specialized sections, and the average attendance at its London meetings was 237.

British Computer Society.—The first annual report of the society records a membership of 1,300 at the end of April. During the year eight regional branches have been formed. The society recently moved to Finsbury Court, Finsbury Pavement, London, E.C.2. (Tel.: Monarch 6252.)

I.F.A.C.—The constitution of the International Federation of Automatic Control, founded in Paris last September, has now been ratified by organizations in 12 countries. The Federation plans to hold its first congress for automatic control in Moscow from June 25th-July 5th, 1960. The address of the I.F.A.C. secretariat is c/o Verein Deutscher Ingenieure, 79 Prinz-Georg-Strasse, Dusseldorf, Germany.

Control Engineering.—A readership in control engineering has been established at the Battersea College of Technology, London. The first lecturer to be appointed is N. Ream who, prior to joining the engineering staff of the college, was in the control section of the National Physical Laboratory. At McGill University, Montreal, a chair of control engineering has been instituted.

University Scholarships.—The first 20 university scholarships have been awarded for 1958 under the scheme established by the English Electric Co. earlier this year to provide professional training for young men likely to attain senior engineering positions. Each scholarship is worth £450 a year for three years.

War Office Civilian Studentships.—A studentship scheme sponsored by the Ministry of Supply on behalf of all the government departments employing scientists gives to a limited number of young men who intend to enter the Scientific Civil Service a university education in science or engineering at the Royal Military College of Science, Shrivenham. Six civilian studentships tenable for three years have recently been awarded. Students are prepared for the London University B.Sc. degree.

High-Quality Reproduction.—A series of lectures on high-quality sound reproduction is being given by P. Collings-Wells, technical manager of Goodmans, at their Wembley works. Particulars of forthcoming lectures are obtainable from Goodmans Industries, Ltd., Axiom Works, Wembley, Middlesex.

Broadcast receiving licences current in the U.K. at the end of April totalled 14,621,275. Combined television and sound licences increased by 57,330, bringing the total to 8,147,333. Sound-only licences numbered 6,473,942, including 336,519 for car radio.

Amateurs' Emergency Work.—The clause in the Amateur (Sound) Licence prohibiting British amateurs sending messages for a third party was amended in 1956 to permit the passing of messages for the British Red Cross Society and the St. John's Ambulance Brigade "during disaster relief operations." At the request of the Home Office, the P.M.G. has now amended the wording to cover the passing of messages for the Police.

Personalities

S. E. Goodall, M.Sc.(Eng.), chief engineer of W. T. Henley's Telegraph Works Company, is the new president of the I.E.E. He has been a vice-president since 1953. Mr. Goodall represents the Institution on a number of national committees including the Board of Studies (Engineering) of the National Council for Technological Awards.

Sir Hamish D. MacLaren, K.B.E., C.B., D.F.C., LL.D., B.Sc., director of electrical engineering in the Admiralty since 1945, is elected a vice-president of the I.E.E. for a second period of three years. Sir Hamish was for two years with the B.T.H. Company before joining the staff of the Admiralty in 1926 as assistant electrical engineer at the Chatham and Devonport Dockyards. He was at one time superintending electrical engineer of the Singapore naval base.

A. H. Mumford, O.B.E., B.Sc.(Eng.), deputy engineer-in-chief of the Post Office, has been elected a vice-president of the I.E.E., He was chairman of the I.E.E. radio section in 1945/46. Mr. Mumford joined the Post Office engineering department in 1924 and after a short period at headquarters went to the Dollis Hill research station. He took charge of the radio branch in 1938.

L. W. Brown, B.Sc., Ph.D., M.I.E.E., F.Inst.P., has been appointed assistant chief electrical engineer (light current) of Metropolitan-Vickers, in addition to his present duties as chief engineer of the company's electronics department. Educated at King's College, London, where he obtained his B.Sc. and Ph.D. working under Sir Edward Appleton on ionospheric research, he entered the Royal Air Force in 1939, and was engaged on the operational development of airborne interception by radar. In 1940 he joined T.R.E., and at Rugby collaborated in the development of centimetric radar. Three years later Dr. Brown went to the B.T.H. Company, where he continued the development of airborne, ground and marine radar equipment. He joined Metropolitan-Vickers in 1950 as chief engineer of the radio department, and since 1955 has been chief engineer of the electronics department. This department covers work on particle accelerators, digital and analogue computers, electronic railway signalling equipment and equipments for missiles.

Dr. L. W. BROWN

Sebastian Z. de Ferranti has succeeded his father, Sir Vincent de Ferranti, as managing director of Ferranti, Ltd. Sir Vincent remains chairman of the company.

A. E. Falkus, B.Sc.(Eng.), M.I.E.E., has left the Plessey Company, where for the past eight years he has been chief loudspeaker designer, and, together with **D. A. Newbold,** has formed Fane Acoustics, Ltd. (See "News from the Industry"). Mr. Falkus was at one time chief engineer of Reproducers & Amplifiers, Ltd., of Wolverhampton. Mr. Newbold was until recently technical director of Richard Allan Radio, Ltd., of which he was one of the founders.

J. Bell, B.Sc., F.Inst.P., has been appointed manager of the G.E.C. research laboratories at Wembley. He has been manager of the telecommunications division of the laboratories since its formation in 1953, and will retain the leadership of this work in addition to assuming the administration of the group of establishments. The responsibility for the laboratories' scientific policy and programmes will remain with the present director of research, **O. W. Humphreys,** C.B.E., B.Sc., F.Inst.P., who is also director of the company's applied electronics laboratories at Stanmore. Mr. Bell joined the G.E.C. in 1929, and his work has been largely in the field of radio and radar transmitting valves.

J. BELL

GRP. CAPT. L. R. RIDLEY

Grp. Capt. L. R. Ridley, O.B.E., assistant director, electronics research and development at the Ministry of Supply for the past four years, has retired from the R.A.F. and has joined Masteradio and its subsidiary R.M. Electrics. He has assumed responsibility for the company's radar and electronics division. Grp. Capt. Ridley worked under Sir Robert Watson-Watt in the pre-war development of radar and was responsible for maintaining the radar network in the S.E. sector during the Battle of Britain. Masteradio, which is a member of the Francis Sumner group of companies, was concerned with the war-time development of the original Eureka Mk. 1 and Rebecca Mk. 1 radar beacons.

Capt. G. J. A. Lumsden, D.S.C., R.N. (Retd.), has joined Decca Radar to lead a new sales division for naval shipborne radar, coast defence radar and harbour surveillance equipment. Capt. Lumsden was a specialist in navigation in the Royal Navy and has been closely associated with air defence, surface warning and navigational radar systems for many years.

Bernard Greenhead, appointed technical controller of A.B.C. Television, the television programme contractors for the Midlands and the North, started his television career as development engineer with E.M.I. where he worked on the development of the B.B.C.'s original television system. For two years he was with the B.B.C. prior to joining High Definition Films in 1953 as technical controller of the Highbury studios. Two years ago he joined Alpha Television Services—TV programme producers—as chief engineer, and subsequently became general manager.

J. W. Dick, who has been appointed representative in Singapore by the Marconi Marine Company, was for some time instructor at the Glasgow Wireless College before joining the company's sea-going staff. In 1950 he transferred to the shore staff and has been at the Liverpool depot.

Hilary F. C. Williams, whose appointment with Andec, Ltd., we mentioned last month, was assistant chief engineer of Racal Engineering, and not, as was inadvertently stated, chief engineer.

M. Minton is resigning on June 30th his position as chief development engineer of Cosmocord, which he has held for three years, to become chief engineer with the Dulci Company. Prior to joining Cosmocord he was for 16 years with the Air Ministry and Ministry of Supply engaged on the development of navigational aids.

M. MINTON

J. H. R. Manners, B.Sc., deputy head of the Brimar valve application department of Standard Telephones and Cables at Footscray for the past five years, has joined Masteradio as chief development engineer. For seven years before joining S.T.C. he was with Felgate Radio.

R. G. Friend, B.Sc., M.A., F.Inst.P., has been appointed director of electronics research and development (telecommunications) in the Ministry of Supply in succession to **Brigadier J. D. Haigh,** O.B.E., who has retired. When Brigadier Haigh was appointed in 1954 there were only two directorates of electronics research and development—air and defence—now there are three, ground, air and telecommunications. Mr. Friend has been assistant director since 1954. Before the war he was at the Air Defence Experimental Establishment, Biggin Hill.

F. C. Brooker, A.M.I.E.E., has been appointed by the B.B.C., engineer-in-charge, London (sound), in succession to **C. E. Bottle,** M.B.E., who has retired after 34 years' service with the corporation. Mr. Brooker joined the B.B.C. in 1935, and in 1941 became an instructor in the engineering training department, where he remained until 1948. During this period, he wrote the B.B.C.'s first engineering training manual.

Gordon F. Wylde has joined Benjamin Electric, Ltd., as assistant manager of the radio department. He was for five years at T.R.E. (now R.R.E.) and three years at the Royal Aircraft Establishment, Farnborough. He then joined E.M.I. Engineering Development as components liaison engineer, and for the past three years has been with McMurdo Instrument Company.

N. MacKinlay, B.Sc., who joined Richard Allan Radio, of Batley, Yorks., last year, has been appointed chief engineer. After graduating in natural philosophy and mathematics at the University of Glasgow in 1945, he joined the Royal Naval Scientific Service and was engaged in research in underwater acoustics.

OUR AUTHORS

N. M. Rust, the first part of whose article on the Doppler effect appears in this issue, was for many years in Marconi's research department until his retirement in 1955. During the war he was working for the Admiralty on micro-wave radar and was associated with the development of metal lens and f.m. and Doppler radar. Joining Marconi's in 1913 he was posted to Clifden transatlantic station as receiving engineer, and seconded to the R.N.V.R. for interception work during World War I. Mr. Rust was concerned with a number of propagation investigations and worked with Capt. H. J. Round on the development of oscillating crystal detectors, microphones for broadcasting and also steel tape magnetic recording equipment for the B.B.C.

L. G. White, who contributes an article on the "Cathoguard" in this issue, joined Wayne Kerr Laboratories as an apprentice in 1948. After completing his apprenticeship he spent some time on the design of transformer ratio arm bridges and latterly was working on the application of measuring bridges in industrial control. He recently left Wayne Kerr and is now an electronic design engineer with Marconi Instruments at St. Albans.

OBITUARY

Sir Louis Sterling, D.Litt., who died on June 2nd at the age of 79, had served on the boards of a number of companies in the radio and gramophone industries. Rising from humble beginnings in the gramophone trade he became managing director of the Columbia Graphophone Company and subsequently of E.M.I. He resigned from E.M.I. in 1939 and joined the board of Cossor, becoming chairman in 1941. He left the company in 1943. At the time of his death he was a director of RCA (Great Britain). Sir Louis, who was knighted in 1937, served on the council of Brit.I.R.E. for some years and was president in 1943/44.

G. C. Cunningham, O.B.E., joint managing director and a founder director of Racal Engineering, Ltd., of Bracknell, Berks., died on May 16th. During the war he was in the Royal Air Force, serving mainly in Canada where, as deputy chief signals officer with the rank of Wing Commander, he was associated with the formation of the North Atlantic Ferry Command. In 1945 he was appointed signals controller of B.O.A.C. having been on the staff of Imperial Airways before the war. For a short while in the late 1940s Mr. Cunningham was with Plessey's as communications sales manager.

News from the Industry

Air Surveillance Radar.—Decca have produced a 3-cm long-range air-surveillance radar which, by utilizing two scanners back-to-back and at slightly different angles, gives an unbroken coverage up to a height of 40,000 ft. and to a distance of about 120 miles. Each scanner is fed from an 800-kW transmitter and both linear and circular polarization are provided. The first order for the equipment (D.A.S.R.1) has been placed by the Swedish Board of Civil Aviation for sets to be installed next year at the air terminal at Stockholm and the airport at Gothenburg.

Welwyn Electrical Laboratories, Ltd., held an open day at their works in Bedlington, Northumberland, at the end of May to celebrate the 21st anniversary of their establishment in Welwyn Garden City, Herts. The company manufactures something like 5,000 different types of resistor with about 30 per cent of the output going into sound and television equipment and the remainder to industrial, engineering and military equipment.

Silicon Production.—A new technique for the production of hyper-pure silicon, originally developed by Standard Telecommunication Laboratories and employed commercially by Standard Telephones & Cables at their Harlow works, is to be used under licence in America and Canada by the Du Pont Company. The process, which involves the thermal conversion of silane gas into silicon, enables silicon of the highest purity to be produced.

Relay Exchanges, Ltd., and its subsidiaries, which include the receiver renting companies Rentaset, had a trading profit of £1.6M in 1957 compared with £1.4M in 1956 and £0.97M in 1955.

Aero Research, Ltd., of Duxford, Cambridge, which is affiliated to the Swiss CIBA organization, is changing its name to CIBA (A.R.L.), Ltd. Formed in 1934 for research into aircraft structures, its activities have been centred mainly on the development of synthetic resin adhesives. The trade names, such as, "Aerolite," "Araldite" and "Redux" will remain unchanged.

G. & E. Bradley, Ltd., who recently completed their move from Alperton, Middx., to Electral House, Neasden Lane, London, N.W.10 (Tel.: Gladstone 0012), announce that K. Jones, formerly a director and general manager of British Communications Corporation, has joined the board. L. E. White, formerly general manager has also become a director, and is succeeded by L. H. Weall, lately with the Plessey Company.

A. Prince Industrial Products, Ltd., importers and distributors of West German domestic equipment, including Blue Spot, Akkord, Uher and Dual, have been acquired by Camp Bird Limited. John Dalgleish, chairman of the Camp Bird group, which includes Hartley-Baird, Ambassador, E-V, Duratube & Wire, and Electronic Reproducers, is now chairman of the company. Dr. Andrew Prince continues as managing director.

Atkins, Robertson & Whiteford, Ltd., of Thornliebank, Glasgow, announce their association with A. F. Stoddard & Co., Ltd., carpet manufacturers. Sir Robert A. Maclean, chairman and managing director of Stoddards, has been elected chairman of Atkins, Robertson & Whiteford, Ltd., who will continue to manufacture transformers and electronic instruments.

Audio-plan is the name of a new company formed to take over the retail sales distribution and demonstration facilities of B. K. Partners, Ltd., who will deal exclusively with the trade. The address of both companies is 229, Regent Street, London, W.1. (Tel.: Regent 7363.)

Dynatron Radio, Ltd., have recently taken occupation of their new factory and offices at St. Peter's Road, Furze Platt, Maidenhead, Berks. (Tel.: Maidenhead 5151.)

C. T. Chapman (Reproducers), Ltd., have moved their sales office from Chelsea to the works at Chapel Lane, High Wycombe, Bucks. (Tel.: High Wycombe 2474.)

Arthur's, the well-known retailers, have moved from 150, Charing Cross Road, to 125, Tottenham Court Road, London, W.1. The business, founded by Arthur Gray, has been in Charing Cross Road since the early 1920s.

The Keyswitch Company, manufacturers of relays and keyswitches, have moved to Irongate Wharf Road, Praed Street, London, W.2. (Tel.: Paddington 2231.)

Roberts' Radio.—The telephone number of Roberts' Radio, of East Molesey, Surrey, has been changed to Molesey 7474.

Racal Engineering, Ltd., of Bracknell, Berkshire, have been appointed exclusive agents in the United Kingdom for the sale of Transitron equipment manufactured by Van Norman Industries Inc., of Manchester, New Hampshire, U.S.A. Included in the Transitron range are v.h.f. and u.h.f. signal and sweep generators.

Fane Acoustics, Ltd., of Batley, Yorks., (Tel.: Batley 1578), has been formed by A. E. Falkus and D. A. Newbold for the manufacture of high-fidelity loudspeakers, etc. They have the manufacturing rights of the "Quartet" four-speaker combination.

EXPORTS

S.H.F. radio links capable of providing up to 600 telephone circuits are being supplied by Standard Telephones & Cables for the telephone service in Malaya. The main link between Singapore and Kuala Lumpur will employ four unattended repeater stations (5-watt) and there will be several spurs from the main route.

Telecommunications equipment, including the battery-operated radio-telephone "country set" for linking isolated localities to the telephone network, and Hivac subminiature valves were shown by the Automatic Telephone & Electric Company at the recent Poznan International Trade Fair. For the second successive year the company also exhibited at the Washington show of the Armed Forces Communications and Electronics Association.

Two mobile demonstration units equipped with industrial and marine gear manufactured by Kelvin & Hughes are touring Europe. Both units were at the Poznan Fair and the larger—a 9½-ton articulated vehicle carrying the industrial equipment—is making a four-month tour of Hungary, Czechoslovakia, Rumania and Yugoslavia. The smaller unit, equipped with marine gear, is visiting Polish, West German and Belgian ports.

Air traffic control consoles for installation at seven airports in the Belgian Congo have been ordered from International Aeradio Ltd.

British Electronic Centre.—Seven companies participated in the composite exhibition in the British Electronic Centre at the Hannover Fair. They were Ardente, British Electric Resistance Co., Geo. Bray, Cosmocord, E.M.I. Electronics, Gresham-Lion Group, and Painton.

U.S.A. Visit.—R. E. Burnett, general manager of Marconi Instruments Ltd., and S. G. Spooner, production manager of the company, left London on June 5th for a three weeks' tour of the U.S.A.

Uganda.—Electronics Ltd., P.O. Box 1869, Kampala, are interested in representing U.K. manufacturers of loudspeakers and microphones and tape recorders specially designed for operating from a 12-V or 6-V battery.

Transmitter for the new Jordan broadcasting station being built in Amman is to be supplied by Marconi's. The 100-kW m.w. station is due to open early next year.

Radar Control Room.—Marconi's have supplied three complete radar installations for the new Royal Aircraft Establishment at Bedford. In this view of the control room the two operators in the centre are at the control positions of the two 10-cm sets providing high and low long-range coverage and the operator on the right is controlling the 50-cm general surveillance radar.

By
H. B. DENT

Measuring Decimetric Wavelengths

Use of Resonant Lines for Calibrating an Absorption Wavemeter Covering 450 to 750Mc/s

RECENTLY the need arose to calibrate a simple absorption wavemeter for use over a frequency band of 450 to 750Mc/s, the primary purpose being to have available an unambiguous measurement of frequency in the region of 650Mc/s. The available literature contains plenty of data on the precise measurement of frequencies on u.h.f. and microwaves, but little or nothing could be found on how to achieve only a modest order of accuracy. By modest order of accuracy the writer has in mind an accuracy of one or two per cent.

There were two main reasons why only a modest order of accuracy was the target. In the first place the wavemeter is a simple "coil and condenser" type, the "condenser" admittedly being a u.h.f.

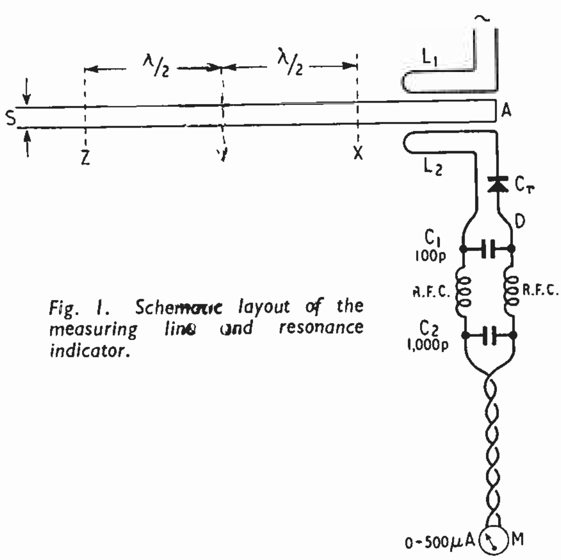


Fig. 1. Schematic layout of the measuring line and resonance indicator.

split-stator 10+10pF type, while the coil is a strip of copper 1.5in long bridging the two banks of fixed vanes. More details of the wavemeter will be given later. Secondly, the drive is an epicyclic type with a 6 to 1 reduction and a direct-reading scale of 1.75in radius is fitted, so that both tuning and reading facilities render calibration accuracy better than one or two per cent not only unnecessary but unusable.

No precision equipment was available for calibration purposes, and although a few single-frequency, crystal-controlled oscillators up to 150Mc/s could be pressed into service, initial attempts to calibrate the wavemeter with an uncalibrated variable oscillator, and relying on harmonics of the crystal-controlled oscillators to fix the frequency produced some most exciting, but utterly unrealistic, calibration curves.

The unreliability of these curves was evident from the basic fact that the ratio of the maximum and minimum frequencies covered cannot possibly be greater than the square root of the ratio of the maximum and minimum capacitances of the tuning capacitor. With a 10+10pF capacitor and with each section having a nominal minimum capacitance of 3pF the capacitance ratio, used as a split-stator component, is 5/1.5 or 3.33 to 1 and the frequency ratio cannot be greater than 1.8 to 1, while in practice it is somewhat smaller. This basic fact serves as a clue if one goes off the rails during calibration and this can quite easily happen when relying on harmonics from fixed frequency oscillators to identify the frequency.

Whilst we have come to think almost exclusively in terms of frequency in recent years a few decades ago it was the wavelength rather than the frequency one spoke about and with the utilization of the u.h.f.s for television and communications, as well as for radar, it may be more convenient once again to think in terms of wavelength. For example 10,000Mc/s, or 10kMc/s, is an unwieldy way of indicating a wavelength of 3cm. The practice of referring to microwaves in terms of centimetres or millimetres is quite common now among radar people so that many "old timers" may find themselves once again on familiar ground, or will they?

Frequency is based on a time scale while wavelength is a linear measure and provided means can be found to identify precisely two consecutive and exactly similar points on a train of waves, such as a maximum or minimum amplitude of voltage or current, then it only remains to measure this distance, preferably in metres, to find the wavelength. Standing waves on a Lecher wire system provide this condition.

If the waves are propagated in air, or by such means that the velocity of propagation is the same as in air, then knowing the wavelength it is quite easy to find the frequency, if one wants it. The relationship as everyone knows is:—

$$v = \lambda f, \text{ or } f = \frac{v}{\lambda}$$

where v=velocity of propagation in air, f=frequency, λ=wavelength.

Taking v as 3×10^8 metres a second (the same as light), if λ is in metres then f is in cycles per second. These are too unwieldy quantities to cope with when the wavelengths concerned are decimetric (and these are the only variety that can conveniently be measured with a rule), so that it is better to take v as 3×10^4 and λ in centimetres when f becomes megacycles.

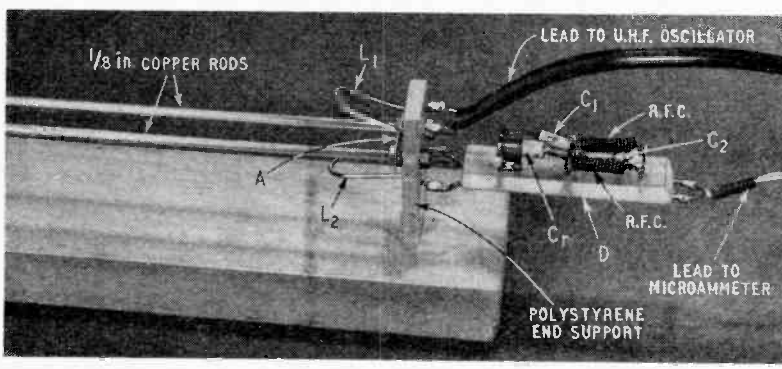
Fortunately it is easier to measure centimetric wavelengths than one might suppose provided the accuracy required is not too high. With apparatus that any keen amateur v.h.f. and u.h.f. worker can acquire reasonably cheaply an accuracy of about 1% to 1.5% in measuring wavelength is possible.

