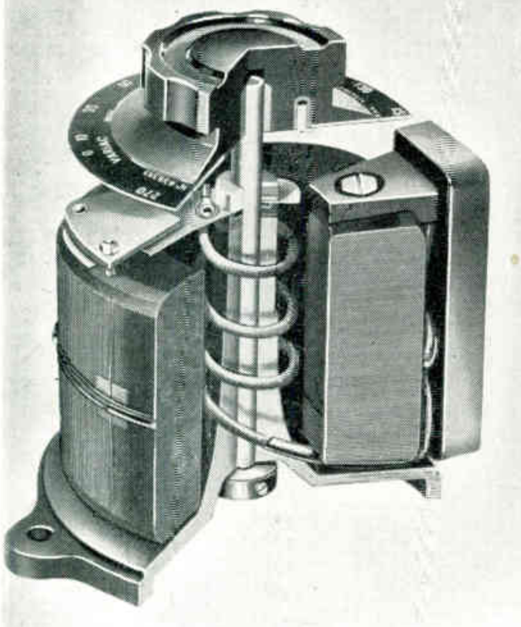
WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

DECEMBER 1952

VOL. 29 No. 351 THREE SHILLINGS AND SIXPENCE



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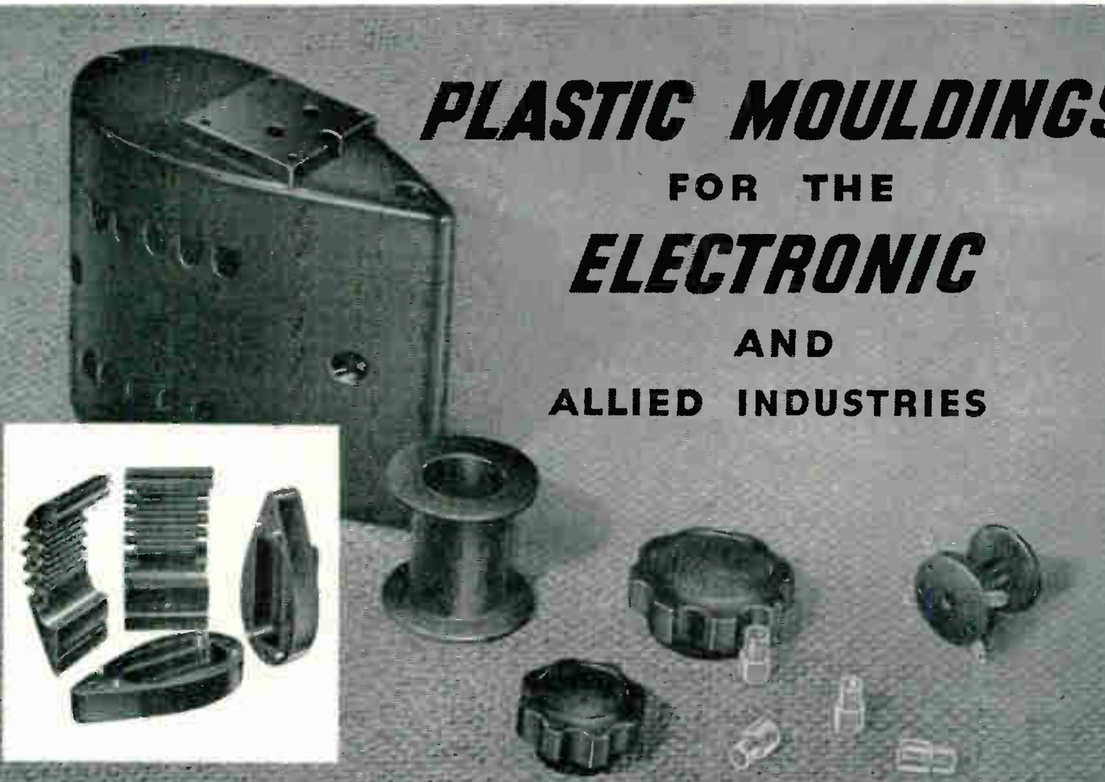


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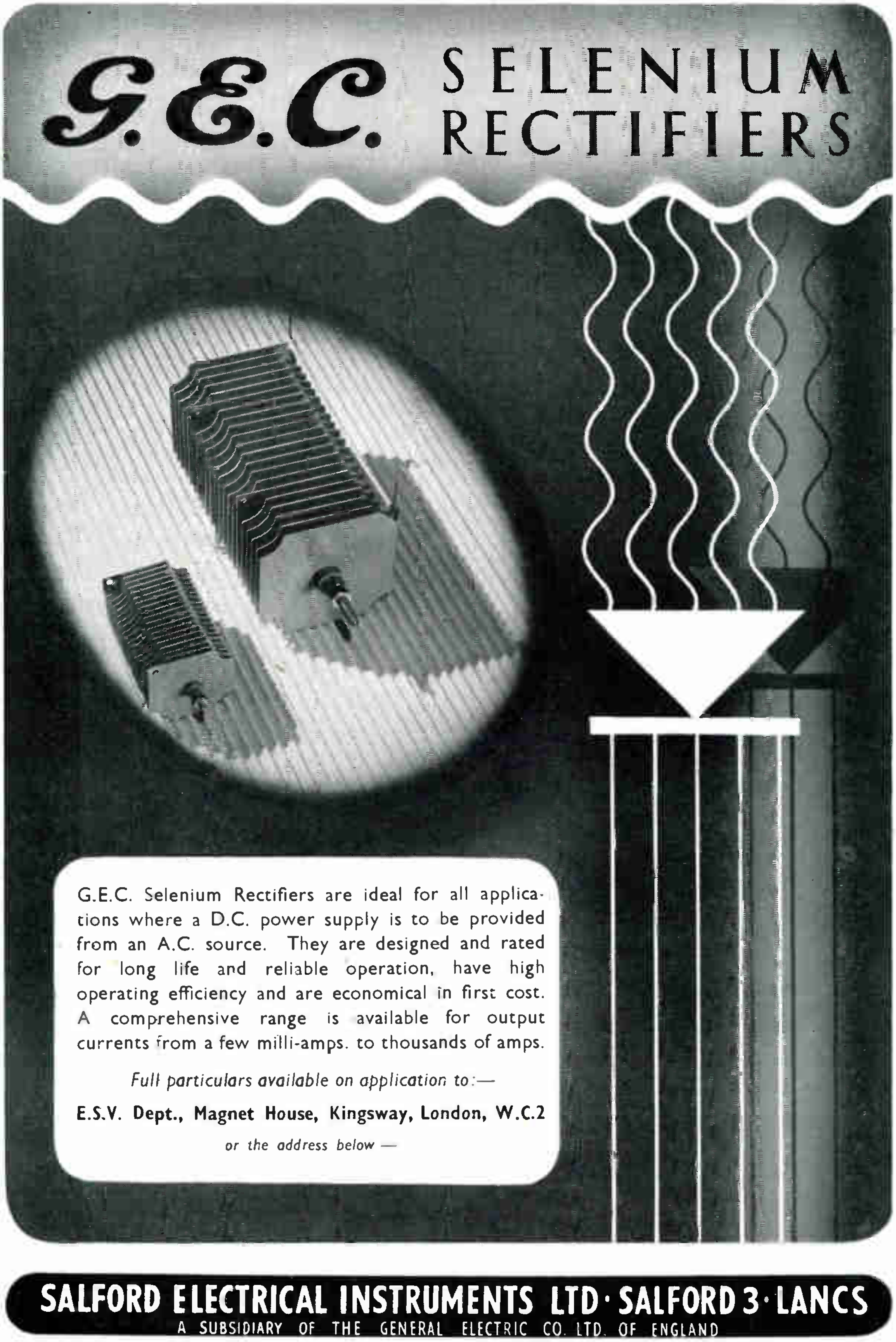

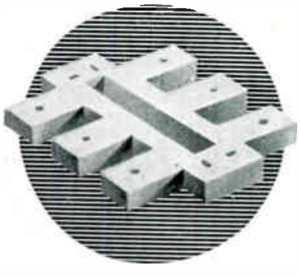

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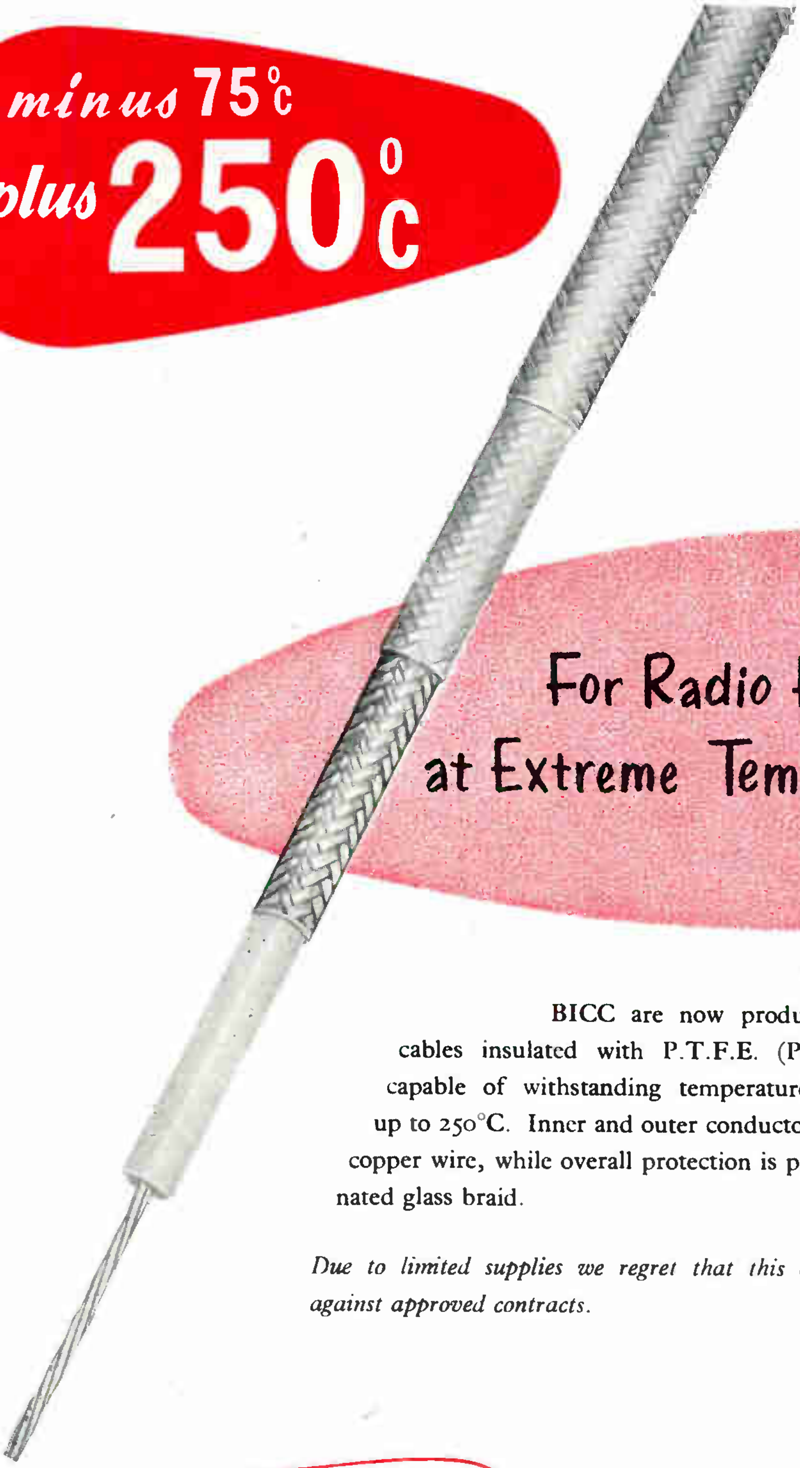