There are several ways of making the measurements but the writer favours a transmission-line method with apparatus laid out as shown in Fig. 1. Here two rigid parallel lines are laid out on a board which for the purpose in hand (450 to 750Mc/s calibration) need not be more than 4ft 6in long. The lines are made of $\frac{1}{8}$in diameter copper rod perfectly straight and free of kinks of any kind. They are supported at intervals of about 9in on polystyrene insulators made from $\frac{1}{4}$in thick sheet and fabricated as shown in Fig. 2. This illustration shows also the method of mounting the insulators on the board and the position of the two $\frac{1}{8}$in copper rods. The part cut away in the centre of the insulator is to leave as little as possible solid dielectric between the two rods as any quantity of this will affect the velocity of propagation of the waves on the transmission line. As it is, there is certain to be some disturbance of the velocity but with insulators fabricated as in Fig. 2 it is a minimum of the transmission line remain rigid and equispaced throughout their length while the shorting bar is moved along them, otherwise the accuracy of the measurements will suffer.

One end of the line is left open, as shown in Fig. 1, while the other end is short-circuited as shown at A and coupled to it are two loops, L_1 and L_2, both about $1\frac{1}{4}$in long and made of No. 16 s.w.g. copper wire. One loop is mounted above the line and the other below and spaced about $\frac{1}{2}$in from it. Both the size of these loops and their coupling to the line must be adjusted to suit the particular apparatus available.

Oscillations from an uncalibrated oscillator are injected into the line via loop L_1 and a detector, D, for indicating resonance and consisting of a crystal diode, C_r, an r.f. filter and leads to a microammeter, is joined to loop L_2. A disposal plug-type radar silicon crystal diode was used for C_r but the GEX66 would no doubt be satisfactory as it is suitable for use at u.h.f. The r.f. chokes consist of 8in of No. 20 s.w.g. enamelled copper wire wound on a $\frac{1}{8}$-in diameter mandrel with turns spaced to occupy $\frac{3}{4}$in. The mandrel is removed of course, the chokes being self-supporting.

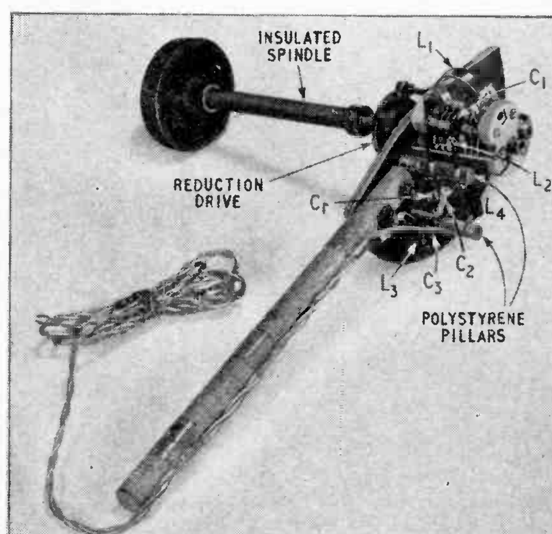
It is essential to work with the loosest possible coupling between loop L_1 and the line and between the loop terminating the end of the lead remote from L_1 and which is coupled to the oscillator,



Left:—View of the transmission line used for measuring wavelength. Note the arrangement of the two loops L_1 and L_2 and the indicator D (Fig. 1).

and does not appear to noticeably affect the measurements of wavelength.

The rods are cradled in semi-circular indentations filed in the top of the polystyrene supports and are held in position by drilling a hole through the copper rod and down into the insulator as shown in Fig. 3. The hole in the copper rod is a "tight fit" for No. 18 s.w.g. copper wire, but the hole in the polystyrene is slightly undersize. The hole in the copper is countersunk on the top face and the wire soldered in position. By inserting the end of the wire in a slightly enlarged guide to the hole in the polystyrene and applying the soldering iron to the top of the copper rod over the hole the wire will slowly sink into the polystyrene and when cold will be firmly sealed in the hole. Excess solder should be trimmed off the top face of the rod and the surface rubbed smooth and polished with very fine emery cloth. If the copper rods are perfectly straight and free of kinks it may be found that they need securing, as described and shown in Fig. 3, at every other insulator only. It is absolutely essential that the two rods



Below:—Rear view of the wavemeter showing the arrangement of the indicator A (Fig. 5).

otherwise the varying loading on the oscillator caused by movement of the shorting bar along the line will affect the frequency and thus the accuracy of the measurements. Incidentally the shorting bar used consisted of a $2\frac{1}{2}$-in length of No. 14 s.w.g. copper wire inserted into the end of a 4-in length of $\frac{1}{2}$-in diameter insulated rod.

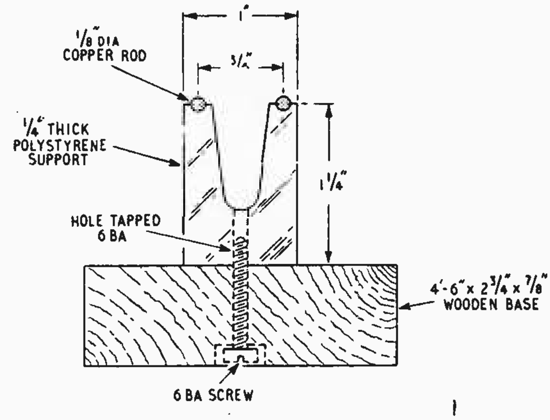
The principle of this measuring equipment is based on the fact that with standing waves on a transmission line short-circuited at one end as shown at A Fig. 1, the voltage, or current, waveform is sinusoidal reaching a maximum value and falling to a minimum value at intervals of a quarter wavelength. Thus voltage (or current) maxima will appear at intervals of a physical half wavelength if the line is wholly or mainly supported by air. A section can be said to be resonant if its physical length is any multiple of a half wavelength, thus it can be $\lambda/2$, λ, $3\lambda/2$ and so on. It behaves as a high-Q circuit so that at resonance a detector, such as D, Fig. 1, will indicate considerable r.f. voltage on the line. Quite a loose coupling suffices between the loop L_2 and the line for a working reading on the meter M. As most of the point-contact, radar-type silicon crystal diodes are easily damaged by excessive d.c. the current measured by M should never be allowed to exceed about 1.5mA. A good working level is 250μA.

Owing to the presence of the coupling loops L_1 and L_2, and the influence exerted by the external equipment connected to them, the distance measured between A and X (Fig. 1), the first position of the shorting bar indicating line resonance, is not a reliable measure of wavelength and it is necessary to move the shorting bar to the next position (Y in this case) and measure the distance X-Y. The writer gums a strip of paper along the baseboard supporting the line and marks the positions of the shorting bar on it. While the distance between X and Y will be an acceptable measurement of the wavelength, the writer prefers to take a further measurement by moving the shorting bar to the next maximum, i.e. Z, and averaging the distances X-Y-Z, or the distance X-Z can be taken as one whole wavelength.

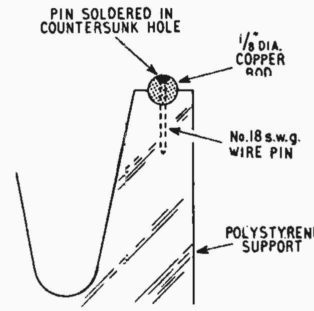
Checks with the crystal-controlled oscillators, which become possible once a reliable calibration is achieved, show that with a line spacing of $\frac{3}{8}$in the spacing cannot be ignored in the measurement of wavelength where the highest accuracy possible with this method of measurement is desired. The presence of the supporting insulators also affect the measurements slightly and it was found that half the line spacing (centre-to-centre) added to the distances X-Y or Y-Z gives quite close agreement.

Having found a simple way of measuring wavelength it now only remains to find a way of storing the information in a convenient form for practical use. This is where the absorption wavemeter comes in and for which purpose it was designed.

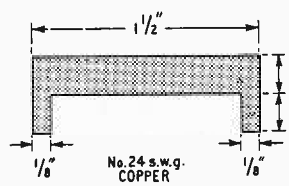
As previously stated it consists of a 10+10pF split-stator capacitor (Jackson Bros. Type C808) with a copper strip cut as shown in Fig. 4 bent into a semicircle and soldered across the two banks of fixed vanes. The small lugs at each end are to enable the strip to be soldered to both of the soldering tags provided for each set of fixed vanes. Diagramatically the measuring part of the wavemeter consists of C_1L_1 in Fig. 5. A scale, a pointer and a slow-motion drive are included, also an indicator



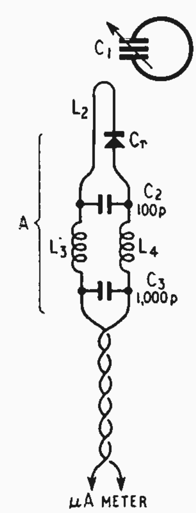
Above:—Fig. 2. Details of the insulating supports for the line and method of fixing them to the baseboard.



Right:—Fig. 3. Methods of securing the rods of the line to the insulating supports.



Above:—Fig. 4. Details of the copper strip "coil" for the absorption wavemeter.



Right:—Fig. 5. Schematic arrangement of the u.h.f. absorption wavemeter.

which can be arranged as shown at A, and which consists of a crystal diode, C_r, an r.f. filter, $C_2C_3L_3L_4$, and a pair of leads to a microammeter, exactly similar to the indicator used on the line in Fig. 1. A 0-500μA meter was used as it happened to be available, but any sensitive meter from 200μA to 1mA full scale deflection will serve. In the present case the diode C_r is a point-contact germanium type of unknown origin but the GEX66 would be quite suitable, while an alternative would be one of the radar-type crystal diodes. There are a few American plug variety radar diodes (1N21A or similar) obtainable at some surplus equipment stores and these are ideal for use on the u.h.f. bands.

The indicator portion of the wavemeter is not

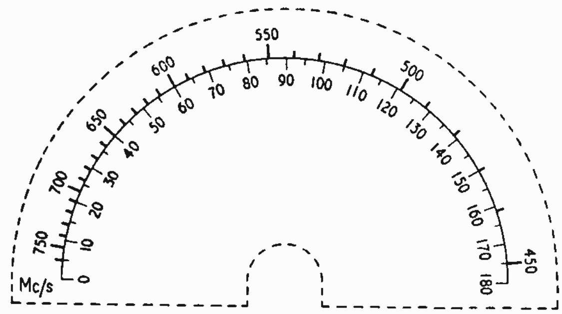


Fig. 6. The calibrated scale on the u.h.f. absorption wavemeter. The 0-180° scale can be pencilled in and rubbed out after the frequency scale is added.

required for calibrating the wavemeter as the equivalent indicator in the transmission line assembly is used for this purpose. The procedure is as follows. After locating the nodal points, indicated by X, Y and Z respectively in Fig. 1, the shorting bar is left in position at Y or Z (Fig. 1) so that the meter M is reading a maximum for the particular set-up; about 250 to 300μA as previously stated is a convenient reading. If now the "coil" of the wavemeter, L_1 in Fig. 5, is brought to within 4in or 6in of the line the needle of the meter will dip sharply when the wavemeter (L_1C_1) is tuned to the wavelength of the line. The point on the 180° wavemeter scale (described later) is recorded and the procedure repeated until ten or a dozen readings have been taken. It is very important to obtain reference points at each end of the wavemeter scale, as shown in the calibration curve Fig. 7 at 8° and 170° respectively. The wavelength measurements have here been converted to frequency.

The design of this wavemeter is a little unusual but it has been used before by the writer[1] and found to be a very convenient style. An indicator of resonance was not embodied in the earlier wavemeters as crystal diodes were unknown at that period. Another refinement embodied in the present version is the addition of a 6 to 1 reduction drive; the earlier models did not have this. Although the expression "ultra shorts" was employed in 1935 the actual wavelengths covered then were ten times longer than the present ones (*circa* 5 metres instead of 50cms), and a slow-motion drive was not found necessary.

The pointer is fixed to the epicyclic drive (Jackson Bros. Ball Drive) by drilling and tapping the slow-motion hub 6BA and inserting a 1⅜-in length of brass rod which is tapped at one end and secured by a nut. The free end of this rod is shaped, by filing, into a pointer.

The scale is drawn on thick cartridge paper which, before calibrating the wavemeter, is stuck on the semicircular wooden base of the wavemeter by "Durofix" or other suitable adhesive. Initially only the 0-180° scale shown in Fig. 6 can be drawn in and, if preferred, this scale marked in pencil so that it can be rubbed out when the final calibration is transferred to the scale.

[1] "Measuring the Ultra Shorts", *Wireless World* July 12th, 1935, p.28.

Calibrating the wavemeter by means of a degree scale, drawing a curve on graph paper then transferring the measurements from the curve to the upper part of the wavemeter scale (Fig. 6) may seem a roundabout way of doing the job, but a little thought will show that it is the only way of providing a rational scale as shown in Fig. 6. It also ensures that any errors in measuring the wavelength are brought to light and either discarded or further measurements made. There are always liable to be slight errors in measurement but if reasonable care is exercised a "good fit" curve will pass through almost all the points plotted on the chart. This is seen to be the case in Fig. 7 where only one point falls wide of the curve, e.g. at 137° on the scale; something apparently went astray here and it exemplifies the advantages of the procedure outlined.

It is quite within the bounds of possibility that if a wavemeter is assembled using the same type of capacitor employed here and the "coil" cut exactly to size so that exactly 1¼in of the strip is free of the capacitor lugs, the calibration curve in Fig. 7, and the transferred calibration in Fig. 6, would be sufficiently accurate for many amateur requirements. The C808 capacitor has wide-spaced vanes, the airgaps are 0.045in, and modern production methods are sufficiently precise to ensure that the capacitances of different specimens taken at random will be in close agreement.

U.H.F. Oscillator

Nothing has been said about the u.h.f. oscillator as this is a subject not capable of being discussed adequately here. There was an article recently[2] giving details of a u.h.f. oscillator and while this is more ambitious and gives far more output power than needed here, it serves as a guide to the type of oscillator that can be used.

The writer used a single triode, an obsolete

[2] "Double Tetrode Oscillator" by J. H. Andreae and P. L. Joyce, *Wireless World* April 1958, p173.

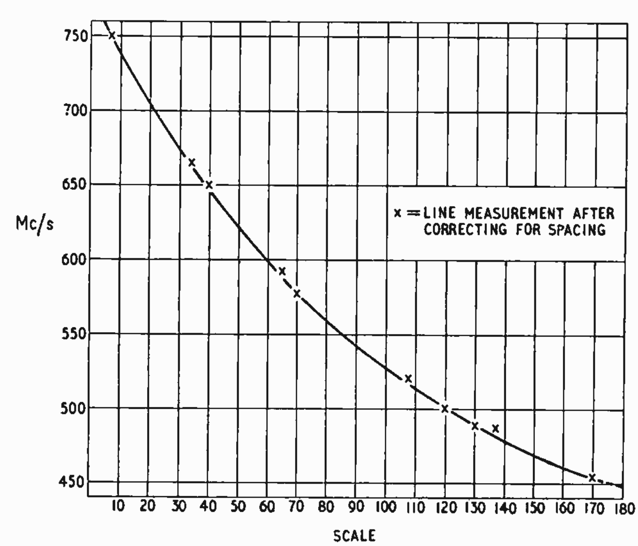


Fig. 7. Calibration curve of the u.h.f. absorption wavemeter after applying correction for spacing of the measuring line.

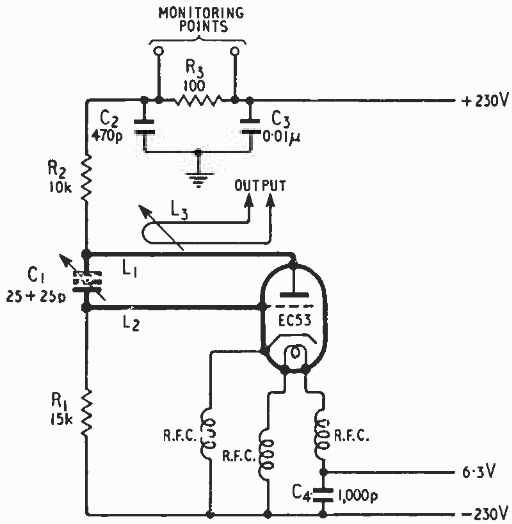


Fig. 8. Circuit of one of the u.h.f. oscillators used for the measurements.

EC53, which has anode and grid connections brought to two pins on top of the miniature glass envelope. A Colpitts-type circuit, as shown in Fig. 8, is used with the lines L_1L_2 made of $\frac{1}{8}$-in copper tube and spaced the same distance as the anode and grid pins on the valve. The valve ends of these tubes are drilled and tapped 8BA and the pins are inserted into the ends and secured by 8BA screws passing through the side of the tubes. The far end (the tubes are 2in long for the middle part of Band V) terminate at a split-stator capacitor C_1 of about 25+25pF and are soldered directly to the banks of fixed vanes.

This tuning system would not serve, even with L_1L_2 reduced to less than 1in, for the higher part of the band, but after some experiment oscillation on a spot frequency was obtained at 750Mc/s by replacing L_1 and L_2 by two copper clamps ($\frac{1}{2}$-in lengths of $\frac{1}{8}$-in diameter tube with 8BA fixing screws for grid and anode pins) across which is connected a 3-pF disc-type ceramic capacitor. The anode feed and grid-leak resistors are soldered direct to their respective copper clamps. As this is a direct short circuit, via the 3-pF capacitor across anode and grid pins of the valve it represents the highest frequency obtainable with this valve. As might be expected the r.f. output was very small at 750Mc/s, but nevertheless sufficient to give a usable reading on the line indicator. There are far more suitable triodes now available as oscillators up to 1,000Mc/s. One is the M.O.V. A2521, another the Brimar 6AF4A and a third the EC93, but the writer has not yet had an opportunity to try any of these valves in the measuring set described here.

Measuring TV Aerial Performance

On page 294 in the June 1958 issue equation 8 was given incorrectly; it should read:—

$$Z_i = \frac{Z_o (Z + Z_o \tanh Px)}{Z_o + Z \tanh Px}$$

Telecommunications at Gatwick Airport

GATWICK Airport—recently reopened—has much new telecommunications equipment. Two radars (which both provide moving target indication) are installed, feeding identical display units in front of each controller. The Marconi S232 is a 50cm radar and the Cossor ACR6 is a 10cm system using circular polarization to combat rain clutter. An artificially-generated video-map of the environs of the airfield is available to aid controllers on the "approach to land" phase. Instrument landing and precision approach radar facilities are also available.

A multichannel recorder (British Communications Corporation) registers the seven v.h.f. ground-to-air channels on a $\frac{1}{2}$in wide tape. Eight hours of recording is possible before the 4,800ft spool needs changing.

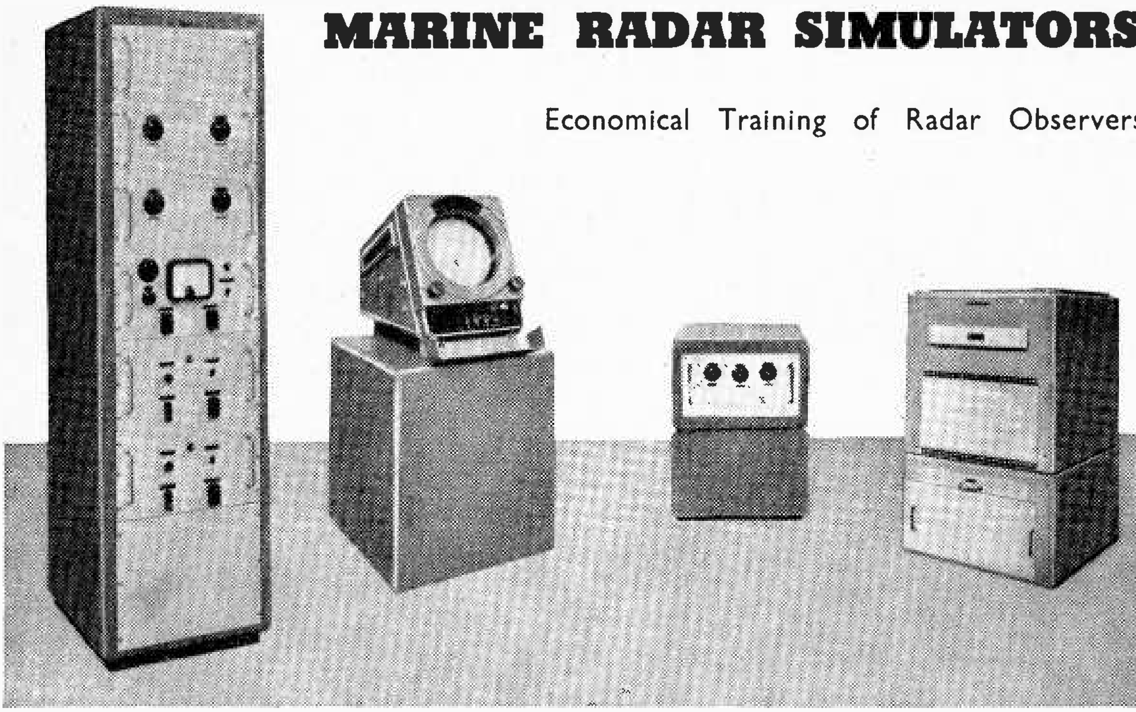
Semi-automatic teleprinter message handling is another new item. Incoming messages are stored on a magnetic drum during switching operations and until an operator is available. As soon as the operator sees the message address he presses a button automatically routing the message to its destination. The mechanism by which this is achieved is known as STRAD—Signal Transmitting, Receiving And Distribution system.

Smaller Colour TV Receiver

A colour receiver comparable in size with an existing 21-in monochrome set has been achieved by a programme of continuous circuit development at the G.E.C. Research Laboratories. It works on British N.T.S.C. type signals and uses 35 valves with a 21-in shadow-mask c.r. tube. The power pack is based on a.c./d.c. technique, with a series heater chain and a voltage doubler for the 450-V h.t. line. Seen here with the receiver are some of the members of the team responsible for its development: (left to right) E. Ribchester, P. Carnt, Dr. J. Biggs and R. Harman.

MARINE RADAR SIMULATORS

Economical Training of Radar Observers



Redifon C819 simulator. Left to right: "Other-ship" computer rack; Decca display; "own-ship" control and computer unit, and video-map generator.

"UNLESS observed by a fully trained operator, the world's best radar set is as useless to a mariner or airman as yesterday's weather report."* We would interpret that as meaning—radar can be the eyes of a ship in the hands of an operator who knows what radar can do, and, what is vastly more important, what it cannot do. Experience is essential, but experience unsupported by sound fundamental concepts is worse than useless; in fact, a man who does not understand fully the limitations of radar endangers not only his own ship; but he may put others in hazard also.

Recently the Ministry of Transport and Civil Aviation announced that for promotion to second mate (foreign-going) or mate (home waters), officers of the Mercantile Marine must possess a Certificate of Proficiency as Radar Observer to be gained by undergoing successfully two weeks' training in the use of radar.

This immediately raised a problem—how was the training to be carried out? Practical training at sea under a qualified instructor can be dismissed mainly because the number of students would be strictly limited, the cost would be too great and the students could not be allowed to learn by making mistakes.

A small, inexpensive and versatile simulator could provide the answer, and two such simulators have been developed recently by Redifon and Ultra.