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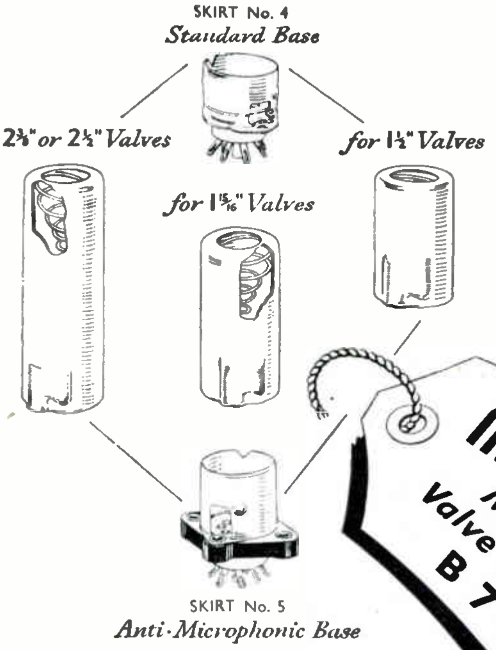
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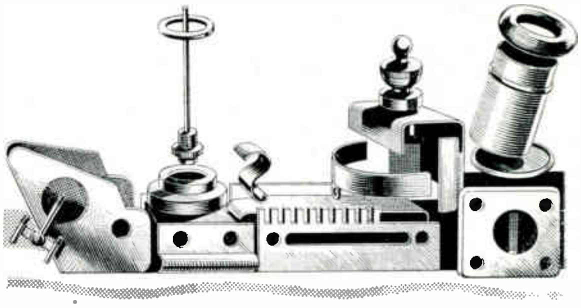

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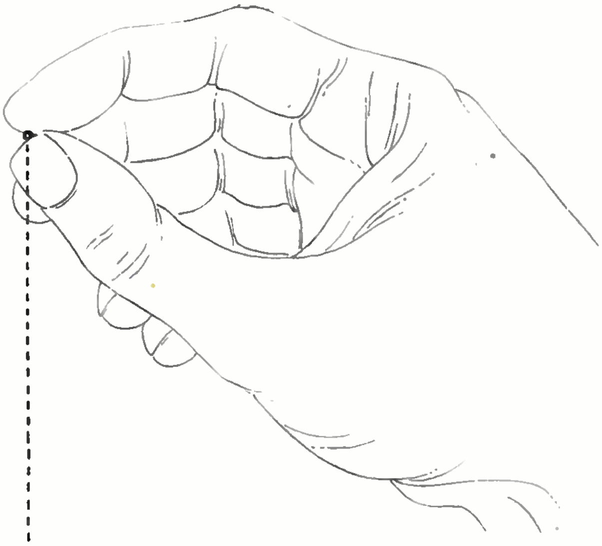

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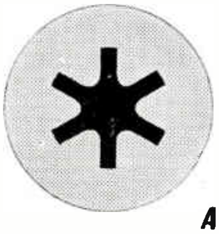

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The Journal of Radio Research and Progress

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V_h	12.6	6.3V
I_h	0.65	1.2A

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Each Section	
$c_{g1\text{-}all}$	6.5 μμF
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Two Sections in Push-Pull	
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p_{g1} max	2 x 0.5 W
I_k max	2 x 55 mA
f max. (at reduced ratings)	600 Mc/s

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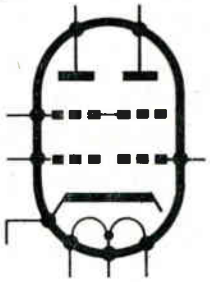

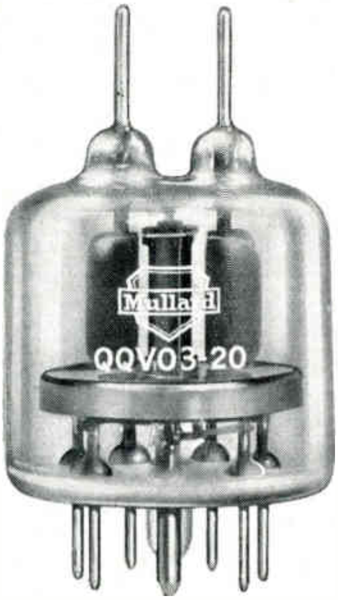

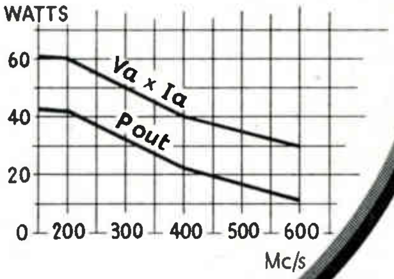

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Vol. 29 DECEMBER 1952 No. 351

Photoelectric Properties of Ionically-Bombarded Silicon

OUR August Editorial was devoted to the wonderful changes produced in silicon, with special reference to its rectifying properties, by ionic bombardment. In the July number of *The Bell System Technical Journal* there is an article with the above title by E. F. Kingsbury and R. S. Ohl devoted mainly to the effect of ionic bombardment on the photoelectric properties of silicon. It was discovered more than 10 years ago that when some types of commercially-available high-purity silicon were melted and allowed to cool, the material separated out into two different types, the lower part being of the *n*-type and the upper of the *p*-type. The former contains electron-donor impurities, such as phosphorus, and the latter electron-acceptor impurities such as boron. The transition from the one to the other takes place in a horizontal layer referred to as the barrier.

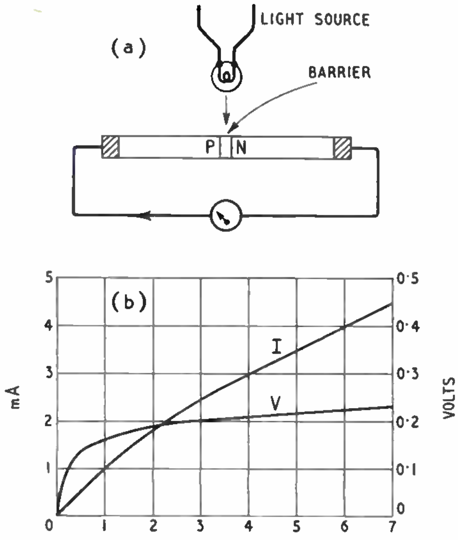


Fig. 1.

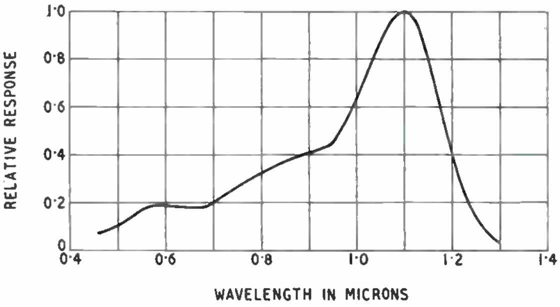


Fig. 2.

If one cuts from the material a vertical rod, the two ends will have different properties and if connected up as shown in Fig. 1(a), a current is produced by illuminating the barrier layer. Fig. 1(b) shows the results in an actual example of using a tungsten filament at 2848°K as the source of light and varying the intensity of illumination. One curve gives the voltage produced on open circuit and the other the current produced on short circuit. Owing to a rapidly decreasing internal resistance, the current continues to increase almost proportional to the illumination, although the voltage approaches a saturation value. Fig. 2 shows the effect of using radiation of different wavelengths but of equal energy; over the visual spectrum (0·4 to 0·8μ) the response is relatively small, but reaches a maximum in the infra-red at a wavelength of $1{\cdot}1\mu$. The direction of the current is from P to N across the barrier, but if tests are made of the rectifying properties of the device by inserting a battery in the circuit, the results (Fig. 3) show that the favoured direction of current is in the opposite direction to the photoelectric current. Fig. 3 shows the characteristic curves for the dark and for an illumination of 6·4 lumens; an applied p.d. of a fraction of a volt from N to P stops the photoelectric current and sets up a considerable current in the reverse direction, whereas a p.d. of 5 V in the direction of the photoelectric current only multiplies it by about four.