Redifon C819 Radar Navigation Trainer.—This equipment consists of four units—a rack containing the computing mechanisms for producing the "other ships" and controlling their movements; a coastline generator, which produces a "video-map" of the coastline, buoys, harbour defences, etc.; an "own-ship" computer in which the manœuvres of the ship controlled by the student are computed; lastly, a display unit.

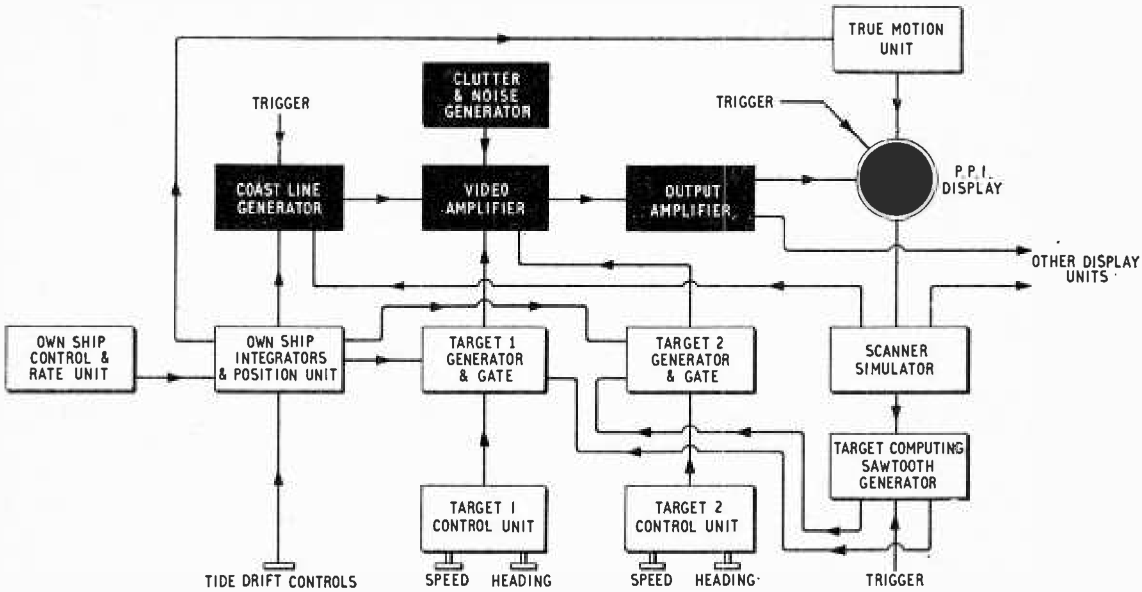
For the demonstration seen by *Wireless World* an unmodified Decca indicator with a 12-in tube was used, the main controls functioning as they would if the indicator were in use on a radar system on board ship. The true-motion unit appropriate to the indicator can be fitted, if desired, to provide training on this type of display. (True-motion is the name given to the stabilized type of display across which ships (including one's own), move with their true course and speed.)† Up to six displays can be operated under normal conditions and the manufacturers say that more can be fitted if needed.

The video-map is generated by using a flying-spot scanner displaying a radial time base to read a 2ft square photographic transparency of the coastline. The movement of own ship is simulated by moving, on a carriage, the flying-spot tube and pick-up cell over the transparency in accordance with information supplied by the own-ship computer. In this unit electronically simulated phenomena such as sea and rain clutter, receiver noise, range fall-off, etc., are added. Another facility of the coastline generator unit is the provision of a plotting board on its top which indicates, by a spot of light, the position of own ship.

When helm is applied a ship takes time to respond; also this applies to an increase in engine

* *Radar Bulletin*: Autumn 1956, p. 3.

† *Wireless World*, Vol. 62, p. 585 (Dec. 1956).



Simplified block schematic of Redifon simulator.

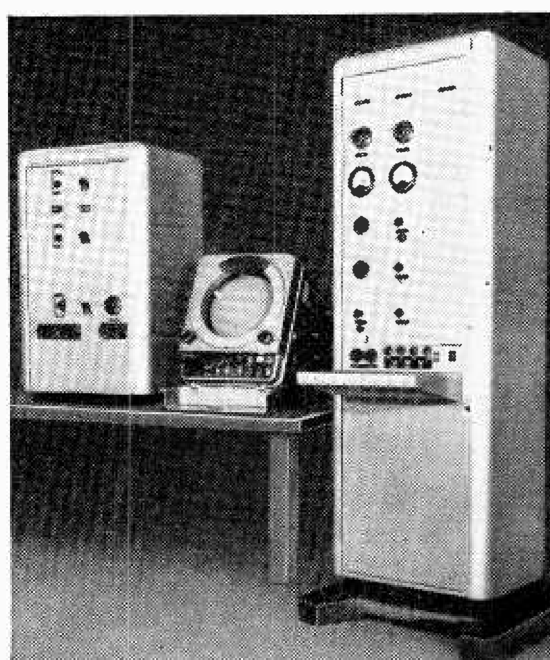
revolutions so that the own-ship unit has to compute not only course and speed; but rate-of-turn and acceleration, which can be preset to reproduce the performance of the simulated vessel. Drift of the parent ship due to tide effects can also be fed in and computed. The own-ship unit can be controlled directly by the student, by the instructor or another student acting as "helmsman." The computing actions are achieved by electro-mechanical analogue devices and the other-ship unit can generate up to six simulated ships although the basic equipment generates only two, each independently controlled and set up for course and speed by the instructor. Rate-of-turn, acceleration and tide-drift simulations are not provided on the other ships, so that new "problems" can be set up quickly.

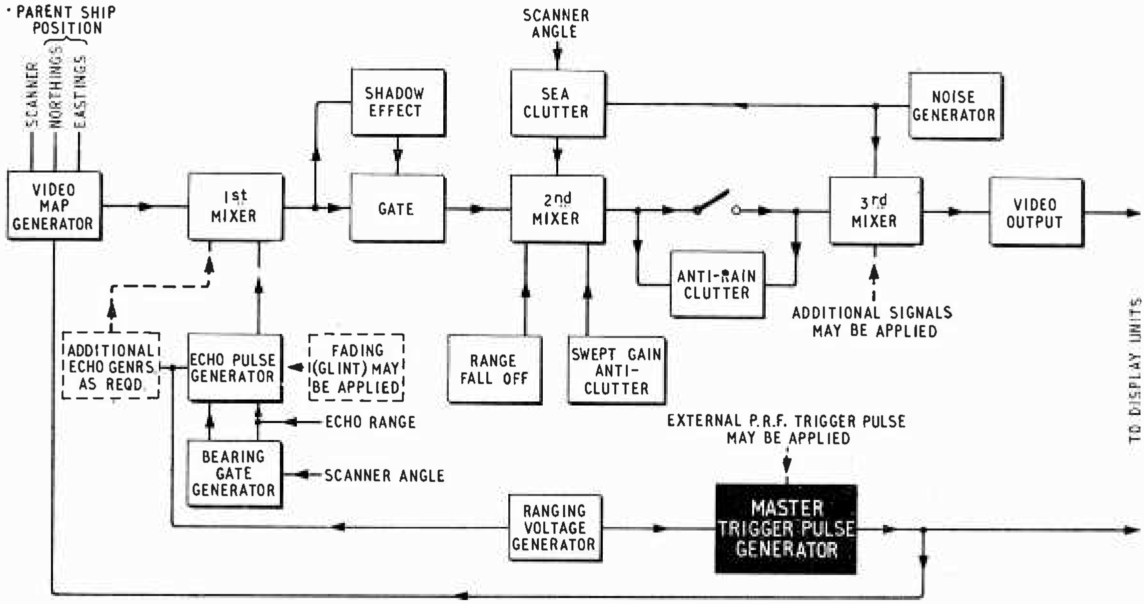
Ultra UE71 Marine Radar Simulator.—This system is built up from permutations of "standard" units (with the necessary ancillary equipment—such as power supplies, etc.) so that almost any depth of training and any number of students can be catered for. This also makes it possible to install a minimal simulator and extend it as finances permit.

The basic system consists of five units:—own-ship computer, other-ship computer, relative position data computer, "electronics" unit (which generates the video waveforms) and a true-motion unit. To these can be added a video-map generator. This basic arrangement thus provides only one other ship, but additional ships can be provided by incorporating an extra other-ship computer, position computer and electronics unit. Another important effect is possible with this equipment; namely that by using an own-ship computer in place of the other-ship computer it is possible to simulate two radar-equipped vessels on a collision course each taking independent avoiding action.

The computers are electro-mechanical analogue devices, as in the Redifon simulator. The basic "ship" outputs are in the form of northing and easting voltages which are fed to the relative position computer: this obtains the difference velocity vectors, integrates to obtain northing and easting voltages representing the position of the other ship relative to own ship, and converts these voltages

Ultra UE71 simulator. Left to right: "Own-ship" and true-motion computer; Decca display, and control rack containing "other-ship" computer, relative position data computer and electronics unit. The video-map generator is not shown.





Block schematic of video chain of Ultra simulator.

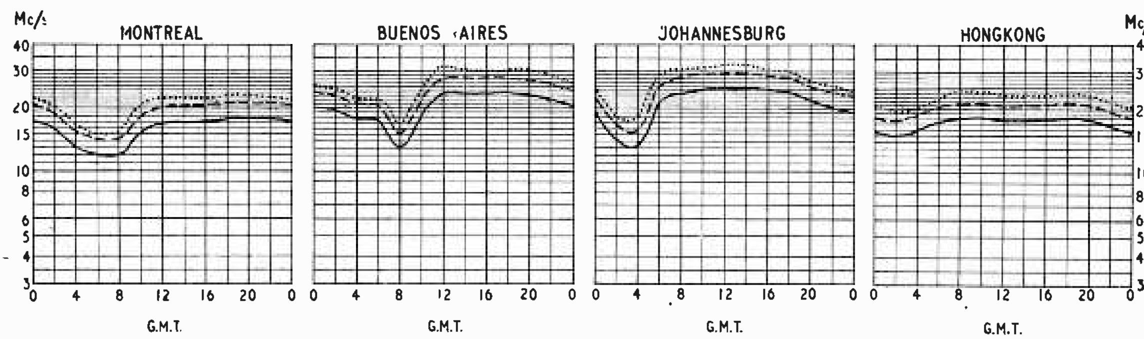
into range and bearing information. This is fed to the electronics unit which generates the pulse to simulate the other ship on the p.p.i. and, for own ship, sea clutter, receiver noise, range fall-off and shadowing.

The flying-spot scanner which produces the video-map does not rely on mechanical movement for simulation of own-ship movement. Instead, this is accomplished by using a small slide ($1\frac{1}{4}$in diameter) and deflecting the radial scan over the face of the flying-spot tube. The video-map generator has a picture element discrimination of better than 50 yards (i.e. roughly equivalent to a 0.3μsec pulse length) over a map area of 625 square miles.

The display unit can be any display in current use, but the equipment is designed to work with an unmodified Decca indicator, the main controls functioning as in a shipborne installation. Ultra incorporate their own true-motion unit which enables them to integrate the true-motion display with the rest of the simulator more easily.

SHORT-WAVE CONDITIONS

Prediction for July



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

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

·········· FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

- - - - PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

———— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

LETTERS TO THE EDITOR

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

Direct-coupled Transistor Amplifier

ALTHOUGH, as Mr. Tait has kindly acknowledged in his article in the May issue, I did discuss during the course of an I.E.E. meeting the possibility of such direct coupling techniques, the idea was originally proposed by Dr. G. B. B. Chaplin (Patent Appln. No. 32013/56). The basic principle has, in fact, a wide range of application apart from that mentioned above.

Having examined Mr. Tait's version of the amplifier in detail it appears that, unfortunately, his design is extremely temperature-dependent, as, indeed, he admits. The reason for this lies in the temperature sensitivity of the leakage current i_{co} of the input transistor. As is well known, i_{co} for a germanium transistor is doubled by a 7°C rise in temperature. Thus, considering the OC71 input transistor, a typical value for i_{co} of 3 μA at 20C° becomes 6 μA at 27°C, 12 μA at 34°C, 24 μA at 41°C, and so on (Ref. 1). Since the d.c. stabilizing feedback resistance connected from the output collector to the input base (Fig 2 of Mr. Tait's article) is given the high value of 1MΩ, the change in output collector voltage level for a temperature change of only 7°C (from 20°C to 27°C) is 1M$\Omega\times3$ μA=3V. A further rise in temperature, or the use of a transistor whose i_{co} happens to be on the high side, would render the amplifier inoperative due to the output transistor becoming bottomed.

However, the problem is easily solved by reducing the d.c. feedback resistance to about 10kΩ, which means that the shift in output d.c. level under the above conditions is now only 10k$\Omega\times3$ μA=30 mV. The feedback can be rendered inoperative for signal frequencies by splitting the 10kΩ resistance into two 4.7kΩ units and shunting the centre point to earth with a suitably large decoupling condenser. (A low voltage electrolytic is satisfactory as it has never more than about 0.5V across it.) (Fig. A.)

With the above arrangement the output collector voltage is very nearly at earth level due to the low value of feedback resistance. Three volts or more is required to bias the output collector into the operating region, so that reasonable voltage swings may be obtained. This may be carried out by means of a current bleed I into the feedback network. If the output level is required to be 3V then the value of I is readily determined from the value of the feedback resistor into which it flows. Thus in the present instance $I=\dfrac{3V}{4.7k\Omega}=0.6$ mA. This method gives the designer considerable freedom in choosing, for example, the d.c. load resistance, and the voltage of his battery supplies, since the biasing is now completely defined by feedback and is sensibly independent of transistor parameters.

Negative feedback at signal frequencies may now be applied (a) by bridging the d.c. feedback network with a suitable resistor (Mr. Tait uses the range of values 100kΩ to 1MΩ) or (b) by inserting a small resistance in series with the decoupling capacitor (see Ref. 2 for the limitations of this method) or, preferably, (c) by arranging local feedback loops within the main d.c. feedback loop (Ref. 3). This allows greater latitude in the choice of feedback factors and also allows more feedback to be applied without giving rise to the peak in h.f. response which Mr. Tait obtained with 17 dB of feedback.

Very high stable gains are available using these techniques. As an example, two versions of this circuit, described in Ref. 3 and shown in Figs. B and C, have

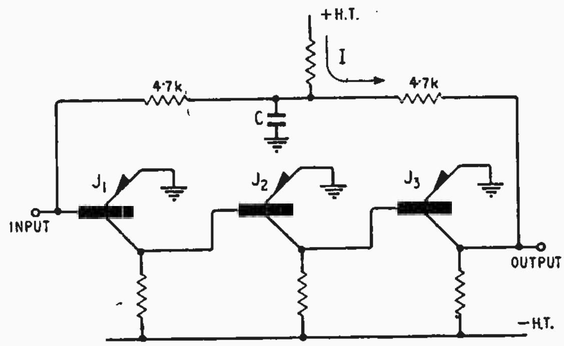


Fig. A.

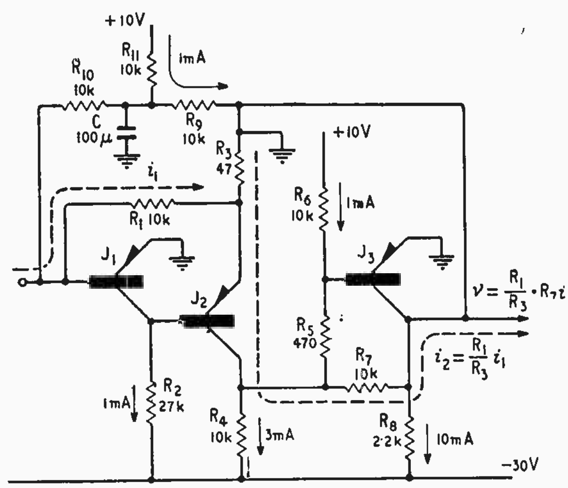


Fig. B.

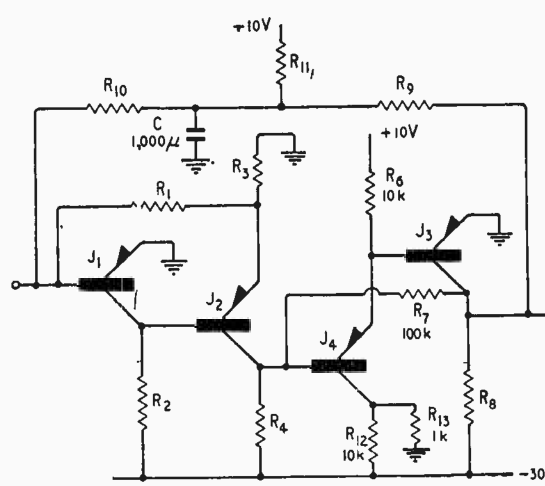


Fig. C.

stable gains of 2V and 20V output respectively for 1 μA of input current, with a bandwidth in each case extending from 60 c/s to 30 kc/s.

Harwell. A. R. OWENS.

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1. Chaplin & Owens: "Some Transistor input Stages for High-Gain D.C. Amplifiers," *Proc. I.E.E.*, May 1958, Part B, p. 249.
2. Almond & Boothroyd: "Broadband Transistor Feedback Amplifiers," *Proc. I.E.E.*, Jan. 1956, Part B, p. 93.
3. Chaplin & Owens: "A Transistor High Gain Chopper Type D.C. Amplifier," *Proc. I.E.E.*, May 1958, Part B, p. 258.

Suppressing Television "Bright Spot"

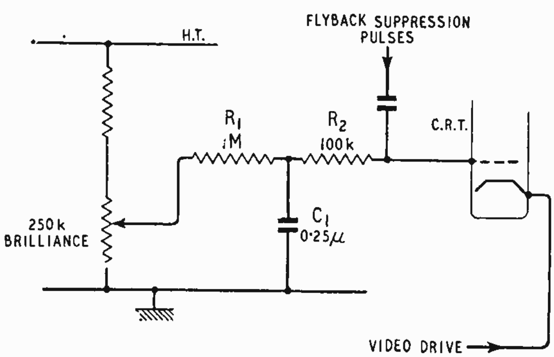
I WOULD like to make one or two comments on Mr. E. Moston Kenny's article in the March issue of this journal.

He states that the television set should not be switched on for several minutes after being switched off, with which I agree, although in practice this can—and does—happen. The system proposed is based upon not allowing the tube to conduct after switch-off has taken place, resulting in the e.h.t. being at maximum value with no method of discharge except through the leakage of the e.h.t. capacitor or through a bleeder resistor across the capacitor. Owing to its very function in life, the e.h.t. capacitor normally has an exceptionally high dielectric resistance and very few sets are fitted with bleeder resistors. This results in the e.h.t. remaining on the tube for some considerable length of time. On one set tested, the e.h.t. decayed by only 25 per cent after 15 minutes.

The second feature of the system which I find undesirable is the fact that the grid is not only not decoupled, but hum is actually fed on to it from the h.t. supply via C_1. Additionally, the system would seem to preclude the possibility of using the grid for the application of flyback suppression pulses.

A third point is that the mains switch is coupled to the brilliance control, resulting in the user having to wait until the picture appears before being able to adjust the brilliance level. With the mains switch coupled to the volume control, the user quickly gets used to rotating the control approximately to the position required but, whilst the ear can readily adjust itself to some variation of volume, the eye is not so accommodating.

In brief, as I see it, the system has many disadvantages



which are not apparent if the e.h.t. is made to discharge as the h.t. collapses. This can be done easily and simply at no greater cost than that of the scheme proposed by Mr. Kenny. One such method which has been used on production receivers for several years is shown in the diagram.

On switching off the receiver, the grid voltage—due to the time constant C_1R_1—collapses at a slightly slower rate than the e.h.t., thus maintaining the tube beam current during the collapse of the line scan and discharging the e.h.t. to such an extent that the bright spot does not appear. The tube grid is prevented from going appreciably positive by R_2 but if grid current does flow the voltage across C_1 decays at an even greater rate.

This scheme will, of course, fail if the brightness control is turned to zero. This, however, does not happen in practice, since it would mean a hopelessly over-contrasted picture. One criticism which may be levelled at it is, however, the fact that adjustment of the brilliance control is not immediately followed by change of brilliance on the screen, due to the time constant R_1C_1. However, the values shown give a time constant of $\frac{1}{4}$-second and this has been found not to be of such length as to be objectionable.

BRIAN G. SCOTT,
Peto Scott Electrical Instruments, Ltd.

Weybridge.

Why Valves?

IN your June issue "Diallist" falls into the common error of supposing that the word "valve" means only a one-way device. If he refers to the Concise Oxford Dictionary he will find that the word means more than this, for it also describes a device for controlling the flow of liquid, etc.

A steam valve, for instance, is not necessarily merely on or off, it is used for the precise regulation of the quantity of steam, as in a throttle valve.

I submit, therefore, that so far from being wrong, "valve" is the only correct word for thermionic devices. In the radio valve the passage of a current is precisely controlled in magnitude by the adjustment of the grid voltage. This is exactly analogous to a throttle valve which, by the mechanical adjustment of an obstruction in a passageway controls precisely the magnitude of flow of steam, air, liquid, etc.

Ewell, Surrey. W. T. COCKING.

I SUGGEST that "Dialist" is thinking possibly of valves in an engine or pump when he discusses this mechanico-electric analogy. In this case the glove fits the hand well for a diode but would seem off the mark for an amplifier pentode, etc.

However, if the full application of the word valve is considered we see that it also refers to devices such as throttle valves, needle valves and gate valves.

The first two types surely "modulate" the flow of a current in a fluid while the last acts as an electronic switch giving the familiar "cut off" beloved in radar technology.

By comparison the French term is definitely démodé, while the American is blatantly superficial. Let us therefore rather congratulate ourselves on this logical development of our language.

Oxford. I. G. HOLT.

Reconditioned CR Tubes

I REFER to "Diallist's" remarks on the subject of rehabilitating cathode ray tubes. Some six months ago I fitted one of these "rebuilt" tubes into a friend's television receiver and found that its performance was—and indeed still is—in every respect equal to that of a new tube. The only difference, of course, being the price, which was one-third of that of the new article.

Like "Diallist" I too cannot see why a properly rebuilt tube should not be perfectly satisfactory, and the fact that the "rebuilders" give a full six months' written guarantee, surely confirms their own confidence in their methods, as well as safeguarding the customer.

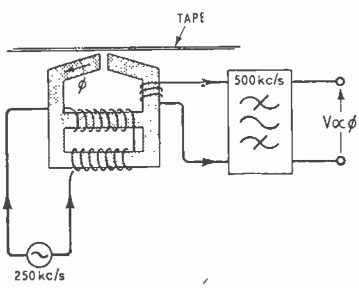
It is to be hoped that the advent of such a process will also have the effect of reducing the exorbitant prices now charged for new tubes.

London, S.E.5. L. D. KITCHEN.

Variable-Output Mains Transformer.—In Fig. 2 on page 263 of the June issue the 2V bulb should be connected directly to the 1V winding, not via the switch as shown. Also the output markings L and N should be transposed.