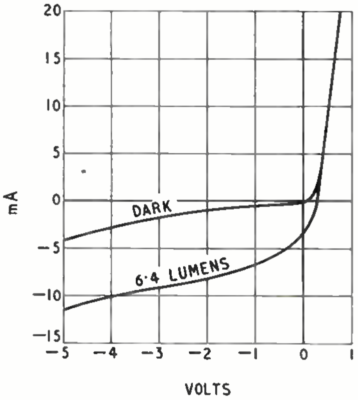


Fig. 3.

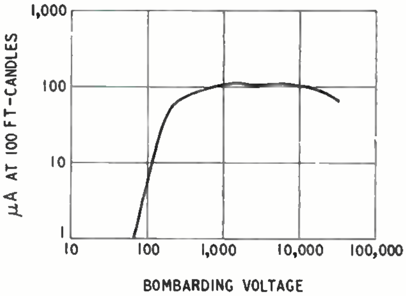


Fig. 4.

A different type of cell can be made from the silicon melt by cutting a thin horizontal plate containing the barrier, which is only about 0·5 mm thick, but with either type the process of manufacture is such that consistent results can hardly be expected, and it was this that led to the development of the ionic-bombarded type with which we are mainly concerned. One of their great advantages, however, was their remarkable stability; their properties were very little affected by heating to redness and quenching in water, or by immersion in oil or liquid nitrogen. In the bombarded type very pure silicon is employed so as to exclude the action of impurities; a piece cut from the melt is ground to a cylinder about 1·5 in. diameter and then cut into wafers about 0·025 in. thick. One side is usually left rough and the other ground and polished to a good optical surface; the disc is then cleared with hydrofluoric acid and distilled water. The polished surface is then bombarded as described in the August Editorial, and collector electrodes of evaporated rhodium are then applied to the two sides. The disc is then mounted in a holder so that the activated side is exposed to the illumination, and connections made to the collector electrodes. It should be explained that the collector electrodes of rhodium cover only a very small fraction of the illuminated surface. Fortunately the surface conductivity of the silicon is increased by the illumination. Fig. 4 shows how the photoelectric effect depends on the bombarding voltage; a number of cells were made with different bombarding voltages and then used to measure the same illumination; the curve shows that little is gained by using more than about 500 V for the bombardment. The best result is obtained by maintaining the silicon disc at a temperature of about 400°C during the bombardment, which should amount to about 600 microcoulombs per square centimetre; that is, a current of, say, 10 microamperes for a minute.

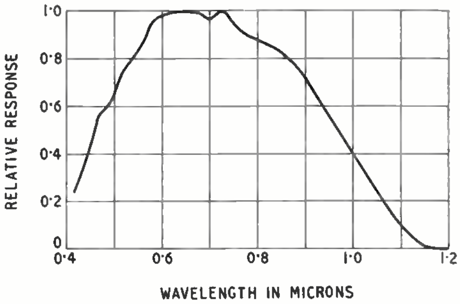


Fig. 5.

Tests of the spectral response of these various cells showed that those bombarded at a very low voltage, less than 250 V, gave maximum response to a wavelength of $0{\cdot}6\mu$, but even with a bombarding voltage of 30,000 V this optimum wavelength only increased to about $0{\cdot}72\mu$. Fig. 5 shows the spectral response curve of a cell made of 'hyper-pure' silicon prepared by reduction from $SiCl_4$ and bombarded with helium positive ions at 1,000 V. The response is a maximum in the visual range, falling rapidly to zero at about $0{\cdot}4\mu$ and less rapidly in the infra-red up to $1{\cdot}2\mu$.

An interesting problem is the nature of the change effected in the surface layer of the pure silicon which enables it to convert the energy of illumination into a steady electric current.

G. W. O. H.

CATHODE-FOLLOWER AS HIGH-IMPEDANCE INPUT STAGE

By D. A. Bell, M.A., M.I.E.E., and H. O. Berktay, B.Sc.

SUMMARY.—If a cathode-follower is used as the first stage of an amplifier in order to raise the input impedance, the conductance of the grid-leak (between grid and cathode) may not be negligible compared with the conductance of the source (between grid and earth) from which the signal is derived. The noise performance under these conditions is examined, both in terms of the cathode-follower regarded as a 1 : 1 voltage device and in terms of the 'noise figure' which takes account of the difference between input and output impedances.

1. Introduction

An examination of the effect of feedback on the overall gain-bandwidth figure for an amplifier leads to the general conclusion that it is not possible to improve the figure of merit of a specific piece of apparatus by using feedback.[1] It is also well-known and obvious that feedback cannot directly modify the input signal/noise ratio to an amplifier, though there may be an indirect effect if feedback modifies the input resistance of the amplifier.[2] The present note arose from a very simple problem: if a cathode-follower is used as the input stage of an amplifier, in order to reduce the effective input capacitance, how will the equivalent input noise of the amplifier compare with that which would have been obtained if the same type of valve had been used in the first stage as a voltage amplifier?

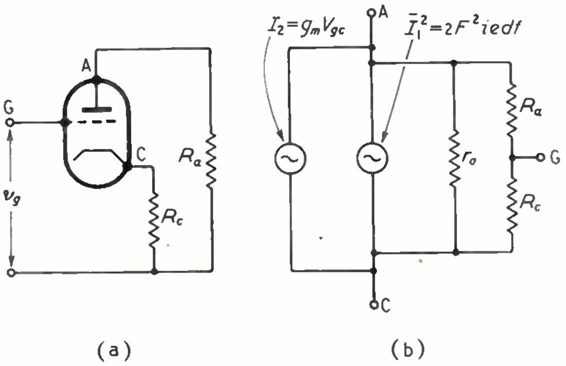


Fig. 1. *(a) Simple circuit with cathode feedback; (b) Equivalent circuit; $\overline{I_1^2}$ represents anode-current fluctuations and I_2 represents anode current due to grid voltages.*

2. Cathode-Follower with Voltage Output

Considering only frequencies at which electronic loading of the valve grid is negligible, so that the physical source of valve noise is fluctuation of the anode current, which may be represented by a constant-current generator within the valve, the general triode amplifier with resistive loads of Fig. 1(a) has the equivalent circuit shown in Fig. 1(b). (Here r_a is the anode slope resistance, i the mean anode current, e the charge of an electron, df the bandwidth and F^2 the 'mean-square smoothing factor'.) If x denotes the proportion of the total current from the generator which flows through the branch $R_a + R_c$ (i.e., $x = r_a/(r_a + R_a + R_c)$) we have the following equations for no-signal conditions:—

MS accepted by the Editor, April 1952.

$$I = I_1 + I_2 = f(i) + g_m V_{gc} \quad .. \quad .. \quad (1)$$

$$V_{gc} = -R_c x I \quad .. \quad .. \quad .. \quad .. \quad (2)$$

The noise component is entered in (1) as $f(i)$ because we are assuming correlation between V_{gc} and the noise current, and it is therefore impossible to use either the mean-square value of I_1^2 or its root-mean-square value. An instantaneous value is in fact only available in terms of a probability, but as our feedback system will merely produce a scalar multiplier, we may calculate this multiplier in terms of an arbitrary $I' = f(i)$ and then assume that the mean-square value I_1^2 will be multiplied by the square of the scalar factor. Eliminating V_{gc} from (1) and (2) yields the following results:—

$$I = f(i)/(1 + g_m R_c x) \quad .. \quad .. \quad .. \quad (3)$$

$$\overline{I^2} = 2F^2 iedf/(1 + g_m R_c x)^2 \quad .. \quad .. \quad (4)$$

$$\overline{V_{gc}^2} = R_c^2 \overline{I^2} = 2F^2 iedf \, . \, R_c^2/(1 + g_m R_c x)^2 \quad (5)$$

The output signal produced by an input voltage between grid and earth [v_g of Fig. 1(a)] would be

$$V_s^2 = g_m^2 v_g^2 \frac{R_c^2}{(1 + g_m R_c x)^2} \quad .. \quad .. \quad (6)$$

and by the usual process of comparing (5) and (6) and equating v_g^2 to the Johnson noise of a hypothetical resistor R_n we find that the equivalent noise resistance, in terms of open-circuit voltages across R_c, is the same as for a voltage-amplifying triode:

$$R_n = \frac{F^2 i}{g_m^2} \cdot \frac{e}{2kT} = \frac{20 F^2 i}{g_m^2} \quad .. \quad .. \quad .. \quad (7)$$

for T at room-temperature.

Note that R_n is independent of the degree of cathode-following (i.e., of the ratio of cathode voltage to grid voltage) since the term $g_m R_c x$

enters in the same way into both signal and noise formulae.*

The precise calculation is more complicated if there is a grid-leak, and in discussing this case the anode load R_a will be dropped. The equivalent circuit of the complete cathode-follower of Fig. 2(a) is then as shown at 2(b). The total mean-square fluctuation current flowing in the anode circuit is made up of three components: $\overline{I_1^2}$ is due to the valve itself, which may be represented as $4kT_e df/r_a$ (T_e = effective temperature of valve anode resistance) or in the empirical form $2F^2iedf$; $\overline{I_2^2}$ is the result in the anode circuit of whatever voltage is applied between grid and cathode; and $\overline{I_3^2}$ is the Johnson noise in the cathode resistor. One might expect to add a similar contribution from the Johnson noise in $R_g + R_s$; but this is taken into account when calculating the current through R_c which results from R_g and R_s being connected to the grid. If R_0 is the resultant resistance between A and C (i.e., the resultant of the three parallel branches r_a, R_c, $R_g + R_s$) the total mean-square fluctuation voltage between terminals A and C (which are also the output terminals) is shown in the Appendix to be

$$\overline{V_0^2} = \frac{g_m^2 R_0^2}{(1 + yg_mR_0)^2}\left\{2F^2iedf/g_m^2 + 4kTdf/g_m^2R_c \right. \\ \left. + y^2 4R_skTdf + (1-y)^2 4R_gkTdf\right\} \quad .. \quad (8)$$

where $y = R_g/(R_g + R_s)$. Note that in the idealized cathode-follower (with $R_g \rightarrow \infty$), $y \rightarrow 1$ and $1 - y \rightarrow 0$ so that the contribution from the grid-leak would vanish and the contribution from Johnson noise in the source resistance would be added without modification.