Technical Notebook

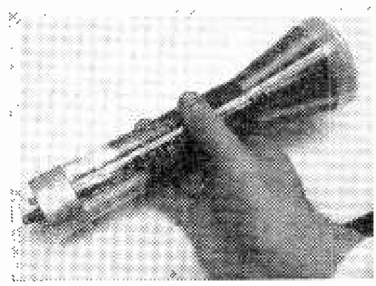
Flux Sensitive Heads for playback in data magnetic-tape recording systems have been developed by the M.S.S. Recording Company. Normally, of course, the output of a conventional playback head is dependent on the rate-of-change of the recorded flux and falls at 6dB per octave with decreasing frequency. This makes it very difficult to use conventional heads for certain data recording applications involving very low frequencies, since the output signal amplitude can fall to little more than the noise level. Hence the need for a head which responds to the actual value of the flux and not its rate of change. The principle of the M.S.S. design is similar to that of the head developed by E. D. Daniel (see November, 1955, issue, p. 562). The flux from the tape is caused to modulate a supersonic frequency flux produced by a winding on the



head, and the resultant product is picked up by a search coil. The supersonic flux itself does not appear across the head gap by virtue of the winding being arranged in two mutually opposing halves. A supersonic frequency up to 250kc/s can be used, and at this frequency the output from the head when in contact with a saturated tape is 10mV r.m.s. A maximum signal/noise ratio of about 50dB can be obtained over a large range of wavelengths. The heads in production have a track width and track spacing of 0.03in with a gap length of 0.005in. These dimensions give four tracks on $\frac{1}{4}$-inch tape or eight on $\frac{1}{2}$-inch tape. Driving power of about 5mW per track is required, while the impedance of the windings is 1.5Ω at 100kc/s.

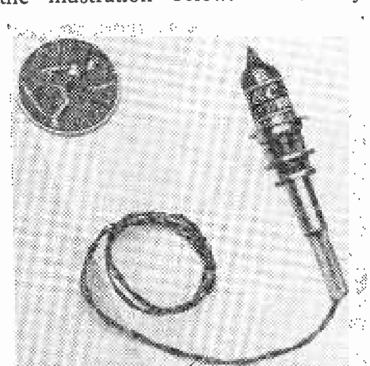
One-c/s Klystron analogue devised by the G.E.C. Research Laboratories in order to give a simple picture of bunching processes uses a rotating glass tube with its axis horizontal, apart from two short lengths between bends. Ball bearings injected into the tube are velocity modulated at the short non-horizontal portions at a frequency of about 1c/s by the rotation. The level part of the tube between the two non-horizontal portions provides a first drift space about 2ft long, at the end of which some bunching of the ball bearings can be seen. The second non-horizontal portion is placed at the right distance to give additional modulation. This produces almost perfect bunching at the end of a rather longer (4ft) drift space; the ball bearings being ejected in groups of three.

Battery C.R.O. Tube, suitable for operation from a transistor d.c. con-



verter and mentioned in the May, 1958, issue (p. 220), is shown above. Made by Electronic Tubes, it requires an h.t. voltage of only 1,000 volts and has a heater consumption of 1 watt.

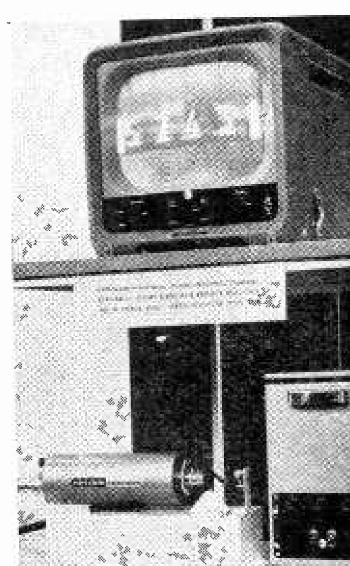
U.H.F. Triode of the disc-seal type, capable of giving the high output of 2 watts at 4,000Mc/s, is shown in the illustration below. Made by



G.E.C., it is practically subminiature in size and is conduction cooled. The mutual conductance (static) is 14mA/V and the maximum operating frequency 6,000Mc/s.

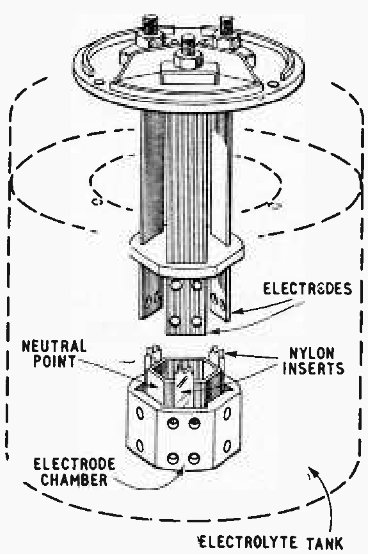
Shirt Button Size high-temperature triodes, produced in prototype by General Electric of America and described in the 28th March, 1958, issue of *Electronics (Engineering Edition)*, use no heaters as the designed ambient operating temperature (about 700°C) is sufficient to produce emission from the cathode directly. These metal and ceramic valves can operate up to at least 1,200Mc/s.

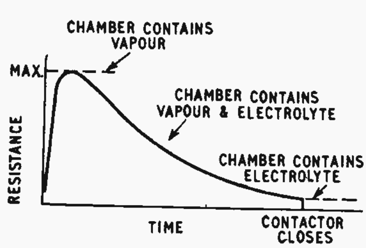
Automatic Sensitivity Control is a feature of a small industrial television camera which Marconi's have recently introduced for closed-circuit applications. This automatic system compensates for wide variations of lighting levels and allows the equipment to operate completely unattended. The camera unit itself is a small steel cylinder 4 inches in diameter and 11 inches long, containing a 1-inch photoconductive pick-up tube with its scanning coils and head amplifier. The camera control equipment is a separate unit and contains the final video amplifier, scanning circuits, scan protection system, power supplies and all operational controls except optical focus, which is at the rear of the camera. Scanning standards can be either British, American or C.C.I.R., and a random interlaced picture is produced unless an external synchronizing source is utilized. The illustration shows the camera (bottom



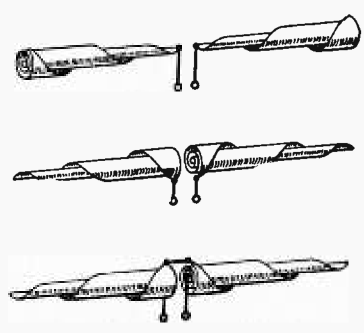
left) in a demonstration for remote viewing of a high speed counter made by Counting Instruments. The numerical display can be seen on the monitor screen above.

Vapour Motor Starter for slip-ring motors is an automatic rheostat which gives a smooth change of resistance, as distinct from the conventional stepped-resistance starter, and so obtains smoother acceleration and protects the motor from mechanical shocks. It is smaller and cheaper than conventional starters of equal capacity. Devised by M. Berard of the French company Association des Ouvriers en Instruments de Precision, the rheostat depends on the great difference in resistance between a liquid electrolyte and its vapour (of the order of 1:50). It consists of a three-phase electrode system (see sketch) carrying the rotor current of the motor, contained in a perforated Steatite chamber and immersed in a tank of electrolyte. The initial high current on switching on heats the electrolyte in the space between each electrode and the neutral point and vaporizes it almost instantaneously. This gives the initial high resistance shown in the graph. As the motor accelerates, the rotor current gradually diminishes, so that the rate of vaporisation is decreased and the electrolyte tends to return progressively into the Steatite chamber. The resistance, which depends on the ratio of liquid to vapour in the chamber, is therefore reduced in proportion to the rotor current, as shown by the falling part of the graph. Eventually the electrode chamber is filled with electrolyte once again and the conductivity of this is sufficient to carry the full-load rotor current. At this point, when the resistance is at its minimum, a contactor is brought into action by a simple thermistor timer and short-circuits the whole rheostat so that it is taken out of the motor circuit. Nylon inserts are put in the electrode chamber (as shown in the diagram) to regulate the effective area of the electrodes and the volume of the vapour spaces according to the starting conditions of the motor. The equipment is being manufactured in Great Britain by Lee Guinness of Northern Ireland.





Rolled Triangle Aerials described by J. R. McDougal, S. Adachi and Y. Mushiake in the *Reports of the Research Institute of Electrical Communication, Tôhoku University* (Japan), Vol. 8, No. 3, 1956, consist of triangular sheets of metal rolled up into the spiral forms shown in the sketch. The first type is fed from the apexes of the triangles, the second from the spirals at the larger ends, while the third is a folded dipole fed from the origins of the spirals. In the unrolled state these aerials resemble fan or butterfly types, and the main object of the



Tôhoku University work has been to retain the wide-band characteristics of the fan aerial while improving its mechanical stability. The measured impedance curves indicate that wide-band operation is best when the aerial is used as a full wavelength dipole. When used as a half-wave dipole its behaviour is similar to that of an ordinary cylindrical dipole, except that it gives a marked increase in electrical length—making possible half-wave dipoles of short physical length. In general the radiation patterns of the rolled-triangle aerials have the familiar figure-of-eight look associated with half-wave dipoles, however, there is one important difference—they retain this characteristic well past the frequency where the aerial length is equal to one wavelength.

H.F. Power Transistor, the device we have all been waiting for, has now appeared in the lists of two manufacturers. Hitherto, of course, the geometry of the electrodes of the average power transistor has made operation at high frequencies impossible. Now Mullard have the type 1520C and Newmarket the types V15/20IP and V30/20IP (for different collector voltages), and both makes are said to be capable of providing an r.f. output of 3 watts at 500kc/s.

Crystals for Masers.—The Royal Radar Establishment are concentrating work on the solid-state maser having a paramagnetic impurity suspended in a regular dia- or non-magnetic crystal structure. Large crystals are required, since the technique used is to cut the crystal into suitable shapes for insertion into a resonant cavity or waveguide. The two main substances in use are gadolinium ethyl sulphate and potassium chromicyanide in a high degree of dilution as a solid solution in alum, which possess a suitable type of crystal structure.

In preparation a saturated solution of the salts required is made, and its temperature is allowed to drop at a rate depending on the solubility of the salt, the surface area of the crystal and the volume of the solution. The temperature is maintained to within 0.05°C of its correct value over 10 to 14 days. In this solution is placed a small "seed" crystal. Growth starts and is continued until a specimen of sufficient size has been produced. To ensure regular growth the crystal is kept moving in the solution.

Ice Crevasse Detector using four shallow dish-shaped electrodes attached in front of a vehicle is described in *Electronics (Engineering Edition)* for 17th January, 1958. Two of the electrodes are fed with a signal at about 150c/s. The field between the other two electrodes due to this signal is amplified and fed to an alarm system. When a crevasse is approached, it alters the field and sets off the alarm. If the detecting electrodes are on an equipotential of the field, crevasses which are parallel to this equipotential will not be detected. This possibility is avoided by using an asymmetrical electrode arrangement.

Turntable Driven Tape transport and record/replay mechanism (the "Gramdeck") is marketed by Stevenage Tools and Switches. The tape speed is 7½in/sec for a gramophone turntable speed of 78 r.p.m. Equalization and high-frequency bias are provided by a three-transistor battery circuit. Signals on the tape are normally erased by a permanent magnet.

Long-distance H/F Broadcasting

FACTORS GOVERNING EFFECTIVE COVERAGE OF TARGET AREA

By T. W. BENNINGTON*

PERHAPS the most important factor in ensuring good broadcast coverage of a distant target area, where the transmissions are by ionospheric propagation of the radio wave, is the correct choice of working frequency to suit the time of day, season of year, phase of the sunspot cycle and length and geographical disposition of the transmission path. The complex variables which govern this have been the subject of much study over the past three decades, and considerable progress has been made, which is not to say that the problem has, as yet, been completely solved. Nor is this surprising when one considered the complex nature of the ionosphere and the fact that, concurrently with our exploitation of it as a transmission medium, our knowledge of its physical characteristics has been, and still is, slowly advancing.

In this article, however, we turn to another problem which is of great importance in ensuring good coverage; that of "directing" the transmitted energy towards the ionosphere in such a manner that the distant target area is most efficiently "illuminated." Unless this is done power will be wasted—that much is obvious. What may not be so apparent are the facts that this subject itself is, like that of the correct choice of working frequency, bedevilled by an imperfect knowledge about the precise transmission mechanism which is operative under all conditions, and by the necessity for continual compromise in order to allow for changes in the ionospheric parameters involved.

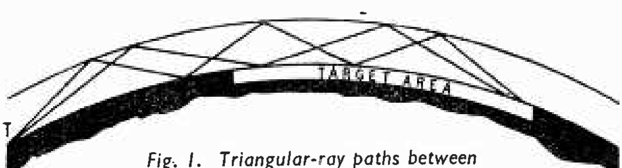


Fig. 1. Triangular-ray paths between transmitter and the target area.

Before describing the problem and detailing the methods by which its solution has been, and at present is being, attempted it must be remarked that work is going on at the D.S.I.R. Radio Research Station, Slough, which aims to determine the precise trajectories of transmitted waves at given times over given paths[1], and so to learn more about the transmission mechanism which can be directly applied to improving the present methods. However, this article will be confined to the application to h.f. broadcasting of the methods at present in use, and will not include anything of this new work, the results of which are not yet available.

The General Problem.—The "illumination" provided over a distant target area depends, in the first instance, upon the geometry of the earth/ionosphere transmission path and upon the azimuthal and vertical radiation patterns of the transmitting aerial system. Best coverage will result when the latter is such as to excite most strongly those ray paths which, under all ionospheric conditions, produce the strongest field at all points across the target area. In the case of one-hop transmission this is a relatively simple matter, but our remarks here will be confined to the coverage of target areas lying beyond the region that can be reached by one hop of the wave between earth and ionosphere, i.e. where the near boundary of the area is distant greater than about 4,000km from the transmitting station.

In the method to be described the paths of the rays which cover the area are assumed to be those obtained from the geometry of triangular paths between earth and the virtual height of the reflecting layer, assuming a spherical ionosphere and earth. An example is given in Fig.1, where, for the sake of clarity, only two ray paths are shown. In fact these virtual heights, even assuming F_2-layer propagation only, vary constantly with time of day and season and, since this means that they may vary all along a given transmission path, hops of unequal length may result for the various rays. Moreover, the idea of triangular paths of equal length is only, of course, a convenient assumption, because the actual curved apex trajectories may vary with the different electron distributions at the different ionospheric locations. Again, although the assumption that F_2-layer propagation predominates in multi-hop transmission is true enough, it is known that at certain seasons and at certain geographical locations at some times of day Sporadic E propagation may occur, in which case the trajectories are drastically altered.

In short, the actual trajectories of many rays traversing a long path involving many hops and with a changing ionosphere may be very complicated, and even if full details of this subject were known it is hard to see how it could yet be used effectively in the planning of systems which must give coverage at all times of day and season over many years. Therefore the simplified model of triangular hops from an F_2 layer whose median virtual height is known is taken, for purposes of long-term planning, to approximate to the actual conditions over a long period, and is generally used to provide a working solution to the problem. This does not preclude consideration of the effects

* Research Department, British Broadcasting Corporation.

of Sporadic E or normal E layer in cases where their effects become of prime importance.

Test Results.—It was realized from the early days of h.f. broadcasting that it was important to distribute the radiated energy in the vertical plane so that the target area would be efficiently and uniformly illuminated, and as little power as possible wasted. The procedure of the B.B.C. in this matter has been largely based upon the results of tests made with different types of aerial in 1933-35[2], and upon those of later tests made during 1940-43. These indicated that for transmission to the main target areas where multi-hop transmission was

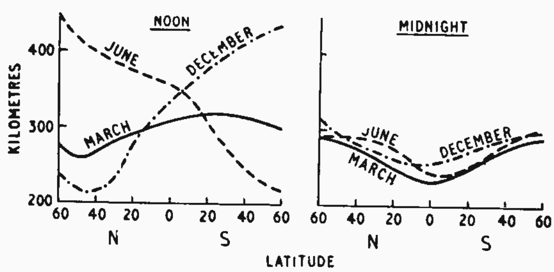


Fig. 2. Approximate values of F_2 virtual height for noon and midnight for March, June and December.

involved the optimum radiation angle was 7° to 8° to the horizontal, and that the vertical radiation pattern should include, between half-field points, a range of angles from 3° to 13° to the horizontal. The standard arrays for long-distance transmissions used by the B.B.C. over the intervening years have been arranged to meet these requirements, where mechanically possible, and the small angle of 7.5° used for the centre of the main lobe. Different types of array have been used by many operating concerns[3] and broadcasting organizations, both in this and other countries but little evidence has come to hand which would suggest that a greater angle is preferable. On the contrary, later tests, and particularly some conducted during the period 1952-54[4], indicate that angles of $7° \pm 2°$, and at some seasons those of $5° \pm 2°$, are the angles at which signals arrive most consistently over certain long-distance paths. We are now in a position, however, to examine the matter from the propagation point of view, using the method mentioned above.

Azimuthal Angles.—The procedure for determining the shape of the radiated pattern in the horizontal plane is quite straightforward. The radiated energy is assumed to follow a great-circle path, so it is necessary to determine the azimuthal angles subtended at the transmitter by the great circles joining the transmitter and the two lateral boundaries of the target area at its widest point. The radiated pattern is then arranged to include these angles, where this is possible, within its half-field points. Though it is recognized that some lateral deviation of the radiated energy can occur, particularly under conditions where there are gradients in the ionization transverse to the direction of the transmission path, tests have shown that these are not, generally speaking, of a systematic kind such as would modify long-term planning.

Vertical Angles.—(*i*) *Virtual Heights.* In order to determine the useful vertical angles it is first of all necessary to know the virtual height, i.e., the points where the apices of the triangular hops will occur, and what we need to do in order to obtain a working solution is to find the *median* virtual height. We therefore examine the measured data on virtual heights for the F_2 layer. Fig. 2 gives the approximate values of F_2 virtual height as obtained from ionospheric measurements, for December, March and June in the latitude range 60° N to 60° S, which covers that part of the earth's surface within which most of the target areas are located. During the night the virtual height is fairly uniform over this part of the earth at all seasons, but during daytime large seasonal variations occur, the values being relatively great in local summer and small in local winter. The median value, for practical purposes, is 320km, and the total range, for by far the greater part of the time over the majority of the target areas, is from 240 to 400km.

(ii) *Propagation Modes.*—Using the median value of 320km a diagram can be constructed which will show, in terms of radiation angle Δ against ground distance D, the various propagation modes which will be present at any distance. This has been done in Fig. 3, the assumption being made that the downcoming angle, measured to the horizontal, is equal to the radiation angle at the transmitter. In this article the modes will be referred to, either by the number of hops appertaining to each, i.e., the 1-hop mode, etc., or, when referring to several at a given distance, by their order in the angular scale, i.e., the first mode, second mode, etc. Thus, at a given distance, the first mode is always that arriving by the least possible number of hops.

It is seen that at any given distance there are present, provided the layer ionization along the

TABLE I

Relative Losses and Field Strength at Receiver Input; Second Mode/First Mode. Angles $<1°$ not Included.

Distance (km x 10_3)	Ground Loss Difference (dB)	Ionospheric Loss Difference (dB)	Receiving Aerial Loss Difference (dB)	Field Strength Difference at Receiver Input (dB)
4	6.4	1.8	−1.8	−6.9
5	6.1	0.8	−3.9	−3.0
6	5.9	1.0	−6.1	−1.3
7	6.1	4.0	−11.3	+1.2
8	6.6	0.0	−4.1	−2.5
9	6.3	2.1	−4.3	−4.1
10	6.2	5.4	−6.4	−5.7
11	6.2	8.3	−13.5	−1.0
12	6.9	2.5	−3.6	−6.3
13	7.8	2.8	−6.4	−4.2
14	6.9	6.7	−8.1	−5.5
15	6.9	7.8	−12.4	−3.3
16	6.7	4.0	−3.4	−7.3
17	6.4	6.9	−4.7	−8.7
18	6.9	9.7	−7.0	−9.6
19	6.5	8.3	−11.0	−3.8
20	7.4	0.8	−4.7	−3.5
Mean	6.6	4.3	−6.6	−4.4
		Focusing Effect		−2.0
				−6.4

path is sufficient to support their propagation, several different modes, and that this is often so in practice has been confirmed both by pulse tests and by downcoming angle measurements. For example at a distance of 10,000km, there could be present a 3-hop mode at 2.8°, a 4-hop mode at 8.4°, a 5-hop mode at 12.8°, and so on. The higher-angle modes, however, are less likely to be present because, with their nearer-vertical incidence at the layer they are more likely to penetrate it, and, of the modes which *are* present, it remains to be seen which one makes the most important contribution to the received field.

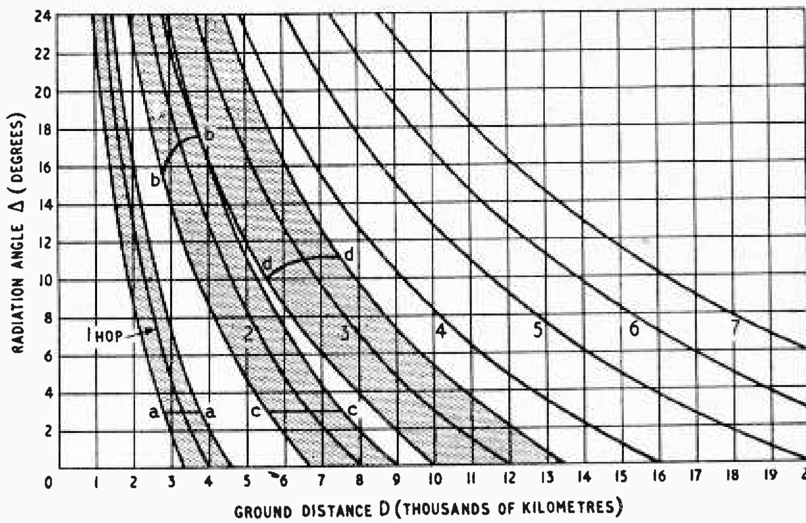


Fig. 3. Mode/distance relationship up to 20,000km for median vertical height of F_2 layer of 320km. Shaded areas indicate effect of variations in F_2 layer height between 240 and 400km.

For the first three modes shown in Fig. 3 the variation in angle or distance occasioned by variations in the virtual height between 240 and 400km has been shown by means of a shaded area, and the purpose of this will be discussed later.

(iii) *Relative Attenuation of the Modes.*—It is now of interest, in order to see which of the modes gives the highest field strength, to calculate the various losses to which the radiated energy will be subject[6]. In order that the results may be applicable to broadcasting, i.e., to serving a target area of wide dimensions, this should be done for

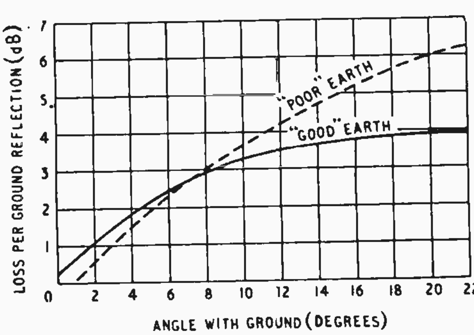


Fig. 4. Ground losses at 15Mc/s.

distances ranging from 4,000 to 20,000km, and it is convenient to do it for every 1,000km within that range. It will be sufficient, in order to see whether there is a preferred mode, to obtain relative figures for the first and second modes only, assuming constant radiation over the necessary angular range by the transmitting array, but taking into account the characteristics of the listener's receiving aerial. Since the latter would have little or no pick up at 0° the first mode may be assumed to fade out at 1° to the horizontal. If, in this way, we find that one mode gives a greater receiver input than the other then the radiation angle at which the strongest excitation of this mode will occur should be the optimum radiation angle for the transmitting array, and the total range of transmitting angles required should also become clear.