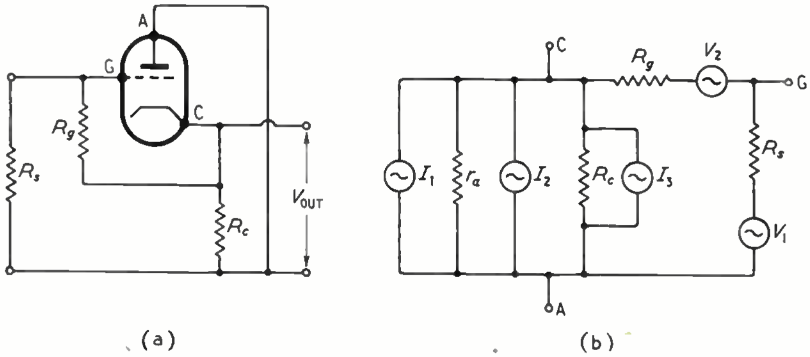
By introducing the equivalent noise resistance R_n, formula (8) may be modified to

$$\overline{V_0^2} = X.4kTdf\{R_n + 1/g_m^2R_c + R_sy^2 \\ + (1-y)^2R_g\} \quad .. \quad (9)$$

where X is written for the common factor $g_m^2R_0^2/(1 + yg_mR_0)^2$ which is due to feedback. But since $y = R_g/(R_g + R_s)$, the terms $y^2R_s + (1 - y)^2R_g$ reduce to $R_sR_g/(R_s + R_g)$ which represents the resultant of R_s and R_g in parallel. Formula (9) therefore becomes

$$\overline{V_0^2} = X.4kTdf\{R_n' + R_s'\} \quad .. \quad .. \quad (10)$$

where R_n' is $R_n + 1/g_m^2R_c$ and $R_s' = R_sR_g/(R_s + R_g)$. (Note that this is exact, and the degree of cathode-following does not affect the relative contributions of R_n', R_s and R_g, but it slightly modifies the magnitude of the whole through the factor X).



(a)

(b)

Fig. 2. (*a*) *Cathode-follower with grid-leak and source impedance.* (*b*) *Equivalent circuit of* (*a*).

A convenient method of checking the input circuit of an amplifier is to regard R_s' as a source of fluctuation current $\overline{I^2_s} = (4kT/R_s')df$ and measure this $\overline{I_s^2}$ by injecting into the input circuit a current $\overline{I^2_d} = 2iedf$ from a temperature-limited diode, adjusting the mean diode current i until the total noise is double that due to R_s'. If R_s' is expressed as a conductance G_s and is varied by adding different values of conductance to the basic input circuit, we expect a linear plot of i against G_s with a slope of $2kT/e$. (The contribution from R_n' is, of course, eliminated in terms of a noise measurement when the input is short-circuited.) This measurement was made with an amplifier in which the input circuit enclosure was at a temperature of 303° K, so that $2kT/e$ = 53·5 mA/mho, and the experimental results are shown in Fig. 3. The abscissæ are values of *added* conductance, so the negative intercept on this axis should give the conductance of the amplifier circuit alone; in this amplifier there was a grid-earth resistance of 4,980 ohms with a grid-leak (grid-cathode) of 100,000 ohms, so that one expects a total conductance of 0·218 millimho. The value obtained from the graph is 0·22 millimho.†

If the input signal is taken as a voltage with source impedance R_s (not a current fed through R_s), the signal voltage v_s may be introduced by adding y^2v_s to $4R_s'kTdf$ in (9), since the signal-voltage generator appears at the same place in the circuit as the Johnson-voltage generator. The equation for signal-plus-noise output is then

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* This result, for a cathode-follower *without grid-leak*, has previously been obtained by R. E. Burgess, "Signal/Noise Characteristics of Triode Input Circuits", *Wireless Engr*, 1945, Vol. 22, p. 56.

† This graph had in fact been drawn before the effect of the grid-leak had been calculated, and the only figure in mind when drawing the graph was the nominal value of 5,000 Ω for the grid-earth resistance.

$$V^2 = X\{y^2 v_s^2 + 4kTdf(R_n' + R_s'\} \quad .. \quad (11)$$

It follows that the signal/noise ratio is a function of y . This is to be expected, since the presence of R_g represents a dissipation of signal power.

The difference between R_n' and R_n, namely $1/g_m^2R_c$, is small, because $g_mR_c \gg 1$ for an effective cathode-follower. If g_mR_c is only 50, while $1/g_m$ is perhaps 200 ohms, the difference is only 4 ohms in a value of R_n of hundreds of ohms.

But the serious drawback to the cathode-follower used as a 1:1 voltage device is that the signal voltage level is not raised before reaching the second stage. The equivalent noise resistance of the whole amplifier is therefore roughly double that which would have been obtained with a voltage-amplifying first stage, and this is the price one pays for raising the input impedance.

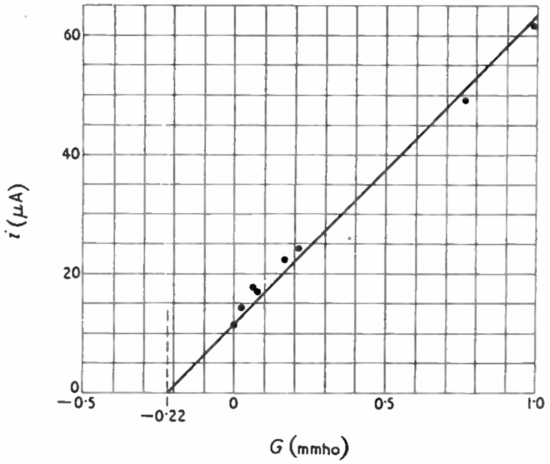

Fig. 3. *Noise-check on input circuit of amplifier. G = added conductance (grid to earth), i = noise-diode current equivalent to fluctuation current in input circuit.*

3. The 'Noise Figure' of a Cathode-Follower

The noise figure depends on the concept of 'available noise power',[2] and the noise figure of a 2-terminal network may be defined as the ratio of the available noise power from the network in question to the Johnson-noise power which would be available from a resistor at room temperature and equal in value to the resistive component of the impedance of the network. This may also be expressed (in a 2-terminal network) as the ratio of the 'effective temperature' of the network to the ambient temperature T. (It is assumed in the definition of 'available power' that any reactive component of the output impedance will be balanced out by an equal but opposite reactive component in the load impedance.) Johnson noise is usually expressed as a power derived from a hypothetical voltage-generator according to the formula $V^2 = 4RkTdf$, whence the available *power* from a resistor is $V^2/4R = kTdf$. It is convenient to express this as so much per unit bandwidth, but it must be remembered that kT is an *energy*, and is only converted to a power by the time factor in 'df cycles per second'. The correct forms are therefore:

Mean Power = kT/second per cycle = 4×10^{-21} watt per cycle

Mean Energy = kT per cycle = 4×10^{-21} watt-sec per cycle
= 4×10^{-21} watt per c/s.

It may seem strange to measure power in 'watts per cycle' and energy in 'watts per c/s', but the equating of mean energy to kT per cycle makes it clear that Johnson noise is an equipartition phenomenon with mean energy kT per mode of oscillation.

Returning to equation (9) and putting $R_s = 0$, the mean-square output noise voltage becomes

$$\overline{V^2} = \frac{g_m^2R_0^2}{(1 + g_mR_0)^2}\left[4kTdf(R_n + 1/g_m^2R_c)\right] \quad (12)$$

But the output impedance of the cathode-follower is $R_{out} = R_0/(1 + g_mR_0)$, so the noise figure or effective-temperature ratio is

$$\frac{\overline{V^2}}{4R_{out}kTdf} = \frac{g_mR_0}{1 + g_mR_0} \cdot g_m(R_n + 1/g_m^2R_c)$$

$$\therefore T_e/T \approx g_mR_n \quad .. \quad .. \quad .. \quad .. \quad (13)$$

The approximate form results from neglecting $1/g_m^2R_c$ compared with R_n, and unity compared with g_mR_0. It will be seen that viewed as a 2-terminal impedance the cathode-follower can have a noise figure greater or less than unity according as R_n is greater or less than $1/g_m$. In practice it will nearly always be greater, and in order to obtain a noise figure substantially less than unity Percival[3] used a circuit allowing a greater feed-back than is obtainable from a cathode resistor.

The noise figure for a 4-terminal network depends also on the power gain, but can be expressed in the form

$$F = N/kTGdf \quad .. \quad .. \quad .. \quad (14)$$

where N is the total available noise power at the output, G the power gain expressed as a ratio, and df the effective bandwidth. The total noise power at the output can be expressed as $N = GN_1 + N_2$ where N_1 is the noise power at the input and N_2 is the additional noise power arising in the output circuit; and if N_1 is simple Johnson noise (therefore of magnitude $kTdf$) it follows that

$$F = 1 + N_2/kTGdf$$

If, in addition, N_2 is expressed in terms of an effective temperature at which the output resistance would generate Johnson noise with available power equal to N_2,

$$F = 1 + (T_e/T)(1/G) \quad .. \quad .. \quad (15)$$

Since equation (13) shows that T_e/T is likely to be of the order of unity, it follows that F is of the order of $1 + 1/G$ where, it will be remembered, G for the cathode-follower is the ratio of input to output impedances. If a cathode-follower is regarded merely as a 1:1 voltage device, implying unity gain, the noise figure is therefore about two. But since the whole point of using a cathode-follower input to an amplifier is to raise the input impedance of the amplifier above that of a voltage-amplifying stage, there is in fact some power gain ($G > 1$), so that the noise figure need be only a little greater than unity.

4. Acknowledgments

This work was associated with research in the Electrical Engineering Department, University of Birmingham, and the authors wish to thank Professor A. Tustin for the facilities placed at their disposal.