(*a*) *Free Space Field.*—In the absence of any other losses the radiated energy is subject to the spatial loss, i.e., the loss occurring in the wave front by reason of its spreading out with distance. In the case of transmission between a curved earth and ionosphere over a given ground distance and with a given virtual height, this loss will be slightly greater the higher the order of the mode. However over the range of angles occurring in practice the increase in loss as between the modes is so small that it can, in fact, be ignored.

(*b*) *Ground Loss.*—Energy is lost when the wave undergoes reflection at the ground. This ground loss, for a randomly polarized wave such as emerges from the ionosphere, is a function of the angles of incidence and reflection at the ground, of the nature of the ground, and of the frequency. Within the range of frequencies used for long-distance communication, and with the angles occurring in practice, the loss increases, for types of ground other than sea water, rather sharply with angle, which means that it is greater the higher the order of the mode. Fig. 4 illustrates the case for a frequency midway in the h.f. range. Then, of course, there is the fact that with each increase in the order of the mode an additional ground reflection occurs, i.e., the 3-hop mode has two ground reflections, the 4-hop mode three ground reflections, and so on.

Thus the highest order mode will be most attenuated both by reason of its larger angle with the ground and also by reason of it undergoing a greater number of ground reflections. An examination was made of the ground losses at 15Mc/s for distance intervals of 1,000km between 4,000 and 20,000km, assuming the loss to be midway between that for "good" earth and "poor" earth, and the results are given in the second column of Table 1 in terms of the loss difference between the first and second modes. The loss is greater for the second mode than for the first at all distances, the mean difference being 6.6dB in favour of the first mode. For sea water the loss difference between the two modes might be as small as 1dB. It must be considered therefore that, on the average, the ground loss for the second mode will be approximately 1 to 7dB greater than that for the first mode.

(*c*) *Ionospheric Absorption Loss.*—The radiated energy is also subject to loss due to ionospheric absorption, which occurs by reason of the dissipation of energy through the electron/molecule collisions which the wave sets up. This occurs principally in the D layer, and since this layer disappears at night, the ionospheric absorption loss over paths in darkness can be considered to be negligible. During daylight, however, this loss must be added to that occurring at the ground. Its magnitude increases with the amount of daylight over the path, with the sunspot number and length of the path, and decreases with increase in frequency. An examination of the ionospheric losses for every 1,000km for 15Mc/s over an all-daylight path during March (for typical high-loss conditions) gave the figures shown in the third column of Table 1. The loss was never less for the second mode than for the first, the mean difference being 4.3dB in favour of the first mode. Thus on the average, the ionospheric loss for the second mode over an area of wide dimensions will be approximately 0dB (night) to 4dB (daylight) greater than that for the first mode.

(*d*) *Ionospheric Focusing.*—Because of the curvature of the ionosphere there is some focusing of the energy such as to favour the most oblique rays. It is difficult to assess the effect of this in practice, but over distances of from 4,000 to 20,000km the mean angle for the first mode would be about 6° and that for the second mode about 11°. The effect of focusing as between these two angles should be to produce a gain of about 2dB in favour of the smaller angle. It would seem reasonable, therefore, to consider that there is a loss of 2dB applicable to the second mode as compared with the first, due to this effect.

(*e*) *Receiving Aerial.*—If the design of the receiving aerial was within the control of the transmitting authority (as is usually the case in the communication services) the next step would probably be to design this so as to have maximum pick up at the angle corresponding to the strongest mode at its fixed distance from the transmitter. The broadcast case is more complex in that the distance is never a fixed one but varies between certain limits, and a variety of aerial types are used, the design of which is outside the control of the broadcast engineer. Dealing with this latter point, it is evident that if the listener's receiving aerial performance is such as to have angular variation in its pick up, then such discrimination will affect the efficacy of the modes in terms of their relative voltage input to the receiver. It is difficult to assess what an *average* broadcast receiving aerial is, but an examination of various types of aerial shows that, in sky-wave reception, they all discriminate markedly against very small angles to the horizontal. In Fig. 5 a curve is given which is the mean value for the five types of aerial listed, of the minimum required field strength against angle, and this may be used for our present investigation. The curve values are given in dB required field strength, so they may be taken directly as relative loss values applicable to the first and second modes. This has been done and in the fourth column of Table 1 are given, for each interval of 1,000km the resultant loss difference between the modes due to the

TABLE 2

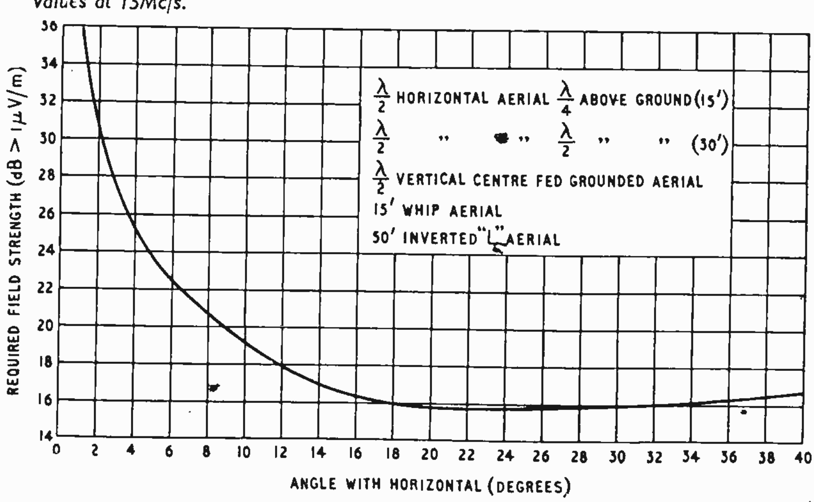
Loss Differences Applicable to First Mode

Cause	Mean Values (dB)	Cause	Least Values (dB)
Ground Loss (Earth)	7.0	Ground Loss (Mixed Sea and Earth)	4.0
Ionospheric Loss (Day)	4.0	Ionospheric Loss (Night)	0.0
Focusing	2.0	Focusing	2.0
Total	13.0	Total	6.0

TABLE 3

Target Area	Distance Ranges (km)	Mean Angle for First Mode
North and West Africa	2,000— 6,000	10.0°
Central and South Africa	5,000—10,000	7.9°
South Africa only ...	8,000—10,000	6.8°
India and Ceylon ...	5,000— 9,000	7.6°
South-east Asia ...	9,000—14,000	5.8°
Australia and Tasmania	14,000—18,000	4.6°

Fig. 5. Minimum required field strength for sky-wave broadcast reception in the presence of set noise only for 90% of days for five types of aerial. Curve shows mean values at 15Mc/s.



receiving aerial. The loss is always greater for the first mode than for the second (as will be obvious from Fig. 5) and the mean value for all distances is 6.6dB in favour of the second mode.

(*f*) *Receiver Input Field Strength Difference.*—The relative difference for each distance between the resultant field strength at the receiver input of the two modes is given in the last column of Table 1. Except for the value for 7,000km —when the receiving aerial discrimination between first and second modes reaches an exceptionally high value—the first mode is always the stronger, and the mean value in its favour for all distances, when the focusing effect is included, is 6.4dB.

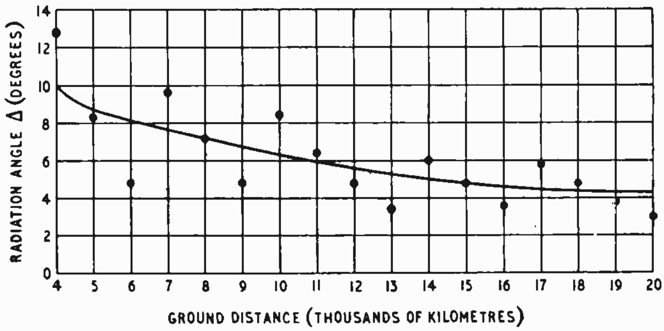


Fig. 6. Variation with distance of radiation angle for strongest mode. Curve gives mean radiation angle for strongest excitation of this mode.

Determination of the Strongest Mode.—It would appear, therefore, that the first mode may be expected to have an average gain of 6dB over any other, and it should be noted, also, that this mode will be the last one to fail due to electron limitation in the ionosphere. However, though this gives us a useful idea of the *average* relative value of the modes, we need to determine the strongest mode for a condition when the relative losses have their smallest value. In this connection it is to be noted that because the first mode is at a relatively low angle, and because the receiving aerial pick up falls so sharply at low angles, there is the possibility that, under the above conditions, the field strength of the first mode may fall below that of the second at a certain low angle. Accordingly, in Table 2 we compare the loss differences applicable to the first mode under these less favourable conditions with the mean loss differences, neglecting the effect of the receiving aerial.

It will be apparent from Fig. 5 that when the angle for the first mode is as low, for example, as 1°, the receiving aerial may discriminate in favour of the second mode by as much as 14dB making it, under these conditions, the strongest by 8dB. In order to select the strongest mode, therefore, we need to establish a low limiting angle at which the receiving aerial discrimination in favour of the second mode will not exceed 6dB. It is evident from Fig. 3 that the angular relationship between the modes varies with distance, but an examination shows that when the first mode is at 3° the second mode has a mean value of 7.8°, at which angle the receiving aerial discriminates in its favour by 6dB. If therefore we take 3° as the low limiting angle for the first mode, we can assume that, even for the least favourable conditions, it should be the strongest mode when averaged over a range of distances. In other words we establish the convention that the strongest mode is that lowest in the angular scale down to a value of 3°, and that at any smaller angle the mode next higher in order becomes the strongest mode, and so on. For the sake of clarity in description we can regard the first mode as fading out at an angle just below 3°, and the next higher mode then becoming the first mode. If then the vertical radiation pattern (v.r.p.) of the transmitting array is such as to excite most strongly the first mode, this should result in the strongest field at any distant point.

One other point should be mentioned here. Though long-distance transmission is generally effected by way of the F_2 layer the radiated energy must, in order for this to happen, be able to penetrate (a) the normal E layer and (b) Sporadic E. For a given ionization in either of these layers it is the energy radiated at the smaller radiation angles which is the less likely to penetrate them, and so reach the target area by way of the F_2 layer. This E-layer " cut off " angle is, however, a variable quantity and at certain times and in some locations may reach a near-vertical angle, in which case it is impossible to effect communication by way of the F_2 layer. These cases can be met in two ways (a) by the use of arrays specially designed for E-layer transmission; (b) by the use of normal arrays with the radiated energy reaching the target area by way of the lower layers, but by means of a greater number of hops than when by way of the F_2 layer. However, because these effects have a limited time duration they are regarded as special cases, and will not be further dealt with here. We should, however, in F_2-layer transmission, avoid paths at very small angles because of these effects.

Optimum Angle for Broadcast Transmission.—In broadcast service the target area often has a distance range across it of several thousands of kilometres, and its distance from the transmitter may also vary. Again, the aerial used often has to be of a " general purpose " kind, capable of serving different areas lying in one, and sometimes in more than one, direction.

Fig. 6 shows, for every 1,000km from 4,000 to 20,000km, the angles, taken from Fig. 3, for the first mode according to the convention we have established. These angles will, of course, start at 4,000km with a relatively large value, decrease to 3°, and then jump to a higher value as the mode corresponding to one more hop becomes the first mode. Though this continually happens with increasing distance the angular range covered decreases as the distance increases. The curve in Fig. 6 shows the mean value of these angles, and thus represents the angle for strongest excitation of the first mode over a distance range. It may be regarded as indicating the optimum angle for transmission to any distance. It has a mean value, for the whole distance range, of approximately 6°, which is not very different from that obtained as the optimum angle from the test transmissions mentioned earlier. It is obvious from Fig. 6, however, that the optimum angle will, in fact, decrease with increasing distance, and will also vary with the dimensions of the target area. Table 3 gives its value for several typical target areas, the angle being read off from Fig. 6 for the centre of the target area.

In general-purpose, long-distance arrays at present in use, in which the centre of the main lobe is at 7.5°, there is a considerable decrease in power density at 5° and 10°, so that, whilst their v.r.p.s are very suitable for general long-distance purposes, an increase in the incident field strength in certain areas might well be effected by the use of arrays designed for respectively greater or smaller optimum angles, i.e. with the centre of the main lobe nearer the mean angle for the first mode across the particular area. It will also be appreciated that aerial test results for a particular place may indicate an optimum angle higher or lower than the mean value for the whole target area, as indicated by the plotted points in Fig. 6.

Total Angular Range.—Apart from the angle for the centre of the main lobe it is necessary to consider, in connection with the v.r.p., the total range of angles to be included, for example, within the half-field points. We have already considered the minimum angle for the first mode to be 3°, as indicated in Fig. 3 by line *aa*. The corresponding angles for the mode next higher in order for the same distances and range of heights is shown by line *bb*, and it is now evident that if the near boundary of the target area is as close as 3,300km it is necessary for the v.r.p. to cover angles from 3° to 17.6° for there to be no possibility of a break in coverage due to the change from 1-hop to 2-hop transmission, under all likely height conditions. It is extremely difficult, however, to arrange for the v.r.p. of a high-gain array with maximum radiation at approximately 7° to include, within its half-field points, angles as great as 17.6°. If, however, the inner boundary of the service area were at a distance of 4,600km, where the median angle is 10° and the maximum 13°, then the v.r.p. specification is much easier to meet, for at the change-over from 2-hop transmission, which occurs for various heights and distances along the line *cc*, the corresponding angles for 3-hop transmission are those along the line *dd*, the maximum of which is 11°. If, therefore, the inner boundaries of the target areas to be served by general-purpose, long-distance arrays were set at 4,600km, a v.r.p. with maximum radiation at approximately 7° and a total range of 3° to 13°, which is relatively easy to achieve, is adequate. This, again, conforms to what the earlier tests indicated. For distances less than 4,600 km (and there are many target areas with inner boundaries nearer than this) a differently designed array should preferably be used. It is evidently a mistake, however, to attempt to cover places lying relatively near to the transmitting site with a general-purpose, long-distance array, for if this is done there is the danger of a gap in coverage at distances between about 3,000 and 4,000km.

Conclusions.—(1) In the long-term planning of broadcast coverage it is not yet possible to take account of the detailed variations in the trajectories occasioned by short-term ionospheric variations, and it is more feasible to plan on the basis of average conditions, assuming geometrical hops and median virtual heights.

(2) For target areas lying less than 4,600km distant specially designed aerials with a main lobe centred at an angle corresponding to the centre of the target area, and with half-field points at angles corresponding to the inner and outer boundaries, allowing for variations in virtual height, should give satisfactory coverage.

(3) For target areas greater than 4,600km distant best coverage should result when the first mode is most strongly excited, provided this is not at a radiation angle of less than 3°, because this mode may be expected to be, on the average, about 6dB stronger than any other. It also lasts longer than any other mode.

(4) From (3) it is deduced that the v.r.p. of a general-purpose, long-distance array should be such that the centre of the main lobe is at about 7°, and contains, within its half-field points, angles between 3° and 13°.

(5) The v.r.p.s of aerials used to serve specific areas may give better coverage if they are such that the centre of the main lobe is at somewhat greater or smaller angles than in (4), this angle decreasing with increasing distance, and being given by the curve of Fig. 6 for the centre of the target area. The total range of angles which it is necessary to cover will also decrease with increasing distance.

References

[1] Report of the Director of Radio Research, Radio Research 1956, H.M. Stationery Office, p. 14.

[2] L. W. Hayes and B. N. McLarty: "The Empire Service Broadcasting Station at Daventry." *Proc. I.E.E.*, 1939, Vol. 14, No. 42, pp. 337-347.

[3] R. J. Hitchcock: "Aerial/Propagation Mismatch." *Wireless World*, December 1957, Vol. 63, No. 12, p. 599.

[4] A. F. Wilkins and F. Kift: "Characteristics of H.F. Signals." *Electronic and Radio Engineer*, September 1957, Vol. 34, pp. 335-342.

[5] The various losses are estimated on the basis of data given in U.S. Signal Corps Radio Propagation Technical Report No. 9.

CLUB NEWS

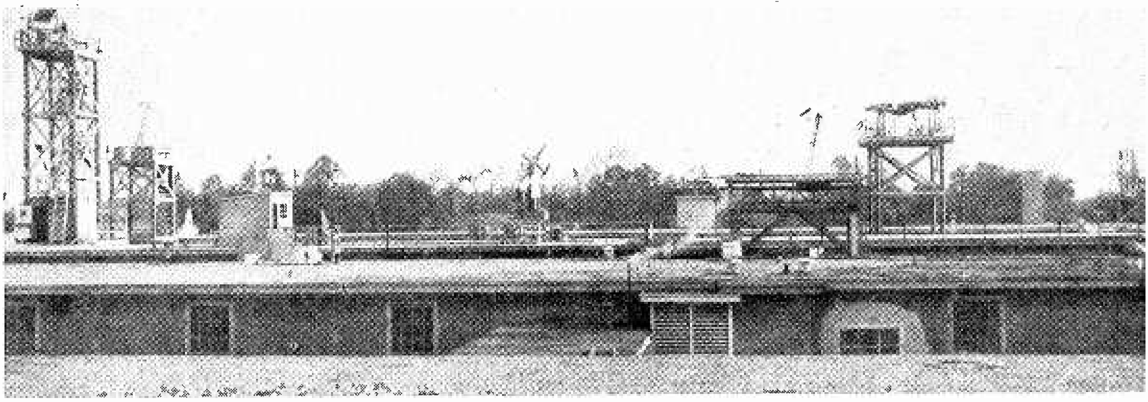
Bexleyheath.—A film show, including Mullard's "Mirror in the Sky," will be given at the meeting of the North Kent Radio Society at 7.30 on July 10th in the Congregational Hall, Chapel Road, Bexleyheath. Arrangements are being made for the Society to participate in the Borough of Erith's annual show on August Bank Holiday Monday. Sec.—D. W. Wooderson (G3HKX), 39, Woolwich Road, Bexleyheath, Kent.

Bradford.—Members of the Bradford Amateur Radio Society will discuss the question "Which v.f.o. is best?" at their meeting on July 1st at 7.30 at the Headquarters, Cambridge House, 66, Little Horton Lane, Bradford. Sec.—D. M. Pratt (G3KEP), 27, Woodlands Grove, Cottingley, Bingley, Yorks.

Prestatyn.—Two outdoor events have been arranged for the Flintshire Radio Society for July. On the 6th the club's second field day will be held on the Caerwys Mountain, and on the following evening there will be a 160-metre d.f. hunt starting from the Railway Hotel, Prestatyn. Sec.—J. Thornton Lawrence (CW3JGA/T), 9, East Avenue, Bryn Newydd, Prestatyn.

Sidcup.—At the meeting of the Cray Valley Radio Club on July 22nd, C. N. Wridgway (G3GGO) will talk on valve applications. The club meets at the Station Hotel, Sidcup, at 8.0. Sec.—W. E. Sutton (G3FWI), 30, Sherwood Park Avenue, Sidcup, Kent.

Uxbridge.—Thirteen people attended the inaugural meeting of the West Middlesex Tape Recording Club held in the Uxbridge Council Offices on May 13th. Monthly meetings are being planned. Sec.—H. E. Saunders, 20, Nightingale Road, Hampton, Middlesex.



Aerial test range on the roof of the Aircraft Radio Systems Laboratory at Stanford Research Institute in the U.S.

Flush-Mounted Aircraft Aerials

The Role of Scale Models in the Study of Radiation Patterns

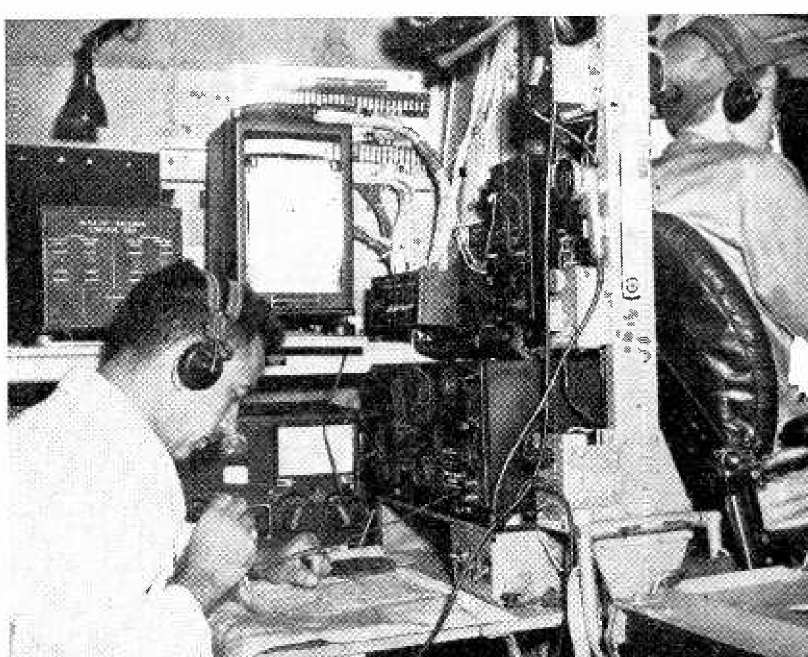
By *MICHAEL LORANT*

THE complete radio equipment normally carried in an aircraft would consume, if operated simultaneously, electrical power to an amount equivalent to a load of about 7.4 horsepower on the aircraft engines. Several aerials are required for the operation of these equipments. External aerials introduce air resistance which "eats up" horsepower. At 300 miles an hour and at an altitude of 6,000ft, over 90 horsepower is consumed in overcoming the air resistance of these aerials. If they were used on an aircraft flying at 600 miles an hour, over 700 horsepower would be required to overcome their air resistance.

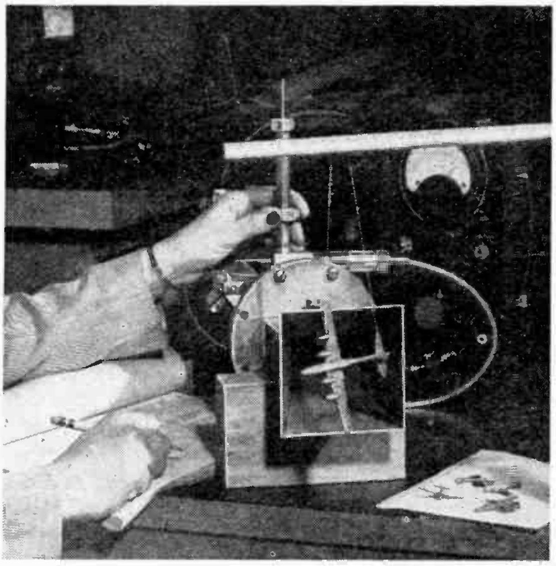
The answer to the problem posed by the poor aerodynamic properties of the aerials lies in "flush mounting,"* the technique in which they are designed in such a way that they can be accommodated wholly within the smooth surface contours of the airframe. The development of this technique requires close co-operation between the aerial and the airframe designers. It requires, as well, the evolution and application of new ideas and new approaches to the mathematical analysis of the behaviour of aerials, and to the experimental determination of their characteristics.

One of the most useful experimental techniques available to the aircraft aerial engineer is the use of scale models. The physical laws governing the behaviour of electro-magnetic waves permit the scaling down of the linear dimensions of the structure under study by a constant factor, provided that

Inside one of the "flying laboratories" used in the study of aircraft aerials.



* Sometimes described as "suppressed aerial" systems.



Resonance phenomena in aircraft structures are studied by the use of microwaves and scale models of aircraft.

the operating wavelength is scaled down by the same factor. This fact permits the use of aircraft models, complete with model aerials and of a size convenient for use in the laboratory, in the determination of aerial characteristics which are equally applicable to the actual aircraft.

Scale models are widely employed in the study of the radiation patterns of aircraft aerials at the Aircraft Radio Systems Laboratory of the Stanford Research Institute in the U.S.A. where advanced studies of aircraft aerial problems are now being undertaken. In this study, a rotatable mount, especially designed and constructed for the purpose, serves to support a model aircraft while it is rotated about the horizontal and vertical axes as the radiated electro-magnetic field is explored. This supporting structure has been designed in such a way that its presence has a negligible effect on the radiated energy. The rotary motion of the model is relayed through a system of electrical repeaters to a recording turntable, on which an electrically-driven recording pen automatically traces out a graphical plot of the radiation pattern.

Similar scale models are being used in the study of the distribution of radio-frequency currents excited on the aircraft skin by the aerial. Since these currents contribute to the radiated energy and to the energy lost to heat because of the electrical resistance of the metal airframe, study of their nature is an important phase of aircraft aerial research.

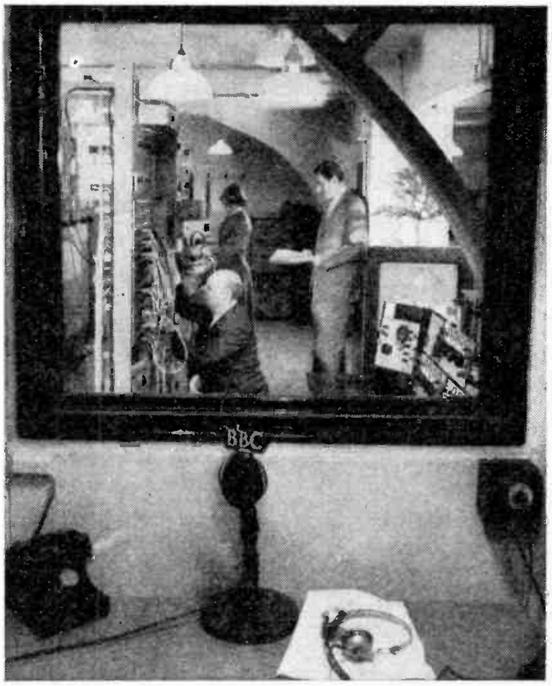
Extremely small scale models of aircraft (so small that the wingspan of the giant B-29 bomber is reduced to about 4in) are employed in a study of electrical resonance effects in the aircraft structure. A knowledge of these resonance effects is important to the design of flush-mounted aerials for long-distance communications between aircraft, and to the development of such navigational aids as the automatic radio-direction finder.

One significant phase of the work currently under way in the laboratory concerns the use of a single aircraft aerial system for a number of radio equipments. This work is part of an extensive programme of aerial development directed towards a reduction in the structural modifications required to provide flush-mounted aerials for the radio equipment used in existing aircraft. One aspect of this study has led to the development of an automatic aerial matching unit, a device which automatically and continuously "tunes" the flush-mounted aerial to the operating frequency of the radio transmitter with which it is employed. Use of this device ensures the maximum operating efficiency of the aircraft radio system of which it is a part, regardless of changes in the operating frequency or in the aerial characteristics. Such changes might result from the accumulation of ice on the aerial, for instance, which may occur in flight.

This programme also includes the development of other components, primarily filter networks, which serve to allow the various equipments to be operated without interaction. Work on some of these units has led to research, still in progress, on circuits with novel characteristics.

The investigations have contributed extensively to an understanding of such fundamental problems as the diffraction of radio waves by aircraft structures, the excitation of the airframe itself as an aerial for medium-high frequencies, and the relationship between the geometrical properties of wing sections and their behaviour as aerials.

"Radiophonic" Workshop



Part of the new studio and laboratory which the B.B.C. has established at Maida Vale for the evolution and adaptation of new sound effects for creating atmosphere in broadcast plays. Technical resources for manipulating either original or synthesized sounds include tape loop recorders, artificial reverberation and a wide range of filtering and mixing circuits.

Semiconductors Again

By "CATHODE RAY"

Understanding Them from the Energy Point of View

WHEN I first broached the subject of semiconductors (July 1956 issue) my diagrams indicated the relative *positions* of the atoms and electrons in the crystal structure. Even if you didn't see those particular diagrams, Fig. 1 may look familiar, for something of the kind appears in most simple explanations of semiconductor theory. Relative position is one of the few things that can be *directly* represented on paper, and so presents least difficulty at a first approach to a subject.

Lately we have been approaching semiconductors by a different route—*energy*. By now we ought to be quite used to diagrams showing the relative energies rather than positions of the electrons around the atom. There are several reasons for our going into the whole thing again in this way, even with diagrams that come less natural. One reason is that we get a clearer impression of anything by seeing it from more than one viewpoint—in the solid, as it were. Another reason is that in electronics energy is more fundamental than position. Indeed, we have learnt that it is impossible ever to know both energy and position of an electron exactly; and since we do know electron energies fairly precisely their positions are wrapped in obscurity which can be represented in a diagram by nothing clearer than a haze, or at best a graph or equation of probability.

In place of the beginners' position diagram, then, we now have an energy diagram. In single atoms there are a number of possible or "permitted" energy levels, which appear on such a diagram as lines one above the other like the rungs of a ladder. Not more than two electrons in an atom can occupy the same energy level. Apart from disturbances by heat, etc., the electrons settle down into the lowest possible levels, all those above being empty. The levels occur in groups, and except for the inert gases (which have all their groups just filled) there are one or more electrons above the highest filled group, called valency electrons. These are much more important than the others, because they bear almost the whole responsibility for external relations, as in chemical combination, solidification, etc. The lower-energy electrons are therefore often lumped together with the nucleus as "the atom" while we concentrate attention on the valency electrons. Fig. 2, for example, ignores all except the valency electrons. In a crystalline solid, to which Fig. 2 refers, the interaction between the closely spaced atoms causes their single equal energy levels to spread out into innumerable closely-spaced levels which can be regarded as a continuous band. The highest levels spread out most, and often two bands overlap, especially in metals, which have no gap between the valency band and the next higher band. These therefore have plenty of scope for the electrons to accept the small amounts of energy available from the electric field set up by an e.m.f., and the material is a good conductor. A sizeable gap—say, several eV

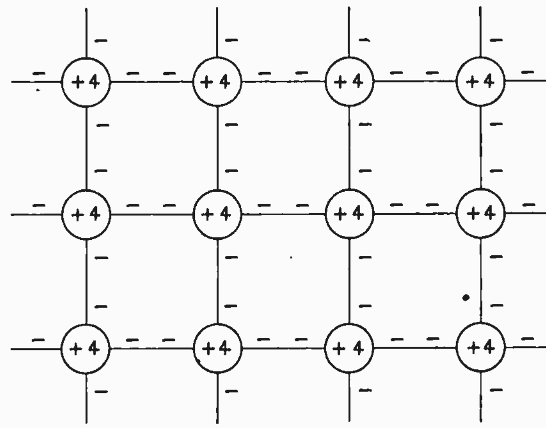


Fig. 1. This kind of diagram is intended to show, albeit somewhat crudely, the relative positions of the parts in solid structure.

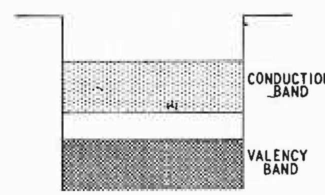


Fig. 2. Simple energy diagram for a solid, ignoring all except the band of energy levels filled by the valency electrons, and the next higher band, which is empty.

(electron-volts)—above a band full of electrons prevents them from accepting such energy, and the material is an insulator. But if the gap is not much more than 1eV an appreciable number of electrons get enough energy from heat (or light) to cross the gap and thereby become available for conduction.

Of the elements whose atoms have four valency electrons each, carbon in the form of diamond has such a wide gap that even at quite high temperatures hardly any electrons can cross, so it is an insulator. Silicon—the next in order of atomic number—has a gap of about 1.1eV, which can be crossed by very few electrons at room temperature but by appreciable numbers when hot. Germanium has a gap of about 0.7eV, which means that it conducts slightly even at room temperature, and quite a lot at 100°C. Like silicon, it is classed as a semiconductor. Tin and lead have no gap at all, so they are good conductors at any temperature.

As the title says, we are concentrating now on semiconductors. I mentioned last month that the sort of semi-conduction just described is called *intrinsic*, because it is a property of the material itself. For most practical purposes it is wholly unwanted. The sort of conduction we actually use, in rectifiers and transistors, is due to impurities. The word "impurity" usually suggests something undesirable, but in this case it is an essential.

Impurity conduction is explained with position diagrams by saying that when an atom of some element with five valency electrons (such as arsenic) usurps a place in the crystal lattice structure it has one spare electron, which is free to take part in an electric current. So such an atom is called a *donor*. An atom with three valency electrons (such as indium) has one electron short, leaving a hole into which an electron from elsewhere can move, again giving rise to a current. This kind of impurity is called an *acceptor*.

While all this agrees pretty well with the behaviour of actual materials and makes a nice easy story for a first approach, it doesn't fit very well into our more enlightened (we hope!) picture in which *all* the valency electrons are in continuous rapid circulation. In this picture, the few electrons that are available for taking part in currents—the conduction electrons—cannot be distinguished by their positions from the many that aren't. That is where energy diagrams come in. In Fig. 2, representing a perfectly pure semiconductor, the valency electrons, which are extremely mobile as regards position, fill the valency band so completely that they are altogether immobile as regards energy. They can do no more than exchange (energy) places, causing only small local currents that cancel one another out. The only ones available for through traffic are the few that get enough energy from heat, etc., to rise into the empty or conduction band.

Last month I advised you not to forget all about Fermi and his curve and you may be wondering when he is going to reappear. The answer is, now. The reason is that the Fermi curve is a great help in understanding semiconductors, and especially junctions between different kinds.

A Fermi curve is plotted from an equation arrived at by theory and confirmed pretty well in practice:

$$F = \frac{1}{e^{(E-E_F)/kT} + 1} \quad \text{or} \quad \frac{1}{10^{0.4343(E-E_F)/kT} + 1}$$

Here E, energy level, is the variable, and F is the proportion of permitted electron energy states at that level which are occupied by electrons.* E_F is a constant energy level for any particular material, and is called the Fermi level. At that level ($E = E_F$) the exponent is zero, and any number to the power zero is 1, so $F = \frac{1}{2}$. In other words, the Fermi level is the boundary between energy states which are more than half full and those that are more than half empty. T is the absolute temperature, which under living conditions is usually about 290°K (17°C); and k is Boltzmann's constant, 8.6×10^{-5} eV per degree, so at 290°K the value of kT is 0.025eV. When E is 0.1eV above E_F, F works out at 1/55, which means that nearly 2% of available energy states are filled. At 10 times that height above the Fermi level, F (thanks to the exponential relationship) is only about 0.0000000000000005%! At *below* E_F, the figures are the same for the proportion of places *not* filled.

Fig. 3 is a typical Fermi curve. A look at the equation shows that at higher temperatures all the values of $E–E_F$ (at a given F) go up in proportion, so that the curve slopes more steeply. This expresses in an exact way the fact that heat raises more electrons to the higher energy levels. When the temperature is reduced to 0°K the curve flattens out until it coincides with the Fermi level E_F, which means that all possible levels up to that are completely filled with electrons, and all those above are completely empty.

In a metal, all energy levels in the range covered by the important part of the Fermi curve are "available" or "possible"—there is no gap between the basic valency levels and those into which electrons can be lifted by heat, etc.—so if the energy levels in a band were all equally spaced the Fermi curve would also represent to scale the actual distribution of valency electrons at the temperature for which the curve was plotted. The whole area below it would represent the total number of electrons in the crystal. As it happens, the levels are not equally spaced, but over the range concerned this doesn't make any very vital difference and the Fermi curve does roughly show the energy distribution of valency electrons in metals. In particular, the portion of area above E_F represents fairly well the number of electrons displaced, and the equal area between E_F and the right-hand half of the curve represents the number of vacancies thus created. The same thing is shown rather crudely but more picturesquely in Fig. 4.

But what happens when there is a gap, as in semiconductors? By definition, a gap is an energy band within which there can be no electrons, so the Fermi curve cannot then represent actual electrons all the way up. But since any electrons displaced inevitably create an equal number of holes, it is clear that the only place for the Fermi level is half-way up the gap, as in Fig. 5. At any other position, the areas representing free electrons and holes would be unequal.

To make the electron displacements big enough to see in this diagram, the Fermi curve has been drawn to represent either an unusually narrow gap or high temperature. In other words, it represents a semiconductor with unusually high conductivity. In practice, the proportion displaced would be far smaller, especially in silicon. Even in germanium only one electron in about five million can cross its 0.7eV gap at room temperature. As we saw last time, the Fermi relationship can be used to calculate the

(*Continued on page 341*)

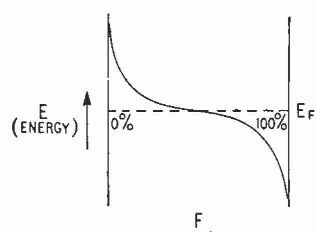
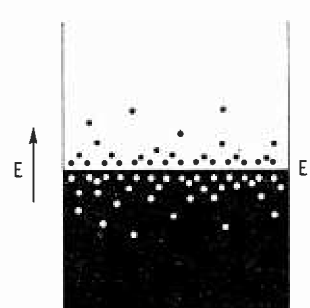


Fig. 3. Typical Fermi curve, showing the proportion of energy states filled (F) at any energy level (E). E_F, the Fermi level, is the half-filled level (except at 0°K, when it is the boundary between completely filled and empty).

Fig. 4. Pictorial and less exact representation of what the Fermi curve conveys—the distribution of electrons (black) and the vacancies created below the Fermi level by those raised above it by heat.



*You may object that there are never more than two places for electrons at any one energy level. But the Fermi curve refers in effect to a very narrow band centred on level E. Even a band no thicker than a printed line on the graph can include vast numbers of electrons.

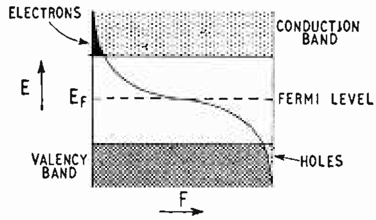


Fig. 5. How the Fermi curve is placed in the energy diagram of a pure semi-conductor. The intrinsic conduction is due to the mobility of the electrons in the conduction band and the holes in the valency band. The higher the temperature, the steeper the Fermi curve, indicating more free electrons and holes, so greater conductivity.

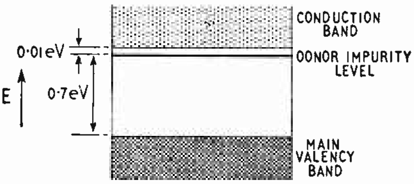


Fig. 6. A donor impurity level is so near the conduction band that at ordinary temperature almost all its valency electrons are found.

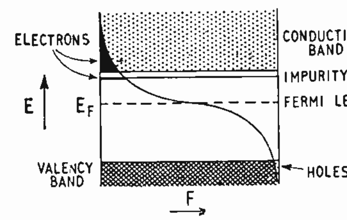


Fig. 7. The increased number of conduction electrons resulting from impurity means that the Fermi curve is higher up the gap, so the number of "intrinsic" holes decreases.

number of electrons raised to the conduction band at any temperature. Some further calculation gives the intrinsic conductivity. As one would expect from the Fermi equation, it increases (i.e., resistance falls) very rapidly with temperature.

Now we come to the interesting part—impurity conduction. Either of the two kinds of useful impurity (donor or acceptor) has its own little valency band. It is higher than that for germanium or silicon; comes in the gap, in fact. If of the donor type, its band is only about 0.01eV below the top of the gap, as shown in Fig. 6.

Now if we assume that the Fermi curve remains in the middle of the gap as in Fig. 5, and calculate the value of F at the bottom of the conduction band at 290°K we find it is less than one-millionth. Only 0.01eV lower it is little different, which means that less than one in a million of the impurity atoms have their valency electrons present. Where have they gone? Across the narrow gap into the conduction band.

Even if there is only about one part in a million of impurity, the fact that practically *all* its valency electrons have been lifted into the conduction band enables them to outnumber the very few electrons that succeed in crossing the main gap. So even when the amount of impurity would seem by ordinary standards to be negligible, impurity conductivity can swamp intrinsic conductivity.

It is not only by outnumbering the original intrinsic conduction electrons that impurity does this. To represent the increased number of electrons in the conduction band, the Fermi curve has to be raised so that the Fermi level is above the half-way position (Fig. 7). This inevitably indicates a reduced number of holes in the valency band, which means that the intrinsic conductivity is less than it was before the impurity was added. If we went into it in more detail we would find that the number of electrons in the conduction band *multiplied* by the number of holes in the valency band was constant.

Obviously the greater the amount of impurity to supply the conduction band with electrons, the higher the Fermi level must be if the area within that band and below the Fermi curve is to represent the number of electrons. It is true that the new position of the curve indicates more electrons retained in the impurity band, but even if it went up from one in a million to ten in a million it would still be negligible.

What happens when we vary the temperature? Raising it steepens the slope of the curve and increases the number of electrons raised from the vast resources of the main valency band. The impurity band, on the other hand, has already yielded practically all its electrons, so is in no state to compete. Beyond the point where main electrons outnumber the impurity electrons the conductivity increases (resistivity falls) very steeply, and the Fermi level approaches the centre of the gap. Clearly, the temperature at which this "roll-off" takes place is higher the greater the amount of impurity or the lower the intrinsic conductivity. So we get curves something like Fig. 8, in which the slope on the right represents the effect of intrinsic conduction. If these curves refer to germanium, a corresponding set for silicon would have this slope farther to the right.

Lowering the temperature has little effect if one starts from a point where most of the conduction is by impurity electrons. There is a slight rise in resistance due to elimination of the remaining intrinsic conduction. When this has happened, the Fermi level is somewhere near the impurity level. Then there is a slow fall for the same reason as in conductors. It is only when the temperature is nearly down to zero that the impurity electrons have much difficulty in crossing the 0.01eV gap; then, with the Fermi curve almost horizontal and above the impurity level, the resistance rises as shown by the turn-up at the extreme left of Fig. 8.

The useful working conditions are within the flat range. It is because room temperature is near the right-hand end of this range for germanium that devices made of it have such limited temperature ratings compared with silicon.

So much for semiconductor with donor impurity, known as *n* type because the current carriers are electrons, which are negative charges. There is hardly need to go through the story of semiconductors with acceptor impurity in such detail, because it is the same except for being upside down. The impurity band is only about 0.01eV above the main valency band, so contributes a completely negligible number of electrons to the conduction band, but electrons in the main valency band cross the narrow gap into the impurity band almost to the complete extent of the very limited accommodation there. Practically all the impurity atoms are thereby converted into fixed negative ions. This removal of some of the top electrons from the valency band leaves room for others to move up, just as removals to Head Office leave room for promotions within a branch. Such movements of electrons, when there is an applied e.m.f., are an electric current. So this sort of impurity too enables the material to conduct. The number of vacancies created in the valency band is limited by the number of impurity atoms, not by the vastly greater number of electrons in the valency band that have enough energy to jump the narrow gap.

These vacancies are commonly known as holes. Many quite learned gentlemen of the old school seem to find them mystifying. I don't know why. It should be as easy to see that the movement of a hole in one direction is really a lot of shorter movements of electrons in the opposite direction as it is to see that movement of the bubble in one direction along a spirit level is really a lot of shorter movements of drops of spirit in the opposite direction. It is just more convenient to refer to what happens as the movement of a bubble or a hole than the much more complicated movements of electrons or spirit. Since movement of electrons in one direction is equivalent to movement of positive charges in the opposite direction, holes are equivalent to positive charges, and material with acceptor impurity is called *p* type.

The only practical difference, apart from polarity, between *n*-type and *p*-type conduction is that—as one might expect—a hole takes rather longer to move past all the electrons concerned than an electron takes to move an equal distance. In official terms, its mobility is less.

The equivalent *p* diagram to the *n*-type Fig. 7 is Fig. 9, and the effects of varying temperature and amount of impurity are similar.

Now we come to the crucial matter of what happens when *p* and *n* materials are brought into intimate contact. The "position" story tells how electrons in the *n* region find themselves with no barrier between them and an almost electronless *p* region, so they start spreading across into it. Similarly the holes in the *p* region spread into the *n* region. Both of these movements are equivalent to a conventional positive current from *p* to *n*, and very quickly the *n* region becomes positively charged relative to *p*. The electrons and holes thus automatically establish a barrier against their own further trespassing. A balance is established when this potential barrier is enough to suppress any net inter-region movements.

Let us see how this compares with putting the corresponding energy diagrams together—Figs. 7 and 9. If we do so with the conduction and valency bands in line all the way across we see that the electrons are unequally distributed, being more on the *n* side than the *p*. Similarly holes are more numerous on the *p* side. If we alter the alignment until electron and hole density is the same at any level, as in Fig. 10, we find that the Fermi level is necessarily the same right through, and it is the energy levels or potentials of the material that have to change on going from one region to the other.

This represents a condition of balance, in which most of the electrons remain on the *n* side because they have insufficient energy to climb the step that leads to the *p* region. The few (intrinsic) electrons on the *p* side of the conduction band tend to drop down this step into the *n* side, but are exactly balanced by the small fraction of the many electrons on the *n* side that have enough energy to bring them to the same level. One can perhaps picture the thing better by replacing the Fermi curves by the Fig. 4 type of picture, with lead-shot electrons kept in a stage of agitation which gives them a Fermi distribution. Similarly holes, like bubbles, tend to float up to the top of the valency band, but again there is a balance with those few that are created at relatively low levels on the *p* side.

There are more scientific ways of examining the *p-n* problem, but they too lead to the conclusion that the whole combination has a common Fermi level. They also confirm that our lead-shot-and-bubble mechanical model is basically sound The level changes less abruptly than suggested in Fig 10, however; there is actually what is called a transition zone, but it is usually only about a thousandth of a millimetre thick.

One of the most important things is the height of the step in volts—the difference of potential at the junction. Our E scale is in electron-volts, and since the particles concerned on the *n* side are electrons the scale also measures p.d. in volts. But because electrons are negative charges, it measures negative volts. So the fact that the *n* side is lower than the *p* side means that it has a *higher* positive

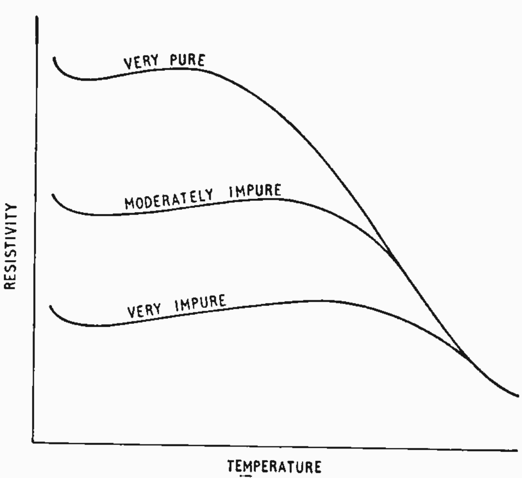


Fig. 8. The peculiar shapes of these resistivity/temperature curves for a semi-conductor can be predicted from Fermi theory.

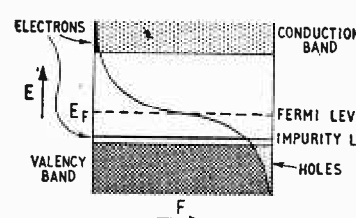


Fig. 9. This diagram is similar to Fig. 7 except that the impurity is p type, bringing the Fermi level below the middle of the gap.