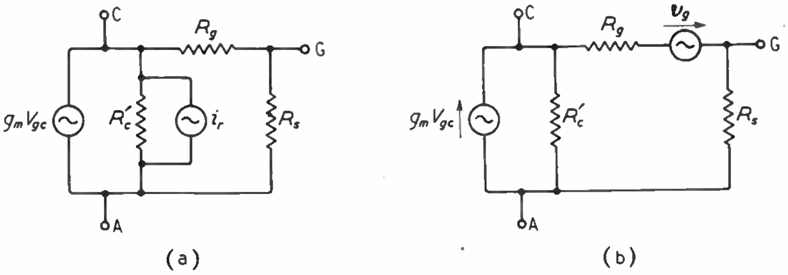

Fig. 4. (*a*) *Simplified equivalent circuit for calculating anode-circuit noise.* (*b*) *Simplified equivalent circuit for calculating grid-circuit noise.*

APPENDIX

Detailed Analysis of the Cathode-Follower Noise.

In calculating the total noise, it must be remembered that the primary sources of current and voltage, namely the shot noise in r_a and the Johnson noise in R_g, R_s and R_c, are all incoherent. It follows that when an equation is written in the form '$V = av_s + bv_g$', it is to be understood that the direct summation is only applicable to instantaneous values: the averages are to be found by compounding squares of voltages. Assuming that the valve is operated in the linear regime one can compute the effect of each noise source separately, retaining in each case the current-generator g_mV_{gc} with an appropriate value of V_{gc}. The complete equivalent circuit has already been shown in Fig. 2(b), but simplified equivalent circuits can be used for the calculation of the various constituents.

A.—Noise Arising in r_a and R_c. In Fig. 4(a) we use the equivalent elements $R'_c = r_aR_c/(R_c + r_a)$, $i_r^2 = 2F^2iedf + 4kTdf/R_c$, and R_0 is written for the resultant resistance between C and A, as used in the paper. Then the resultant voltage between C and A is $V_{CA} = R_0(g_mV_{gc} + i_r)$. But $V_{gc} = -V_{CA}R_g/(R_g + R_s) = -yV_{CA}$ say.

$$\therefore V_{CA} = R_o(-g_myV_{CA} + i_r)$$

$$V_{CA} = R_0i_r/(1 + yg_mR_0) \quad \ldots \quad \ldots \quad \ldots \quad \text{(i)}$$

The feedback factor due to the operation of the valve grid is then $1 + yg_mR_0$ instead of $1 + g_mR_0$ in the simplest cathode-follower, i.e., the effective mutual conductance of the valve is reduced from g_m to $g_mR_g/(R_g + R_s)$.

B.—Noise Originating in the Grid Leak. This is developed with the aid of Fig. 4(b). The generator v_g produces directly across CA a p.d. equal to $-R'_cv_g/R_1$ where $R_1 = R_g + R_s + R'_c$, and there is also a p.d. equal to $g_mV_{gc}R_0$ as a result of the response of the valve to the grid-cathode potential. But the grid-cathode potential is the terminal p.d. of the branch $R_g - v_g$ when a certain current, say i_2, flows round the mesh R_g, R_s, R'_c, and $i_2 = (v_g - V_{CA})/(R_s + R_g)$.

$$\therefore V_{gc} = v_g - R_gi_2 = (1 - y)v_g - yV_{CA} \quad \ldots \quad \text{(ii)}$$

Substituting this value of V_{gc} in the second of the two components of V_{CA},

$$V_{CA} = -(R'_c/R_1)v_g + g_mR_0[(1-y)v_g - yV_{CA}]$$

$$\therefore V_{CA} = \frac{v_g}{1 + yg_mR_0}[-R'_c/R_1 + g_mR_0(1 - y)] \quad \text{(iii)}$$

C.—Noise Originating in the Source Resistance. This is treated in the same way as noise from the grid-leak, except that the source-resistance generator, v_s, is outside the grid-cathode branch. The p.d. across CA due to v_s is found to be:

$$V_{CA} = \frac{v_s}{1 + yg_mR_0}[R'_c/R_1 + yg_mR_0] \quad \ldots \quad \ldots \quad \text{(iv)}$$

D.—Total Noise. Combining all the components, and inserting the appropriate values for the mean squares of i_r, v_g and v_s, the mean-square voltage across CA is given by:

$$V^2 = \left(\frac{g_mR_0}{1 + yg_mR_0}\right)^2 \{2F^2iedf/g_m + 4kTdf/g_mR_c$$
$$+ 4R_gkTdf[1 - y - R'_c/g_mR_0R_1]^2$$
$$+ 4R_skTdf[y + R'_c/g_mR_0R_1]^2\} \quad \ldots \quad \ldots \quad \ldots \quad \text{(v)}$$

By expressing R_0, R_1 and R_c' in terms of the basic elements it is found that $R_c'/R_0R_1 = 1/(R_s + R_g) = y/R_g$. Since we shall usually have $R_g > R_c'$ and $g_mR_c' \gg 1$, the terms in $R_c'/g_mR_0R_1$ can be dropped from (v); and by introducing the equivalent noise resistance, R_n, of the valve, equation (v) can be put in the form used in the text:

$$V^2 \approx$$

$$4kTdf\left(\frac{g_mR_0}{1 + yg_mR_0}\right)^2 \{R_n + (1 - y)^2R_g + y^2R_s\} \quad \text{(iv)}$$

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[2] Friis, H. T., *Proc. Inst. Radio Engrs*, 1944, Vol. 32, p. 419.
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THREE-PROBE METHOD OF IMPEDANCE MEASUREMENT

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SUMMARY.—Replacement of the single sliding probe by three fixed probes in the standing-wave method of impedance measurement minimizes some sources of error, and considerably reduces the time needed for a set of readings, thus making possible continuous recording of impedance variations. A form of apparatus is described, together with the method of calibration.

1. Introduction

AT microwave frequencies, impedance measurement using standing-wave patterns in waveguides is usually carried out by means of a slotted portion along which an exploring probe travels. The theory and practice of this method have been fully described[1], and errors peculiar to it are due to

(a) the compromise necessary between (i) small probe depth to minimize distortion of the field and (ii) large probe depth to reduce percentage variation (due to mechanical irregularities in the slide), and to increase sensitivity,

(b) radiation from the slot,

(c) mechanical distortion of the waveguide cross-section due to the slot.

Furthermore, the time taken for each measurement of an impedance is long enough to render impossible the recording of any continuous variation in that impedance.

Any method using fixed probes reduces all the sources of error mentioned above: the first, because there is no longer a limit to the smallest probe depth usable beyond that of the detector sensitivity; the second and third because the only apertures needed in the waveguide are little larger than the cross-sections of the probes. If, further, each probe has its own detector and galvanometer, then the time taken for each impedance measurement is reduced to that required for recording the meter readings.

The standing-wave pattern in a waveguide is completely specified by three independent values of the field strength, so that in such a method three fixed probes are required. The expression for the load impedance is only simple when these are separated by one-eighth of the guide wavelength.

Two errors not present in the slotted-line method are introduced: these are discussed below.

2. Theory of the Method

In a loss-less transmission line of length l, and characteristic impedance Z_0, terminated in a complex impedance, $Z_L = R_L + jX_L$, the voltage at a distance y from the termination is given[4] by

$$V_y = V_L\left[\cos\frac{2\pi y}{\lambda_g} + \frac{j}{z_L}\sin\frac{2\pi y}{\lambda_g}\right] \quad .. \qquad (1)$$

where $z_L = Z_L/Z_0$, λ_g = wavelength along the line, V_L = voltage across the load.

This formula applies equally well to a loss-less waveguide with the same length, etc., where V_y and V_L are the transverse components of field strengths which are the quantities measured by using probes or loops. Measurement of the voltage at any point would give a value depending on the modulus of the complex quantity, V_y.

Let the values of V_y occurring at points separated by $\lambda_g/8$ along the guide be V_0, V_1, V_2, etc., V_0 occurring at the load. (Fig. 1.)

If the guide is uniform and loss-less, then

$V_0 = -V_4 = V_8$ etc.,
$V_1 = -V_5 = V_9$ etc.

To obtain the load impedance, any three consecutive values may be measured and the resistive and reactive parts of $z_L (r_L = R_L/Z_0$, $x_L = X_L/Z_0)$ calculated. Using equation (1) in each case,

if V_0, V_1, and V_2 are measured:

$$|z_L|^2 = \frac{V_0^2}{V_2^2},\ x_L = \frac{2V_1^2 - V_0^2 - V_2^2}{2V_2^2} \qquad (2)$$

if V_1, V_2, V_3 are measured:

$$|z_L|^2 = \frac{V_1^2 + V_3^2 - V_2^2}{V_2^2},\ x_L = \frac{V_1^2 - V_3^2}{2V_2^2} \qquad (3)$$

if V_2, V_3, V_4 are measured:

$$|z_L|^2 = \frac{V_4^2}{V_2^2},\ x_L = \frac{V_2^2 + V_4^2 - 2V_3^2}{2V_2^2} \qquad (4)$$

and $r_L = \sqrt{|z_L|^2 - x_L^2}$ in every case.

W. L. Barrow,[2] who first described the method applied to artificial lines at frequencies from 50 kc/s to 1·5 Mc/s, obtained equation (2), and P. J. Kibler[3] showed how the calculation of impedance from voltmeter readings could be replaced by graphical interpolation from a Cartesian circle diagram. However, since a square-

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law detector can be used, meter readings can be made proportional to the squares of the voltages, and the expressions (2), (3) or (4) are comparatively simple to evaluate numerically. For instance, if θ_1, θ_2, θ_3 are the galvanometer readings for probes at B, C, D respectively, then the impedance at the point A (Fig. 1) is given by

$$|z_L|^2 = \frac{\theta_3 + \theta_1 - \theta_2}{\theta_2}, \; x_L = \frac{\theta_1 - \theta_3}{2\theta_2} \quad \ldots \quad (5)$$

from (3), provided that

$$\theta_1 = kV_1^2, \; \theta_2 = kV_2^2, \; \theta_3 = kV_3^2 \quad \ldots \quad (6)$$

It is not essential that the impedance to be measured should be situated at A. A Smith chart can always be used to transform the calculated impedance presented at A to the actual impedance at the end of the guide.

3. Errors

Two additional sources of error may arise by using three fixed probes:

(a) the probes may not be accurately spaced apart by one-eighth of the guide wavelength,

(b) the field in the guide will be distorted by reflections from three probes instead of by reflections from the usual single probe.

(a) *Error Due to Wrong Probe Spacing*

In equations (2), (3) and (4), ratios are taken in every case to V_2^2, the square of the voltage $\lambda_g/4$ from the load. It will be assumed here that the position of the probe at $\lambda_g/4$ from the load is accurate, and that small errors occur in the spacing of the other probes.

It can be shown that if the probe spacing be p, fractional errors in the ratios involved in equations (2), (3) and (4) due to an error δp in p are:

$$\delta\left(\frac{V_0^2}{V_2^2}\right) \Big/ \left(\frac{V_0^2}{V_2^2}\right) = -\frac{\pi x_L}{2|z_L|^2} \cdot \frac{\delta p}{p} \quad \ldots \quad (7)$$

$$\delta\left(\frac{V_1^2}{V_2^2}\right) \Big/ \left(\frac{V_1^2}{V_2^2}\right) = \frac{\pi}{4} \cdot \frac{(1 - |z_L|^2)}{r_L^2 + (x_L + 1)^2} \cdot \frac{\delta p}{p} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

$$\delta\left(\frac{V_3^2}{V_2^2}\right) \Big/ \left(\frac{V_3^2}{V_2^2}\right) = \frac{\pi}{4} \cdot \frac{(|z_L|^2 - 1)}{r_L^2 + (x_L - 1)^2} \cdot \frac{\delta p}{p} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

and for V_4 as for V_0, etc.

The factors involving the load in these expressions are of the order of unity or less except for small ranges over which they become very large. Thus, (7) becomes large when $r_L \to 0$, $x_L \to 0$. Hence, if the impedance to be measured is known to be very small, equations (2) and (4) should not be used since they involve the ratio in (7).

For similar reasons, if $r_L \to 0$, $x_L \to -1$, equations (2) and (3) should not be used, and if $r_L \to 0$, $x_L \to +1$, equations (3) and (4) should not be used.

The percentage error in the result due to incorrect probe spacing can thus be made at worst of the same order as the error in the spacing itself.

(b) *Error Due to Probe Reflections*

It can be shown that if ρ_1, ρ_2, ρ_3 are the complex reflection coefficients of the three probes, and $\rho_L\left(= \frac{Z_L - Z_0}{Z_L + Z_0}\right)$ that of the load, then the fractional error in the field at probe 1 due to reflections from the probes is:

$$\left|\frac{2\rho_L(\rho_1 + \rho_2 + \rho_3) + (\rho_1 - j\rho_2 - \rho_3)\,(e^{2j\beta y} + \rho_L^2 e^{-2j\beta y})}{e^{j\beta y} + \rho_L e^{-j\beta y}}\right| \quad \ldots \quad (10)$$

where $\beta = 2\pi/\lambda_g$, and y is the distance of probe 1 from the load. Assumptions made in the derivation of this expression are that the generator is perfectly matched to the guide, and that ρ_1, ρ_2 and ρ_3 are small enough for terms involving their products or powers to be neglected. This error increases if the generator is not matched.

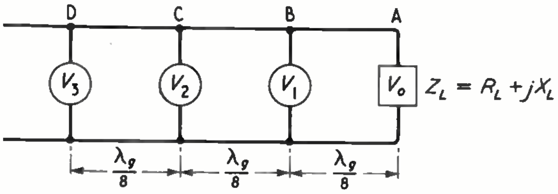

Fig. 1. *Representation of transmission line or waveguide.*

The value of ρ_L is determined by the load to be measured but, at the worst, $|\rho_L| = 1$ on open or short circuit. For the purpose of assessing the value of this error it can be assumed that $\rho_1 = \rho_2 = \rho_3 = \rho$, and if $|\rho_L| = 1$, (10) becomes

$$\left|\frac{\rho\left[3 + (2 - j)\cos\frac{4\pi y}{\lambda_g}\right]}{\cos\frac{2\pi y}{\lambda_g}}\right| = \frac{|\rho|\sqrt{5\cos^2\frac{4\pi y}{\lambda_g} + 12\cos\frac{4\pi y}{\lambda_g} + 9}}{\cos\frac{2\pi y}{\lambda_g}}$$

At the voltage minimum, a zero in the case of $|\rho_L| = 1$, the error is infinite, since $\cos 2\pi y/\lambda_g = 0$, and is very large at points near the minimum. At the voltage maximum the error is of the order of $5|\rho|$, so that with very large or very small impedances great accuracy cannot be expected. The maximum value of (10), however, decreases rapidly with ρ_L, and for $|\rho_L| = 0{\cdot}5$ is of the order of $4|\rho|$. Thus, since the magnitude of ρ can be made considerably less than in the slotted-line method, the error in the present method due to probe reflections will not normally be any greater. Certain precautions must be taken to ensure this however. These are:

(i) the generator must be correctly matched to the guide,

(ii) equations (2), (3) and (4) must be used in such a way that small values of voltage, in which the largest errors occur, are not included in the denominator. This is always possible.

4. The Apparatus

The output of a CV67 reflex klystron, supplied with stabilized unidirectional potentials, was fed to the three-probe standing-wave indicator through a cable providing attenuation to reduce fluctuations of impedance presented to the oscillator. A matching stub was inserted at the input end of the indicator.

The portion of test line consisted of a length of coaxial waveguide of accurately constructed internal dimensions. Three holes, diameter 1 mm, were bored radially in the outer conductor at intervals of $\lambda_g/8$, and supports for detector units were attached centrally around these holes (Fig. 2). The three detector units were standard Service equipment (detector units type 53) fitted with specially-selected crystals.

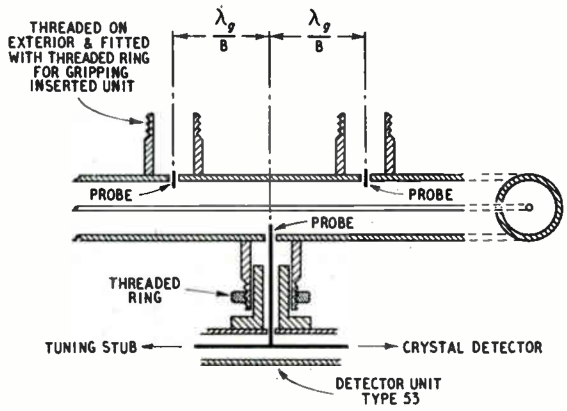

Fig. 2. *Portion of coaxial waveguide fitted with three probes and detector units.*

Three Cambridge spot galvanometers recorded the rectified currents, their sensitivity giving a full-scale deflection of 16 cm for 1 μA. Potentiometers were connected in series with each to afford fine control of the readings.

The whole of the test line, the galvanometers, potentiometers and leads were enclosed in an earthed brass box, easily removable for adjustments, and all leads were separately screened.

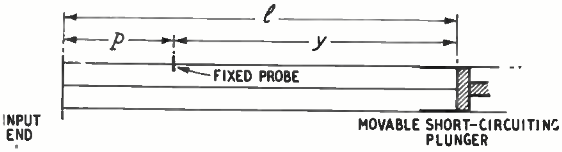

Fig. 3. *Notation for short-circuited line.*

5. Calibration

The galvanometers were calibrated so that correction could be made for any deviations from linearity. The crystals were calibrated using a piston attenuator so that allowance could be made for any departures from square law.

The meter deflections, θ, could now be taken as proportional to the squares of the voltages induced in the probes, V, so that

$$\theta_1 = k_1 V_1^2,\ \theta_2 = k_2 V_2^2,\ \theta_3 = k_3 V_3^2 \quad .. \quad (11)$$

The line was then terminated by a short-circuiting plunger operated by a micrometer head. The expression (1) becomes for a short-circuited line:

$$|V_y|^2_{s.c.} = \text{constant} \times \frac{\sin^2 \dfrac{2\pi y}{\lambda_g}}{1 + |\rho_g|^2 + 2|\rho_g| \cos\left[\phi_g - \dfrac{4\pi}{\lambda_g}(p + y)\right]}$$

where $|\rho_g|e^{j\phi_g}$ is the reflection coefficient at the generator end of the guide, y is the distance from the short-circuiting plunger, and p the distance from the generator end (Fig. 3). As the plunger is moved, varying y only, equation (12) gives the variation of voltage at each of the three probes, with their own values of p.

It can be shown that if the plunger is shifted and the galvanometer readings are plotted against plunger position, graphs of the types shown in Figs. 4 and 5 are to be expected, according to the value of $|\rho_g|$. Fig. 4 is for the extreme case $|\rho_g| = 1$. As $|\rho_g|$ decreases, the maxima become separated by greater distances until, when $|\rho_g| = 0$, the separation reaches $\lambda_g/8$ (Fig. 5).

The short-circuiting plunger could thus be used

(a) to determine the wavelength λ_g by the distance moved between successive zeros on the same galvanometer (AD $= \lambda_g/2$ in Fig. 4),

(b) to check the probe separation by the distance moved between successive zeros on adjacent galvanometers (AB, BC in Figs. 4 and 5),

(c) to ensure correct matching at the generator end by adjustment of the matching stub until the maxima are separated by $\lambda_g/8$ as in Fig. 5.

Having achieved (c), equation (12) becomes

$$|V_y|^2_{s.c.} = \text{constant} \times \sin^2 \frac{2\pi y}{\lambda_g}$$

for all three circuits. If the short-circuiting plunger is adjusted to be a distance $\lambda_g/8$ from the end probe, the galvanometers at B and D should each give readings one half of that of the galvanometer at C (Fig. 1). The probe depths were adjusted in conjunction with the crystal tuning stub until this was nearly so, and a final adjustment was made with the potentiometers. When this had been done, $k_1 = k_2 = k_3$ from equations (11), and expressions such as (5) could be used.