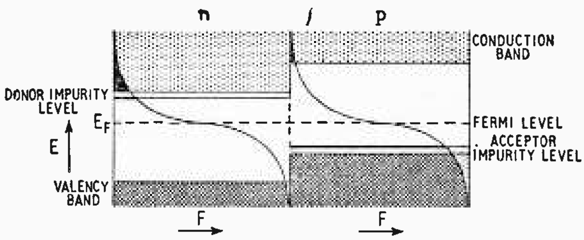


Fig. 10. When n- and p-type materials are in close contact, electron and hole densities at any level must be the same throughout. This necessitates the Fermi level being the same throughout and creates a potential step at the junction.

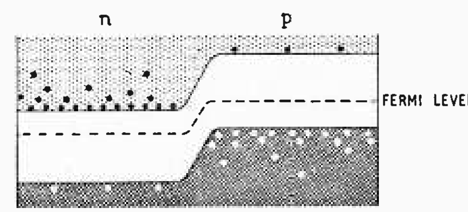


Fig. 11. Forcing the Fermi levels apart by an externally applied voltage either increases the step, restricting the current flow to intrinsic carriers only (as here), or reduces it, increasing the flow of impurity carriers.

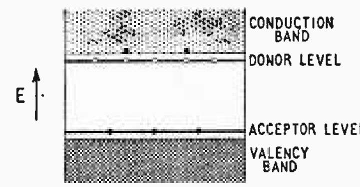


Fig. 12. Diagram showing "compensation," whereby the effective impurity when both are present is equal to the difference between the two.

potential, which agrees with what the particle-diffusion story told us.

If you have been following everything you should be able to predict broadly what happens if the temperature is raised or lowered or if the proportion of impurity is increased or decreased. For example, assuming that the material is germanium at ordinary temperature, so that conduction is predominantly by impurity carriers, the dark area representing free electrons on the *n* side of Fig. 10 must be considerably larger than that on the *p* side. For this to be so the separate Fermi levels must be considerably displaced above and below the centre of the gap. The potential step is equal to the sum of these displacements (usually of the order of 0.3V). If the material is heated, the intrinsic conduction is increased, so the electron area on the *p* side must be greater, the Fermi level displacement less, and the potential step smaller. This also happens if the amount of impurity is less, since there are fewer electrons to be presented by the dark area on the *n* side. If two regions of the same type were in contact, their Fermi levels would be the same distance up the same gap, so there would be no potential step.

Books and articles on this subject carefully avoid explaining how it is that the difference of potential between the terminals of a *p-n* rectifier (or either pair of adjacent terminals of a transistor) is not detectable by even a very high-resistance valve voltmeter. Last September I rashly and rather unthinkingly ventured a diagram (Fig. 7 on p. 434) that purported to supply such an explanation. It drew from Mr. A. Richardson of Newcastle the observation that a homogeneous, electrically isotropic, conducting piece of material at uniform temperature, subject to even a small potential gradient without a current, was such an unusual state of affairs as to be worth an article to itself. He hoped I would return to the subject. This I now do by withdrawing that explanation in favour of the answer that the junctions elsewhere in the circuit (notably the metal-to-semiconductor junctions) introduce counteracting potential steps.

Having (I hope) disposed of that difficulty we can now come to what happens when an e.m.f. is applied to the *p-n* terminals from some external source. Because it alters the relative pontentials of the two regions, it forces their Fermi levels apart by an amount equal to its own voltage. Suppose first the external source is positive to *n*. That is represented on the diagram by a relative lowering of the *n* side, as in Fig. 11. The result is that the impurity electrons on the *n* side are faced with a higher step, so stand even less chance than before of surmounting it. The intrinsic electrons on the *p* side easily fall down to the *n* side. Similarly for holes from *n* to *p*. There is therefore a current from *n* to *p*, which is the direction of the applied e.m.f. But because these carriers are few in number at ordinary temperature, this current will be small. For the same reason, it cannot be increased by applying a greater voltage (short of breakdown). However, it will increase rapidly with temperature.

If the applied e.m.f. is of the opposite polarity, the height of the step will be reduced. This obviously will make the impurity electrons spill over from the *n* to the *p* side. Since the original height of the step was only a fraction of a volt, a "forward" e.m.f. of comparable amount is enough to release very considerable quantities of electrons from *n* to *p*, and similarly holes from *p* to *n*. So it is quite easy to see why a *p-n* junction is a rectifier.

Finally, just one more important point. In real life it is more than likely that there would be some of both kinds of impurity in the same material, and one might expect this to complicate the situation quite a lot. But it's really quite simple. Suppose for example there are five donor atoms for every three acceptor atoms, as shown diagrammatically in Fig. 12. Neglect intrinsic conduction. One might guess that three electrons would jump up from the valency band to the acceptor atoms, creating holes, and the five electrons in the donor band would jump up into the conduction band. In other words, the two impurity conductions would *add*. But the donor electrons find it much easier to drop their electrons to the acceptor atoms, putting them out of action as acceptors from the valency band, and only two donor electrons are left for the conduction band. In general, then, the two impurity conductions *subtract*. The result is that semiconductor material can be "purified" by adding an equal quantity of the opposite kind of impurity to that already present. There are practical limits to this dodge, but it is very useful for converting *p* to *n* and vice versa.

The Schmitt Multivibrator

Reliable Design Procedure and Uses of the Circuit

By *G. L. SWAFFIELD*

Of the several types of multivibrator circuit in use today, one remains in relative obscurity, possibly due to its comparative complexity of design.

In its simplest form this multivibrator circuit comprises a free-running cathode-coupled pair of triodes and is very useful both as a master pulse generator and for providing a repetitive sawtooth waveform.

At one anode a positive-going pulse is generated, being coincident with the flyback of the sawtooth waveform, and this pulse, developed across a " free " anode load, may be used among other purposes for suppressing the flyback of the sawtooth if the last-mentioned is utilized for scan generation.

A high and variable mark-space ratio of the pulse waveform is obtainable without necessarily altering the pulse width, and the circuit p.r.f. is readily synchronized to either a positive- or negative-going external pulse source.

A simplified design procedure is presented below

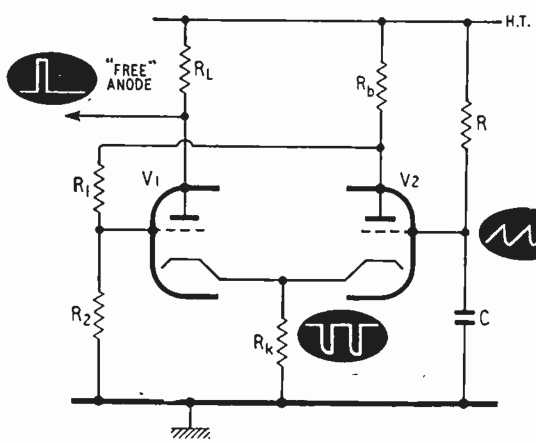


Fig. 1. Basic Schmitt multivibrator circuit.

in which circuit values are obtained by successively substituting the appropriate specification figures in a series of formulæ. Within reason, this process enables the specified a.c. waveforms to be generated at predetermined d.c. levels.

The simple circuit arrangement is shown in Fig. 1, where it is seen to consist basically of the well-known Schmitt trigger circuit.[1] In fact regeneration from stage 1 to stage 2 is due to the high degree of " backlash " or overcoupling between these stages and in this respect it is identical to the conventional Schmitt trigger circuit. Relaxation, on the other hand, is due to the network CR in the grid circuit of V_2.

Before the h.t. voltage is applied to the circuit, capacitor C is uncharged and the grid of V_2 is at earth potential. As soon as the h.t. voltage is applied, however, V_1 grid is raised to a positive potential determined by the chain of resistors R_b, R_1 and R_2. Because V_2 grid is instantaneously at earth potential, V_2 is biased off by the large grid-to-cathode voltage thus produced. Capacitor C will therefore commence to charge through resistor R toward h.t. and the potential at V_2 grid rises according to the exponential curve in Fig. 2.

V_2 grid will thereby rise to within a grid base of the cathode potential, and as soon as V_2 begins to conduct the anode current flowing through the anode load R_b lowers the potential of V_1 grid via the coupling R_1 and R_2. The gain of the circuit in this direction is designed to be great enough to ensure that V_1 is biased off by this drop. This high gain requires a high value of anode resistor R_b and as a result the anode current in V_2 is much less than that in V_1. Consequently the cathode potential is much reduced and V_2 grid is now highly positive with respect to the cathode. Capacitor C then discharges through the diode formed by the grid and cathode of V_2, the time of discharge being determined by the value of C and the effective resistance of the diode and cathode resistor.

As the potential of V_2 grid, and hence that of the cathode, falls during discharge, the bias on V_1 grid decreases, reaching a value at which V_1 can once again draw current.

The cycle of events can now be repeated and a free-running multivibrator action results. The time relationship of the appropriate waveforms is shown in Fig. 3.

The frequency of oscillation depends mainly on the values of C, R and R_k and the h.t. voltage, and can be synchronized to an external source in such applications as line or frame scan generators. Positive synchronizing pulses are fed to the grid of V_2, and negative pulses to either V_1 grid or the cathode.

The diagram of Fig. 3 also indicates the symbols used to denote the positive and negative peaks of the waveforms generated. For example the cathode waveform has a positive peak and hence d.c. level of V_k'' and a negative peak and d.c. level of V_k'. These symbols are used in the formulæ that follow.

In each and every instance the suffix 1 refers to potentials associated with V_1 in all diagrams, and suffix 2 to those relating to V_2.

A procedure which permits the design of a.c. waveforms at predetermined d.c. levels can be complicated by the interdependence of the values of R_b, R_1 and R_2. These values in turn determine the operating conditions of the valves.

If, however, the specification for a multivibrator performance is interpreted first in terms of valve d.c. operating conditions, then appropriate resistance

[1] " A Thermionic Trigger," by O. H. Schmitt. *Journal of Scientific Instruments*, 1938, 15.

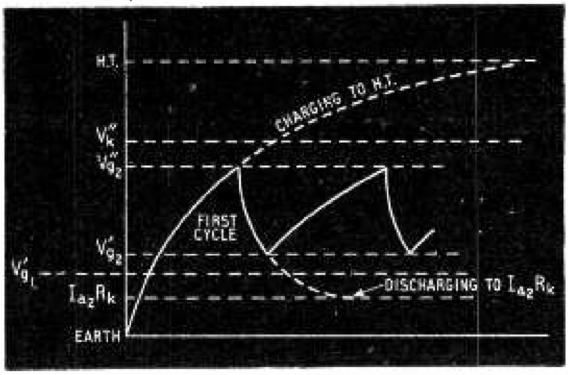


Fig. 2. Sawtooth generation and associated d.c. levels.

values can be solved easily from a series of formulæ.

Typically a specification for the circuit performance may define one or all of the following outputs.

1. Rise time (t_r) of the pulse at the free anode (anode 1) between 10% and 90% full value.
2. Amplitude (V_o) and d.c. level (V_{a1}) of the pulse at the free anode, and pulse width (t_d). (See 5 below.)
3. Amplitude (A) and peak positive d.c. level (V_{g2}'') of sawtooth at grid 2.
4. Time of sawtooth scan (t_c).
5. Time of flyback of sawtooth (t_d). This determines the free anode pulse duration also.

Coming now to the actual design procedure of the circuit, the steps are as follows:—

1. Determine V_1 anode load R_L from the well-known formula:—

$$t_r = 2.2C_sR_L$$

where C_s is the value of stray capacitance associated with the free anode circuit.

$$\text{Hence } R_L\,(\text{k}\Omega) = \frac{t_r}{2.2C_s}\ \frac{(\text{m}\mu\text{sec})}{(\text{pF})}$$

2. Determine V_1 anode current I_{a1} to flow through R_L to give the required output amplitude V_o:—

$$I_{a1}\,(\text{mA}) = \frac{V_o}{R_L\,(\text{k}\Omega)}$$

The specified d.c. level V_{a1} is obviously the difference between the h.t. potential and the amplitude of the output pulse V_o. To obtain the correct d.c. level it may therefore be necessary to resort to dropping and decoupling components in the anode circuit.

3. The peak positive d.c. level V_{g2}'' corresponds within a grid base to V_k'', which in turn equals $I_{a1}R_k$. Allowing for a grid base, estimated from valve curves, calculate V_k'', and hence R_k from:—

$$R_k\,(\text{k}\Omega) = \frac{V_k''}{I_{a1}\,(\text{mA})}$$

4. For the known h.t. value, determine the modified V_1 anode current and appropriate grid bias V_{gk1} (resulting from the use of nearest available values of R_L and R_k to those calculated) necessary to develop the specified d.c. level at either V_1 anode or V_2 grid, whichever is the more important. The grid bias V_{gk1}, added to V_k'', gives the positive peak value of V_1 grid voltage V_{g1}''

i.e. $V_{g1}'' = V_k'' + V_{gk1}$

If no d.c. level is specified either for the sawtooth waveform at V_2 grid or for the cathode potential V_k'', the last-mentioned can only be allocated by intelligent use of the valve characteristic curves. Choose a level which is consistent with valve dissipation requirements while at the same time keeping V_1 out of grid current. As a very rough guide, a minimum level of 30% of the h.t. voltage can be used if power dissipation considerations allow it.

It will then be necessary to add V_{co2}, the grid base of V_2, to V_k'' selected by this means, to determine V_{g2}''. (Note that V_{co2} itself is dependent on V_2 anode-cathode voltage and hence on V_k''.)

Thus $V_{g2}'' = V_k'' + V_{co2}$

5. From V_{g2}'', the positive peak of the sawtooth, subtract A, the required amplitude of sawtooth, to obtain V_{g2}', the negative sawtooth peak:—

$$V_{g2}' = V_{g2}'' - A$$

Since V_2 is drawing grid current at this level, V_{g2}' is slightly positive with respect to the lower cathode potential V_k'. V_k' will therefore be approximately a volt less than V_{g2}'.

Thus $V_k' \doteqdot V_{g2}' - 1$

6. Knowing R_k, the cathode current I_k can now be calculated:—

$$I_k = \frac{V_k'}{R_k}$$

Note that I_k is due to the sum of grid and anode currents of V_2:—

i.e., $I_k = I_{g2} + I_{a2}$

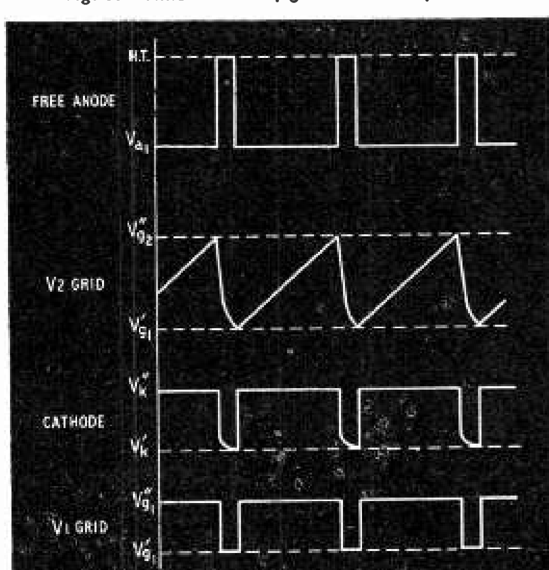
7. Valve curves giving both grid and anode characteristics must now be used to determine the grid and anode currents flowing at the end of the discharge cycle.

Typical curves for the 6J6 or ECC91 are given in Fig. 4.

A trial and error process is involved here, since both grid and anode currents must be selected from separate curves, each corresponding to the grid-cathode potential determined earlier and at the same anode-cathode potential. It may be found at this stage that the positive grid bias estimated in stage 5 is too great, in which case a smaller value must be assumed.

In any event from this process an anode-cathode

Fig. 3. Time relation of generated waveforms.



voltage V_{ak2} will result for V_2 when the last-mentioned conducts, generally lying between 5 and 30 volts.

Adding this value to V_k' will give the conducting anode potential V_{a2} of V_2:—

$$V_{a2} = V_k' + V_{ak2}$$

8. Finally calculate the negative level at V_1 grid, V_{g1}'. To do this use the valve characteristics to estimate the grid base V_{co1} of V_1 for the known h.t. potential and cathode potential V_k'.

Hence $V_{g1}' = V_k' + V_{co1}$

This completes that part of the design procedure involving static valve parameters. The remainder consists first of solving values for the resistance chain R_b, R_1 and R_2 by substituting the appropriate d.c. levels obtained above in the formulæ that follow, and secondly, calculating the value of C and R to produce the specified scan and flyback times.

9. Solve R_b from

$$R_b = \frac{\text{h.t.}}{I_{a2}}\left[\frac{V_{g1}'' - V_{g1}'}{V_{g1}''}\right]$$

10. Solve R_2 from

$$R_2 = \frac{R_b}{\text{h.t.}/V_{g1}'' - V_{a2}/V_{g1}'}$$

11. Solve R_1 from

$$R_1 = R_2(V_{a2}/V_{g1}' - 1)$$

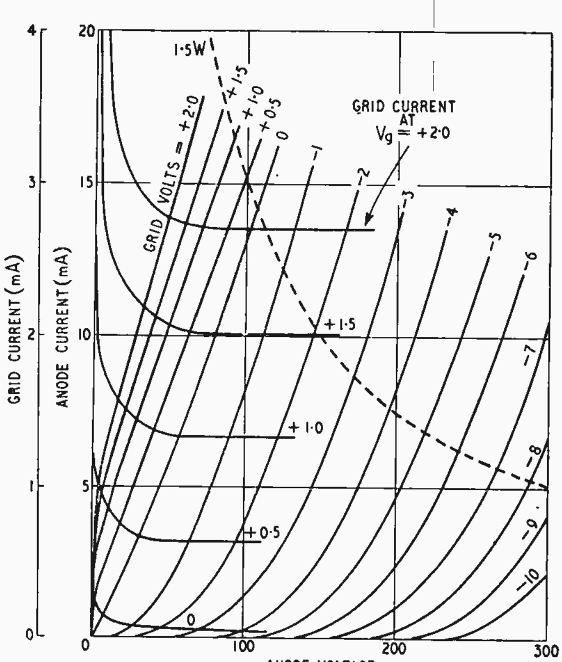
12. While capacitor C discharges via the grid-cathode diode of V_2 into cathode resistor R_k, I_{a2} is approximately constant if R_b is high. C therefore discharges into a grid-cathode impedance in series with R_k across which a potential difference of $I_{a2}.R_k$ exists.

Capacitor C will thus discharge from V_{g2}'' towards $I_{a2}\,R_k$, but will in fact be caught at a level V_{g2}'. If the charging resistor R is high the current drain through this component is negligible and the discharge law is exponential. Fig. 5 gives superimposed graphs of the normal capacitor charge and discharge curves with the time constant ratio $\frac{t}{CR}$ plotted against $\left(1 - \epsilon^{-\frac{t}{CR}}\right)$ and $\epsilon^{-\frac{t}{CR}}$ respectively. The ordinate therefore is plotted in units representing instantaneous fractions of the final charged and discharged capacitor potentials respectively. Using the discharge curve, $\frac{t_d}{CR_d}$ corresponds to

$$\frac{V_{g2}' - I_{a2}R_k}{V_{g2}'' - I_{a2}R_k}$$

Here t_d is the specified flyback (discharge) time, and the duration of the free anode pulse, and $R_d = R_k + V_2$ (grid-cathode impedance), say 1kΩ. The value of C may thus be calculated.

Fig. 4. Grid and anode characteristics of the 6J6 or ECC91 valve.



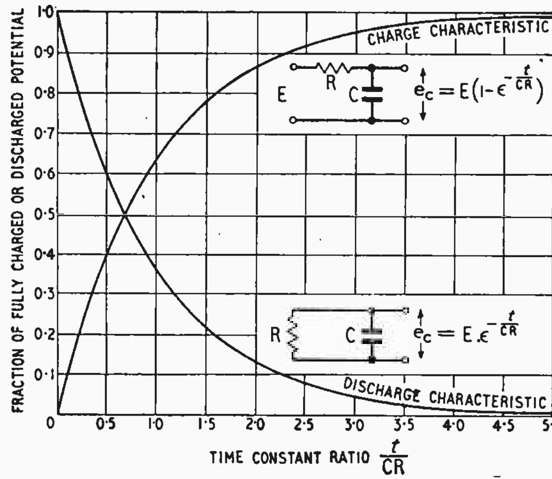


Fig. 5. Capacitor charge and discharge curves.

13. The charging cycle is straightforward; V_2 grid rises from V_{g2}' towards h.t. but is caught at V_{g2}''. Using the charge curve, $\frac{t_c}{CR}$ corresponds to

$$\frac{V_{g2}'' - V_{g2}'}{\text{h.t.} - V_{g2}'}$$

where t_c is the specified scan (charge) time. Knowing C from the previous calculation, the value of R can be solved.

This completes the design process, although since it is very unusual for exact values to be found for resistors R_b, R_1 and R_2 some repetition of the steps 7 to 11 may be necessary to effect an acceptable compromise between specified and obtainable performance.

The following design example serves to demonstrate that the procedure is not as laborious as might be thought. No correction is applied to the calculated values to yield a performance closer to that specified.

The specification is as follows:—

1. Amplitude of pulse (V_o) = 15V with rise time $t_r \not> 0.1\,\mu$sec.
2. Scan amplitude (A) = 50V with peak positive level of 100V d.c.

(*Continued on page 347*)

3. Scan duration (t_c) = 1200μsec.
4. Flyback time (t_d) = 100μsec.

The valve to be used is the 6J6 and the h.t. potential is 300V, while the stray capacitances at the "free" anode are estimated at 30pF.

1. $R_L = 1.5\text{k}\Omega$.
2. For V_o of 15V, $I_{a1} = 10\text{mA}$.
3. Specification requires upper d.c. level of sawtooth to be 100V, and hence cathode level will be more than 100V by the grid base of the ECC91 for approximately 300–100 volts anode-cathode.

Curves give grid base of $-$ 9V for V_{ak} of 200V.

Hence $V_k'' = 109\text{V}$

and $R_k = 10.9\text{k}\Omega$ say $11\text{k}\Omega$, whence $V_{g2}'' = 101\text{V}$

and $V_k = 110\text{V}$

4. For true V_k'' of 110V, V_{ak1} when conducting $= 175\text{V}$. Thus for $I_{a1} = 10\text{mA}$, V_{gk1} from curves $= -2.9\text{V}$. Hence $V_{g1}'' = 107.1\text{V}$.
5. $V_{g2}' = 101\text{–}50 = 51\text{V}$.

Assume $V_{gk2} = 0.5\text{V}$. Then $V_k' = 50.5\text{V}$.

6. $I_k = \dfrac{50.5}{11} = 4.6\text{mA}$.
7. Use grid current curves at $V_{gk2} = 0.5\text{V}$ to determine V_{ak2} when conducting total I_k of 4.6mA due to anode-plus grid-current:—At $V_{gk2} = 0.5\text{V}$, $V_{ak2} = 22\text{V}$, $I_{a2} = 3.9\text{mA}$, $I_{g2} = 0.72\text{mA}$.

Thus $V_{a2} = 50.5 + 22 = 72.5\text{V}$.