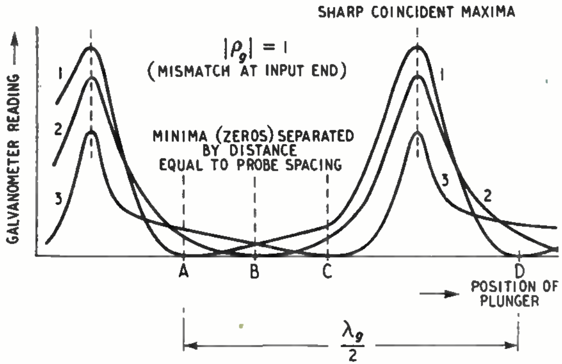

Fig. 4. *Variation of galvanometer readings with position of short-circuiting plunger for* $|\rho_g| = 1$.

6. Measurements

The input reactance of a short-circuited line of length l, characteristic impedance Z_0, is $Z_0 \tan 2\pi l/\lambda_g$. Such a line was used to obtain known reactances of values ranging from + infinity to − infinity and thus to obtain a check on the accuracy of the measurements.

Fig. 6 shows a typical set of such measurements plotted against the known values. The effect of errors considered in Section 3 is to introduce systematic errors into the results which are larger when the galvanometer readings are smaller. Equations (2), (3) and (4) show that numerically larger reactances must involve smaller readings in the denominators, and thus be subject to the larger systematic error. Sections of guide of lengths equal to $\lambda_g/8$ and $\lambda_g/4$ were constructed and could be inserted between the probes and the load, enabling either equation (2) or (3) or (4) to be used as required.

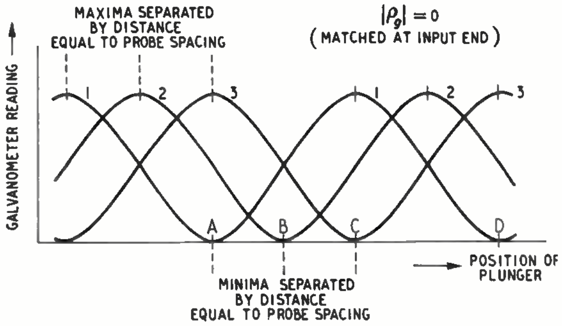

Fig. 5. *Variation of galvanometer readings with position of short-circuiting plunger for* $|\rho_g| = 0$.

7. Applications

A disadvantage of the method is its restriction to the wavelength for which it is designed. It would be possible, however, to modify the apparatus for use over a small range of wavelengths by making the probe spacing variable. Although this would involve short slots rather than holes in the waveguide, no noticeable difference in distribution of field strength should occur.

Apart from this, any measurement of impedance by the three-probe method should be no less accurate than by the travelling-probe method, while the former has the advantage that, when working at a fixed frequency or over a small frequency range, continuous variations in impedance due to changes of temperature or other physical conditions can be continuously recorded.

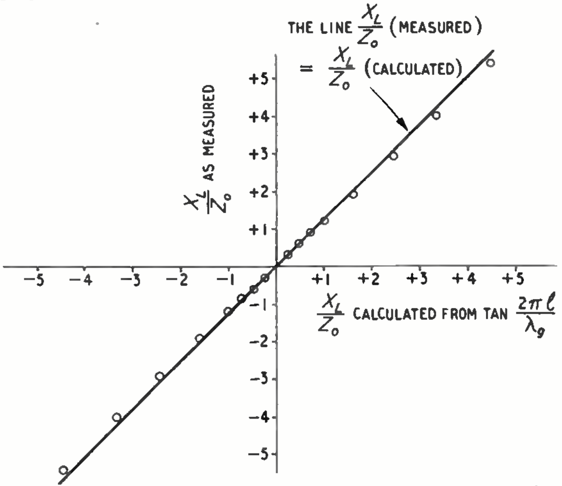

Fig. 6. *Typical set of reactance measurements showing systematic error.*

Acknowledgments

The author wishes to thank Dr. A. Cunliffe and Mr. L. E. S. Mathias, of University College, Hull, where this work was carried out, for the suggestion that the three-probe method could be used at microwave frequencies with advantages in certain cases over the slotted-line method, for designing the section of test line, and for selecting the crystal detectors.

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D.C. AMPLIFIERS WITH LOW-PASS FEEDBACK

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1. Introduction

DIRECT-COUPLED feedback amplifiers are being increasingly employed, not only as straightforward voltage amplifiers, but as adding, integrating and differentiating elements in electronic analogue computers. For accuracy in computing applications very high loop gains must be employed, and the problem of ensuring stability becomes a major factor in the design.

So far as is known, no method of stabilization has been proposed which is equally effective for any of these applications, and amplifiers are usually designed specifically for a particular purpose.

Brockelsby[1] and Mayr[2] have shown how to design a voltage amplifier of high stability with a response of maximal flatness, but their method as stated has the disadvantage that the amplifier must be designed for a particular value of loop gain. If the loop gain is varied by altering the feedback network, the overall frequency response will be seriously affected, while the amplifier may be unstable if used as an integrator or differentiator.

It is the object of this paper to extend the method to cover the case of a d.c. amplifier with a low-pass feedback network and to show that the gain of such an amplifier may be varied over a wide range without appreciable effect on the overall frequency response. It will further be shown that the amplifier can be used without modification as an integrator or differentiator and will be stable under these conditions.

In what follows, the notation and methods developed by Mayr will be used as far as applicable, as they are convenient to apply in practice, but it will be realized that the results given by Brockelsby are exactly equivalent. The author would like to express his indebtedness to both these writers for laying such useful foundations.

2. Response of Feedback Amplifiers

Before proceeding further it will be as well to re-state the general equation for the response of a feedback amplifier and to define the terms used.

The general equation is

$$A = \frac{\alpha}{1 + \alpha\beta} \quad \cdots \quad (1)$$

where α is the gain without feedback, A the gain with feedback, and β the feedback ratio; i.e., the fraction of the output voltage which is fed back to the input terminals. The value of any of these quantities at zero frequency will be denoted by the suffix $(_0)$.

$$\text{Thus } A_0 = \frac{\alpha_0}{1 + \alpha_0\beta_0} \quad \cdots \quad (2)$$

The ratio at zero frequency of the gain without feedback to the gain with feedback will be denoted by n and referred to as the gain reduction factor. It is considered that this term is preferable to the terms 'degree of negative feedback' or 'feedback factor' which are sometimes seen.

$$\text{Thus } n = \frac{\alpha_0}{A_0} = 1 + \alpha_0\beta_0 \quad \cdots \quad (3)$$

A term which may not be familiar to the reader is the frequency attenuation of an amplifier. This is simply the reciprocal of the frequency response and is expressed as the ratio of the response at zero frequency to the response at any other frequency. Thus, using the above notation, the frequency attenuation of an amplifier is α_0/α without feedback and A_0/A with feedback.

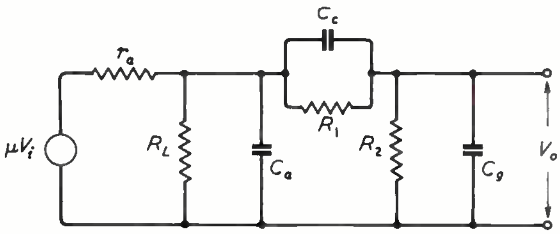

Fig. 1. *Equivalent circuit of d.c. amplifier stage.*

3. Conditions for Maximal Flatness

3.1. *Frequency Attenuation of D.C. Amplifier Stage*

Fig. 1 shows the equivalent circuit of a single stage of a direct-coupled amplifier, including the potentiometer network which is usually required to provide a coupling to the next stage.

It is assumed that the coupling network is correctly compensated for frequency, so that

$$R_1C_c = R_2C_g \quad \cdots \quad (4)$$

The gain of such a stage at any angular frequency ω is given by

$$\alpha = \frac{V_o}{V_i} = \frac{\mu RR_2}{(r_a + R)(R_1 + R_2)} \cdot \frac{1}{1 + j\omega cRr_a/(r_a + R)} \quad \cdots \quad (5)$$

MS accepted by the Editor, March 1952

where

$$R = \frac{R_L\,(R_1 + R_2)}{R_L + R_1 + R_2}\,;\; C = C_a + \frac{C_g R_2}{R_1 + R_2} \qquad (6)$$

The gain at zero frequency is given by

$$\alpha_0 = \frac{\mu R R_2}{(r_a + R)(R_1 + R_2)} \quad \ldots \quad \ldots \quad (7)$$

Whence the frequency attenuation is

$$\frac{\alpha_0}{\alpha} = 1 + j\omega T \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

where $$T = \frac{CRr_a}{r_a + R} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

This should be compared with Mayr's equation for the frequency attenuation of tuned and recoupled stages;

$$\frac{\alpha_0}{\alpha} = 1 + jQ\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right) \quad \ldots \quad \ldots \quad (10)$$

3.2. *Design Equations*

It is clear from the analogy between equations (8) and (10) that all Mayr's results may be applied to d.c. amplifiers by simply writing T_1, T_2, etc., in place of Q_1, Q_2, etc., and ω in place of $(\omega/\omega_0 - \omega_0/\omega)$.