8. $V_{co1} = -10\text{V}$. Hence $V_{g1}' = 40.5\text{V}$.
9. $R_b = \dfrac{300}{3.9}\left[\dfrac{107.1\text{–}40.5}{107.1}\right] = 48\text{k}\Omega$ . . . say $47\text{k}\Omega$
10. $R_2 = \dfrac{47}{300/107.1 - 72.5/40.5} = 46.5\text{k}\Omega$ . . . say $47\text{k}\Omega$.
11. $R_1 = 47\left[\dfrac{72.5}{40.5} - 1\right] = 37.1\text{k}\Omega$ . . . say $39\text{k}\Omega$.

At this point it may sometimes be necessary to recalculate the levels V_{g1}' and V_{g1}'', V_{a2}, V_{k1}' and V_k'' when the approximated practical values differ widely from those of the first calculations in order that the subsequent charge/discharge circuit design is not too inaccurate.

In this instance Table I compares required and approximated ideal values, assuming zero tolerance resistors.

Continuing the design, the value of C is next calculated from the specified pulse with data.

12.
$$\frac{V_g' - I_{a2}R_k}{V_g'' - I_{a2}R_k} = \frac{51 - 3.9 \times 11}{101 - 3.9 \times 11} = 0.139$$

Table I

	Required Level	Approximated Level
V_{g1}'	40.5	41.2
V_{g1}''	107.1	106
V_{a2}	72.5	75.4
V_k'	50.5	51.2
V_k''	110	109

From the discharge curve in Fig. 5, $\dfrac{t_d}{CR_d}$ corresponding to 0.139 is 1.95.

Now R_d is the sum of the grid-cathode impedance of V_2 as a diode and R_k, and is estimated at a total of $11.2\text{k}\Omega$ in this instance.

Further, t_d from the specification is to be 100 μsec.

$$\text{Therefore } C(\text{pF}) = \frac{t_d(\mu\text{sec})}{1.97R_d(\text{k}\Omega)} \times 10^3$$
$$= 4570 \text{ pF.}$$

The nearest available value is, of course, 4700 pF. The scan time of 1200μsec is next attempted.

13. $\dfrac{V_{g2}'' - V_{g2}'}{\text{h.t.} - V_{g2}'} = \dfrac{101 - 51}{300 - 51} = 0.201$ which on the charge characteristic of Fig. 6 corresponds to a ratio $\dfrac{t_c}{CR}$ of 0.22.

$$\text{Thus } R(\text{M}\Omega) = \frac{t_c(\mu\text{sec})}{0.22C(\text{pF})}$$
$$= 1.16\text{M}\Omega \text{ . . . say } 1.2\text{M}\Omega.$$

If the multivibrator is to be used principally as a scan generator then some attention must be given to linearity. In the above example, for instance, the resultant 10% linearity would not be considered good enough for many purposes.

If conventional feedback linearizing circuitry is not permitted then the scan amplitude as a percentage of the total h.t. voltage must be kept small. This requirement can be assisted by making V_{g2}' and Vg_2'' as low as is consistent with continued operation of the circuit. These considerations can assist in determining the performance specification for the circuit.

Circuit Applications.—Apart from its obvious

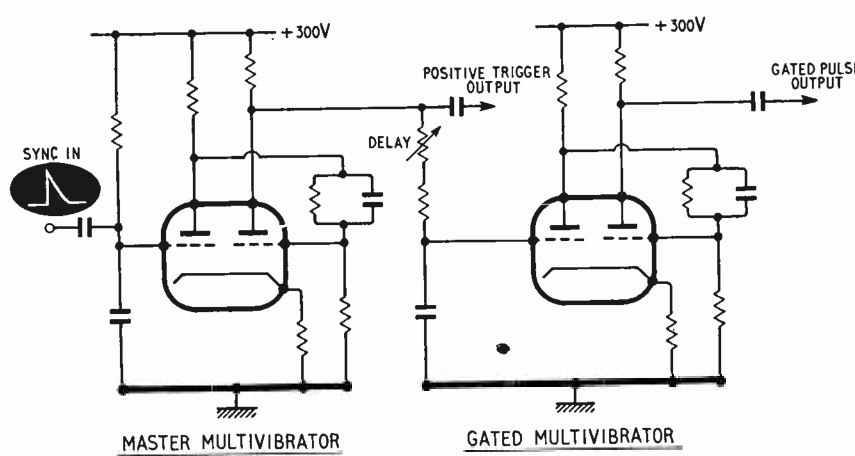


Fig. 6 Gated multivibrator for very low mark/space ratio.

use as a scan generator the circuit has other applications.

Its first recorded use[2] was in an industrial television waveform generator where in addition to generating a sawtooth it is used as a frequency divider. Here the master oscillator is controlled by a voltage derived from a discriminator which compares the master oscillator frequency, after division down to approximately mains frequency, with the mains frequency itself to establish frame lock. The master oscillator frequency, and hence line frequency, is thus maintained at a stable multiple of the frame frequency, which in turn is locked to the mains.

The multivibrator has also been used[3] in the well-known "staircase" dividing circuit, replacing the more normally encountered blocking oscillator.

Three multivibrators have been used in a circuit in which their operation is gated by three Schmitt trigger stages. The device was used as an electronic game.[4]

Two or more multivibrators can be coupled so that one gates the other. In such a connection the combination forms the basis of a useful pulse generator for waveforms of very small mark-space ratios—less than 1 : 3000. Fig. 6 shows the outline of such an arrangement.

A single multivibrator will normally tend to run irregularly at duty cycles less than 1/100. However, by designing one multivibrator to operate only when its charging grid voltage is at a higher potential than the conducting free anode potential of the controlling or master multivibrator, a gated operation results. If the limits of the gate pulse duration are set correctly, the controlled multivibrator will only produce one pulse in the gate duration. By such a means a $\frac{1}{2}$-μsec pulse at a p.r.f. of 1600 p.p.s. has been produced.

The leading edge of the gate pulse can be used as a positive trigger to an oscilloscope monitoring the fine pulse, which will then be displayed with a controllable delay. The master multivibrator can, of course, be synchronized to an external source as described earlier.

A slight variation of the basic multivibrator circuit has been described[5] which uses a triode-pentode combination to achieve similar results. In either form the multivibrator would appear to have several advantages over its oft-quoted astable partner, the cross-coupled multivibrator, and perhaps a simplified design procedure such as that presented here will assist in popularizing it.

APPENDIX

Derivation of Formulæ.—The anode voltage at V_2 is determined jointly by the current flow in the potential divider to V_1 grid and the anode current in V_2. Generally then

$$V_{a2} = \frac{R_1 + R_2}{R_1 + R_2 + R_b}\left[\text{h.t.} - I_{a2} R_b\right]$$

The two levels V_{g1}'' and V_{g1}' are a constant fraction $\frac{R_2}{R_1 + R_2}$ of the two levels at V_2 anode due respectively to no current flow in V_2 and some current flow I_{a2}. Hence

$$V_{g1}'' = \frac{R_2}{R_1 + R_2 + R_b}\ \text{h.t.} \quad \ldots \quad \ldots \quad (1)$$

and

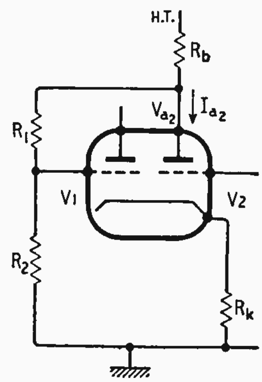
$$V_g' = \frac{R_2}{R_1 + R_2 + R_b}\ (\text{h.t.} - I_{a2}R_b) \quad \ldots \quad (2)$$

Subtracting (2) from (1), and dividing by (1) gives:

$$\frac{V_{g1}'' - V_{g1}'}{V_{g1}''} = \frac{I_{a2}\, R_b}{\text{h.t.}}$$

from which

$$R_b = \frac{\text{h.t.}}{I_{a2}}\left[\frac{V_{g1}'' - V_{g1}'}{V_{g1}''}\right] \quad \ldots \quad \text{formula (9)}$$



When V_2 is not conducting

$$\frac{R_2}{R_1 + R_2 + R_b} = \frac{V_{g1}''}{\text{h.t.}}$$

inverting and dividing l.h.s. by R_2 gives:—

$$\frac{R_1}{R_2} + 1 + \frac{R_b}{R_2} = \frac{\text{h.t.}}{V_{g1}''} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

But the ratio of resistances $\frac{R_1}{R_2}$ is the ratio of their voltage drops:

$$\frac{R_1}{R_2} = \frac{V_{a2} - V_{g1}'}{V_{g1}'} \quad \ldots \quad \ldots \quad (4)$$

and substituting this in (3) gives:—

$$\frac{V_{a2} - V_{g1}'}{V_{g1}'} + 1 + \frac{R_b}{R_2} = \frac{\text{h.t.}}{V_{g1}''}$$

from which $R_2 = \dfrac{R_b}{\dfrac{\text{h.t.}}{V_{g1}''} - \dfrac{V_{a2}}{V_{g1}'}}$ .. formula (10)

Finally R_1 is solved from (4)

$R_1 = R_2\,(V_{a2}/V_{g1}' - 1)$ .. formula (11)

BEAMA Catalogue.—The fourth edition of this massive volume of 962 pages is issued by our publishers on behalf of the British Electrical and Allied Manufacturers' Association. It includes a five-language glossary of technical terms used in the buyers' guide, which lists under more than 1,300 headings the electrical and allied equipment—including radio and electronic equipment—manufactured by members of the association. It costs £6.

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[2] "Simplified Television for Industry," by R. C. Webb and J. M. Morgan. *Electronics*, June, 1950, p. 70.
[3] "An Electrical Backlash Circuit," by C. H. Banthorpe. *Electronic Engineering*, March, 1954, p. 110.
[4] "Electronic Fruit Machine," by G. L. Swaffield. *Wireless World*, September, 1957, p. 447.
[5] "Grid-Diode Saw-tooth Generator," by T. A. Mendes. *Wireless World*, December, 1957, p. 603.

Pneumatically-Operated Aerial Mast

A COLLAPSIBLE aerial mast which can be fitted either permanently or temporarily to a vehicle and quickly and easily extended whenever required is an invaluable aid in taking field-strength measurements of television or v.h.f. broadcasting stations. There are not many masts of this kind available, so that a few details of a recently introduced, British-made mast should be of more than passing interest.

The illustrations show the mast collapsed preparatory to moving to a new site and fully extended to the maximum height of 45 feet. When collapsed the overall height is only 6ft 8½in. An aerial is shown fitted to the mast, and it will support a Yagi or any alternative v.h.f. or u.h.f. aerial of reasonable dimensions and weight.

The mast is telescopic and is pneumatically operated by means of any small motor-driven air compressor capable of delivering air under pressure up to 25 lb/sq in. This is the maximum pressure required and at which the "blow-off" valve in the mast is designed to open. With an aerial weighing about 10 lb an air pressure of 10 lb/sq in is sufficient to raise the mast to its full height in a few minutes. An air bottle could be used instead of a compressor or even an ordinary foot pump would serve. The air seals are very effective and maintain the air pressure in the mast for long periods so that only occasional "topping up" is required.

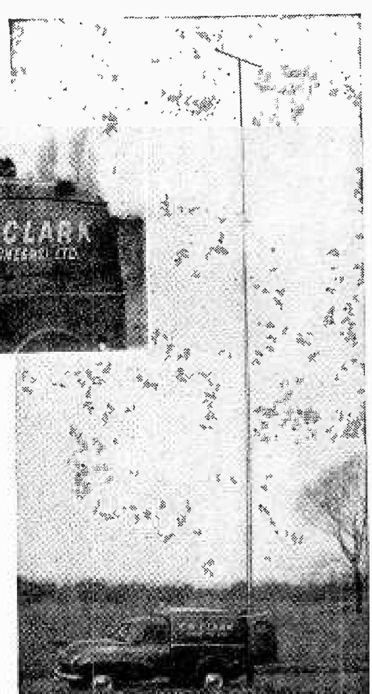
This mast can be fitted in vehicles with the lowest section projecting through a weatherproof seal in the roof or on the roofs of buildings or in any location where a quickly extendable mast is required. The total weight is 125 lb and the finish is hammer grey stove enamel and cadmium plate.

We had an opportunity to witness a demonstration of the mast for which purpose it was supported on the ground and by tie rods from a small 10-cwt commercial van. To reach full height the time taken could not have been more than about four minutes. Only a tiny air compressor was used and driven from the van's engine; a larger pump, or an air bottle, would raise the mast in much less time.

During the demonstration a long extension pole was plugged into the top section, making the mast 45ft in height when fully extended. We felt that with the added top section the weight and size of the aerial would have to be carefully considered, especially when used under "gusty" wind conditions. Without an extension pole the mast is 33ft long.

Advice on matters relating to the use, fitting and capabilities of the mast is available from the makers, A. N. Clark (Engineers), Ltd., 95a Phipps Bridge Road, Merton, London, S.W.19. The price of a mast of this kind depends to some extent on the particular fittings required, but a basic figure is £190.

Clark telescopic aerial mast with dipole mounted on extension pole, also shown collapsed ready for moving to another site.



Constructed of HT30 light-alloy tube (BS1471 specification), the mast consists of seven sections telescoping into each other and tapering (by section) from 4½in outside diameter at the base, to 1½in diameter at the top. A locking device enables the two bottom sections to be locked and the mast then extends to 24ft only. The mast can be supplied with either a fixed base plate or a ball-bearing turntable base and with or without an axial key to prevent relative rotation of separate sections of the mast.

RANDOM RADIATIONS

By "DIALLIST"

Unreliable Valves

THE letter from E. Evenson in the May issue dealing with the far-too-early failures of certain kinds of valve interested me a great deal. Some readers may recall that I pilloried the triode-pentode in these notes awhile ago. As Mr. Evenson says, failures are most frequent when this type of valve is used as an oscillator-output valve in the frame timebase. To me, it's always seemed unsound engineering practice to use a double valve of this sort in a TV timebase, where it is likely to have a heavy job of work to do. The practice may save a bit in the cost of manufacture; but too often it considerably increases the cost of maintenance to the set owner, for if one part of an expensive double valve gives out, the whole thing has to be replaced. Premature failures among valves not really up to the jobs they are called upon to do cannot do the valve-makers' reputation any good and it is surprising that they do not insist on valves being used only for work to which they can stand up.

The E.H.T. Rectifier

Another valve that can give a heap of trouble if it is overworked is the e.h.t. rectifier. I have known them run for only a matter of weeks before renewal became necessary. The trouble here is largely due to the mysterious passion of some designers for using miniature types. As a rule there is bags of room for a full-sized diode—or, at any rate, a little re-arrangement of the layout could make the necessary room. When the 12-inch tube was the largest in general use and e.h.t. voltages of about 4,000 were the order of the day, the small diode did not give much trouble. But with the very much higher e.h.t. voltages in use in to-day's 17-in and 21-in sets it can be a perfect little pest. If you are bothered by the necessity to replace your e.h.t. diode too frequently, the best plan is to discard it altogether, and to fit, or have fitted, a full-sized valve of suitable type. That seldom fails to work a complete cure.

TV Whistle

WRITING from Fayetteville, N.Y., an American reader tells me that ten or a dozen years ago the TV sets of that country often had the same irritating whistle that too many of ours assault the ears with to-day. American manufacturers, he says, overcame the trouble by potting and padding line output transformers. Ours also "pot and pad"; but they do not seem to have worked out ways of doing so as effectively as we would like. My correspondent's high-frequency auditory response must be extraordinarily good, for he tells me that, according to audiometer measurements, he can hear up to 18,000c/s. And his cannot be very young ears either, for he mentions that he has been a reader of *Wireless World* since its infant days, when it was the *Marconigraph.* I wonder how he'd like a walk through a big television showroom in this country with dozens of sets working! I do hope that all of our makers—and not just some of them—will get down to the elimination of line-scan whistle.

Television Controls

THERE is a tendency nowadays to provide fewer and fewer control knobs outside the cabinets of TV receivers. One reason for this is, I suppose, that it makes for a tidier appearance. Another probably is that a pre-set control inside the set costs less than one with an external knob. All goes well so long as it can be guaranteed with reasonable certainty that pre-set controls will continue for a long time to remain at the right settings. But too often some of them do not. Absence of external knobs is a temptation to the viewer (particularly if he has an expert friend who has once shown him how to adjust this or that) to take off the back of the cabinet and to start poking about. This can be a risky business for both viewer and set, for many of the adjustments cannot be made unless the receiver is switched on and working.

Why Not Concealed Controls?

To my mind by far the best arrangement is to provide small knobs for any controls likely to need occasional adjustment at the front of the set and to conceal them under a neat hinged panel. The set looks just as tidy as if they were inside the cabinet and with the controls at the front, adjustment is made as simple and straightforward as it could be, for you can look straight at the screen as your fingers do the necessary twiddling. This arrangement does not (or should not) tempt the viewer to fiddle about inside his set.

The Moon as Reflector

IT IS reported, I see, that signals from the United States have been received in Germany by reflection from the surface of the moon. There seems to be no reason why this should not be done, for radar pulses directed at the moon have been found in the course of many experiments to be returned to earth. The surface of the moon must therefore be a good reflector. But somehow I do not see that the method is likely to be of much practical use as an aid to telecommunications. The difficulties involved in aiming the wave-trains correctly and keeping them properly directed as the earth revolves could, no doubt, be overcome with no great difficulty, but high powers would be necessary to achieve a satisfactory signal/noise ratio. A bigger trouble is that to span a distance in this way the moon must be above the horizon at both the transmitting and receiving ends. If the distance is great, that cannot very often happen and the duration of the favourable conditions would anyhow be short. The suggestion that a sputnik might be used to store messages sent up from a particular point and to retransmit them when over the desired receiving end was mentioned some months ago in these notes: if a large number of artificial satellites were put into suitable orbits and kept there, might not it also be possible to use any that was in the right position at the time as a reflector?

Printed Circuitry

THERE are signs that printed circuitry will rapidly become more and more generally used in domestic sound and television sets. It has many advantages: the "wiring" of all examples of a particular model is identical; you can't have dry joints, which despite all tests at the factory are one of the serviceman's many headaches; connections can't shift so as to cause unwanted capacitance effects or such things as pick-up of hum from the frame timebase of a TV set. But it may have its teething troubles. One dealer told me that when he came to examine a broken-down set he found a section of the printed connections burnt out, though the fuses hadn't blown. I believe and hope that development will be in the direction of printed wiring, rather than printed circuitry. The receiving set of the future may consist of smallish parcels, each bearing printed connections between plug-in components. When a fault occurred any component could be pulled out for testing; if one of the connections was "dis" the panel would just be thrown away and the components plugged into a replacement. But we'll first have to make completely reliable plug-in contacts.

UNBIASED

By FREE GRID

Stature and Statuary

WHENEVER I come up from the country to call on the Editor I am conscious of a distinct odour of sanctity as I pass from Waterloo to Dorset House as so many of the side streets of the district are named after bygone Archbishops of Canterbury. It always makes me wish that the pioneers of wireless could be similarly honoured and I am glad to learn that it is proposed to name a road junction near Faraday's birthplace in Southwark, "Faraday Circus." It is astonishing, however, what little honour is done to wireless and electrical men in the matter of statues.

Here and there one finds a humble plaque, such as the one to Baird in Frith Street, Soho, and Marconi in Hereford Road, Paddington, but nearly all the imposing statues are to naval and military men, politicians and statesmen, and, of course, to former monarchs ranging from Boudicca—known to the foreign invader as Boadicea—to George VI.

"P.H.D. Boffin—inventor of . . ."

I dare say there may be one or two statues to famous electrical figures which I have overlooked but no wireless or electronics pioneer seems to have a statue. Surely a man with the stature of Marconi, who did so much for marine communications, is worthy of a statue in a naval setting like Trafalgar Square. It might, of course, be said of Marconi, the inventor of the elevated electrode, as it is of Wren in St. Paul's Cathedral, *Si monumentum requiris, circumspice.*

Maybe, of course, I am barking up a non-existent tree, and there are statues galore of the electronically eminent. If so I should be very glad to hear of them so that I can at least go and photograph them for exhibition in these columns at a later date, so I would beg you who are knowledgeable in these matters not to let me remain sunk in my ignorance.

Hints for Servicemen

AN interesting letter from a boffin of the I.T.A. calls my attention to a case where, he says, a viewer "was troubled by continuous frame roll which he could not adjust. He discovered, however, that when he switched on his water heater the frame locked in. He continued his viewing with the heater on. Later, the water reached its maximum temperature and the thermostat operated. The frame began to roll again. Our friend was not dismayed, he just ran the hot water tap until the thermostat closed and resumed his viewing uninterrupted save for an occasional dash to the bathroom to run some more hot water.

"We have advised him to re-label his hot water tap 'Frame Hold'."

I can, however, add to this bathwater story another one which occurred long before the days of TV and which I related in *W.W.* for November 18th 1932. In this case the trouble was cured when I was able to persuade a lady not to take a bath in the peak hours of broadcasting as whenever she did so she caused distortion and loss of volume to neighbouring sets.

That particular district was situated at the end of a rather long feeder and as the supply voltage was only 105, any heavy overloading of the mains caused sufficient loss of volts to bring the h.t. and l.t. supply of sets below distortion point. The lady was using an electric geyser, a type of bathwater heater not often seen nowadays as its appetite for kilowatts is more than treble that of a modern thermal storage heater.

Temporarily clearing a fault by means of shock excitation, as in the case mentioned by my correspondent in the I.T.A., is quite commonplace. I have always found it particularly effective in removing—for a time, at any rate—loudspeaker crackles caused by a dry-soldered joint somewhere in the set.

I recollect once making an elaborate sound analyser so that directly the crackles started to come from the loudspeaker they were filtered from the sound of the programme and used to actuate a Weston moving-coil relay. This operated a more robust relay which switched on a shock excitation circuit. In this manner the crackles were used to suppress themselves.

I was at the time thinking of patenting this method of A.C.C. (automatic crackle control) but I found that it wouldn't work with certain types of modern music. The trouble was that the analyser had difficulty in differentiating between the crackles and some passages of the music.

The Negatrons

RECENTLY I was reading a thrilling account of the life of "positronium" which seems to consist of an electron and a positive electron (or positron) circling round each other like a couple of boxers.

The term positive electron always irritates me as somehow it seems improper that our old friend the electron could be associated with anything like a positive charge; to use the term positron does at least cover things up a bit and reduce the insult to the electron.

I wonder if it is not high time for the term "negatron" to be used to describe the opposite of a positron. We could then reserve the honourable title of electron as a generic term to cover the whole of the great and growing "tron" family.

That reminds me that I am not at all sure that I know how many members of the "tron" family there are at the present moment. Whatever the number be now it will certainly be out of date by the time these words appear in print as "trons" have much in common with rabbits*.

[*Not only in that branch of the family which comprises elementary particles, but also in the tribe of special valves.—ED.]

Stereophony

THIS stereophonic listening business is a lot more complicated than I had supposed. In the June issue H. J. F. Crabbe mentions that if he moves his head when wearing 'phones, the whole orchestra and concert hall appear to move. When this sort of thing happens to me I usually take a couple of aspirins and lie down for an hour or so.

The announcer, during the B.B.C.'s stereo experiment in May, said that the two loudspeakers and the listener should form an equilateral triangle having sides from six to twelve feet long. It is quite obvious, therefore, that our houses need to be specially designed so that all the ground-floor rooms can quickly be turned into one large listening room. It should not be a difficult job for an architect to arrange this, and I would suggest that interior walls be of Venetian-blind construction so that they could be pulled up by an electric motor.