In particular, his final design equations (36 to 39) may be re-written thus:

For one stage:

$$\frac{A_0}{A} = \sqrt{1 + x^2} \quad \ldots \quad \ldots \quad \ldots \quad (11a)$$

$$\phi = -\tan^{-1} x \quad \ldots \quad \ldots \quad \ldots \quad (11b)$$

$$x = \omega T/n \quad \ldots \quad \ldots \quad \ldots \quad (11c)$$

For two stages:

$$\left|\frac{A_0}{A}\right| = \sqrt{1 + x^4} \quad \ldots \quad \ldots \quad \ldots \quad (12a)$$

$$\phi = -\tan^{-1}\sqrt{2}\,x/(1 - x^2) \quad \ldots \quad (12b)$$

$$x = \omega T_2(T_1/nT_2)^{\frac{1}{2}} \quad \ldots \quad \ldots \quad \ldots \quad (12c)$$

$$T_1/T_2 = (n - 1) + \sqrt{n(n - 2)} \quad \ldots \quad (12d)$$

For three stages:

$$\left|\frac{A_0}{A}\right| = \sqrt{1 + a_2x^4 + x^6} \quad \ldots \quad \ldots \quad (13a)$$

$$\phi = -\tan^{-1}(b_1x - x^3)/(1 - b_2x^2) \quad \ldots \quad (13b)$$

$$x = \omega T_2(T_1/nT_2)^{\frac{1}{3}} \quad \ldots \quad \ldots \quad \ldots \quad (13c)$$

$$a_2 = n^{-\frac{2}{3}}[(T_2/T_1)^{\frac{4}{3}} + 2(T_1/T_2)^{\frac{2}{3}}] \quad \ldots \quad (13d)$$

$$b_1 = n^{-\frac{2}{3}}[(T_1/T_2)^{\frac{2}{3}} + 2(T_2/T_1)^{\frac{1}{3}}] \quad \ldots \quad (13e)$$

$$b_2 = n^{-\frac{1}{3}}[(T_2/T_1)^{\frac{2}{3}} + 2(T_1/T_2)^{\frac{1}{3}}] \quad \ldots \quad (13f)$$

$$T_1/T_2 = 2(n - 1) + \sqrt{2n(2n - 3)} \quad \ldots \quad (13g)$$

$$T_2 = T_3 \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (13h)$$

For four stages:

$$\left|\frac{A_0}{A}\right| = \sqrt{1 + a_2x^4 + a_3x^6 + x^8} \quad \ldots \quad (14a)$$

$$\phi = \tan^{-1}(b_1x - b_3x^3)/(1 - b_2x^2 + x^4) \quad (14b)$$

$$x = \omega T_2(T_1/nT_2)^{\frac{1}{4}} \quad \ldots \quad \ldots \quad (14c)$$

$$a_2 = n^{-1}[2(n - 1) + 3T_1/T_2 + 3T_2/T_1] \quad (14d)$$

$$a_3 = n^{-\frac{1}{2}}[(T_2/T_1)^{\frac{3}{2}} + 3(T_1/T_2)^{\frac{1}{2}}] \quad \ldots \quad (14e)$$

$$b_1 = n^{-\frac{3}{4}}[(T_1/T_2)^{\frac{3}{4}} + 3(T_2/T_1)^{\frac{1}{4}}] \quad \ldots \quad (14f)$$

$$b_2 = n^{-\frac{1}{2}}[3(T_1/T_2)^{\frac{1}{2}} + 3(T_2/T_1)^{\frac{1}{2}}] \quad \ldots \quad (14g)$$

$$b_3 = n^{-\frac{1}{4}}[(T_2/T_1)^{\frac{3}{4}} + 3(T_1/T_2)^{\frac{1}{4}}] \quad \ldots \quad (14h)$$

$$T_1/T_2 = 3(n - 1) + \sqrt{3n(3n - 4)} \quad \ldots \quad (14i)$$

$$T_2 = T_3 = T_4 \quad \ldots \quad \ldots \quad \ldots \quad (14j)$$

These equations will enable us to design a d.c. amplifier with a response of maximal flatness and any desired high-frequency cut-off. The actual frequency and phase response will be those given by Mayr (Figs. 3 to 8, loc. cit.).

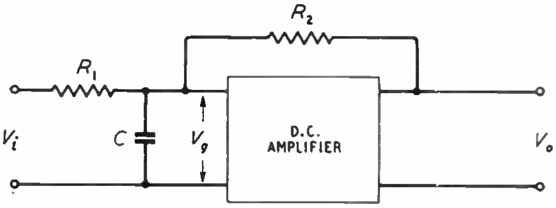

Fig. 2. *D.C. amplifier with low-pass feedback network.*

4. Amplifier with Low-pass Feedback Network

4.1. *Frequency Attenuation*

Fig. 2 shows the type of feedback circuit which is to be discussed. The input impedance of the amplifier itself is regarded as infinite. Then since the sum of the currents at the amplifier input must be zero,

$$\frac{V_i - V_g}{R_1} + \frac{V_o - V_g}{R_2} - V_g\,.\,j\omega C = 0 \;\ldots \quad (15)$$

but $$V_g = -\frac{V_o}{\alpha} \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

whence it may easily be shown that

$$A = \frac{V_o}{V_i} = \frac{\alpha'}{1 + \alpha'\beta} \quad \ldots \quad \ldots \quad \ldots \quad (17)$$

where

$$\alpha' = \frac{\alpha R_2}{R_1 + R_2}\cdot\frac{1}{1 + jC\omega R_1R_2/(R_1 + R_2)} \quad (18a)$$

and $\beta = R_1/R_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (18b)$

Equation (17) is the well-known expression for the gain of a feedback amplifier, and we see that in the present circuit the presence of a capacitor across the amplifier input has the rather surprising effect of modifying the effective forward gain, but not the feedback ratio. From equation (18)

$$\alpha'_0 = \frac{\alpha_0 R_2}{R_1 + R_2} \quad \ldots \quad \ldots \quad \ldots \quad (19)$$

Thus the effective frequency attenuation of the amplifier is

$$\alpha'_0/\alpha' = \frac{\alpha_0}{\alpha}[1 + jC\omega R_1 R_2/(R_1 + CR_2)]$$

$$= (1 + j\omega T_1)(1 + j\omega T_2) \ldots (1 + j\omega T_r) \quad (20)$$

where $T_1 = CR_1R_2/(R_1 + R_2)$ and T_2 to T_r are the time constants of the amplifier stages.

We have already seen that the feedback ratio β is independent of frequency. It follows that we can design an amplifier of $r - 1$ stages with a low-pass feedback network and achieve maximal flatness by applying the appropriate design equations (11) to (14) above as derived for an amplifier of r stages with internal stabilization. The advantages of this method of stabilization will be made apparent in the following sections.

4.2. *Design for Maximal Flatness*

It now remains to determine the value of the stabilizing capacitance C by applying the appropriate design equation.

For a single-stage amplifier with low-pass feedback, equation (12d) gives:

$$C = T_1(R_1 + R_2)/R_1R_2$$

$$= [T_2(R_1 + R_2)/R_1R_2][(n - 1) + \sqrt{n(n - 2)}] \quad \ldots \quad \ldots \quad \ldots \quad (21)$$

But from equations (3) and (19),

$$n = 1 + \alpha'_0\beta = 1 + \alpha_0 R_1/(R_1 + R_2) \quad \ldots \quad (22)$$

In a similar way it can be shown that for two stages:

$$C \approx \frac{4T_2\alpha_0}{R_2} \quad \ldots \quad \ldots \quad \ldots \quad (25)$$

and for three stages,

$$C \approx \frac{6T_2\alpha_0}{R_2} \quad \ldots \quad \ldots \quad \ldots \quad (26)$$

Thus C is independent of R_1 so long as n is large. But under the same conditions the overall gain at zero frequency is given by:

$$A_0 = R_2/R_1 \quad \ldots \quad \ldots \quad \ldots \quad (27)$$

Equations (24), (25), (26) and (27) taken together indicate that the values of C and R_2 can be fixed, and the overall gain varied over a wide range by varying R_1 without appreciably changing the frequency response. It can also be shown that, even if R_1 is made so small that the above approximations are no longer justified, the amplifier remains stable and the frequency response is only slightly worse than the optimum.

It will be realized, of course, that the above results apply only to a feedback circuit of the type shown in Fig. 2, not to amplifiers whose feedback circuits are entirely separate from their input circuits.

4.3. *Amplifiers with Unequal Time-Constants*

In designing a practical amplifier, it is not always possible or desirable to equalize the time constants of all the stages.

It is still possible, however, to adjust C to give the flattest response of which the given amplifier is capable.

The general expression for the frequency attenuation may be written in the form:

$$\left|\frac{A}{A_0}\right| = \sqrt{1 + a_1x^2 + a_2x^4 + \ldots\ldots + a_{r-1}\,x^{2(r-1)} + x^{2r}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (28)$$

whence

$$C = \frac{T_2(R_1 + R_2)}{R_1R_2}\left[\frac{\alpha_0 R_1}{R_1 + R_2} + \sqrt{\left(1 + \frac{\alpha_0 R_1}{R_1 + R_2}\right)\left(\frac{\alpha_0 R_1}{R_1 + R_2} - 1\right)}\,\right] \quad \ldots \quad (23)$$

Maximal flatness is achieved by making a_1 equal to zero and minimizing all the other coefficients, the latter condition being met when all the time constants are equal. If the time constants cannot be equalized, the next best thing is to be content with making a_1 zero.

The general expression for this coefficient is:

$$a_1 = \frac{T_1^2 + T_2^2 + \ldots + T_r^2 - 2(n - 1)\,[T_1(T_2 + T_3 + \ldots + T_r) + T_2T_3 + \text{etc.}]}{n^{2(r-1)/r}\,(T_1T_2\ldots T_r)^{2/r}} \quad \ldots \quad \ldots \quad (29)$$

or

$$C \approx \frac{2T_2\alpha_0}{R_2} \text{ if } \frac{\alpha_0 R_1}{R_1 + R_2} \gg 1 \quad \ldots \quad \ldots \quad (24)$$

There is, of course, little point in applying the method to a single-stage amplifier unless it is desired to take advantage of the sharper cut-off that can be obtained, but the result is included for the sake of completeness.

To make a_1 zero we require to find the value of T_1 which will make the numerator of the above expression equal to zero. The exact solution is somewhat cumbersome, but an approximate solution is readily obtained as follows.

We have already seen that if n is large, T_1 will also be large compared with the other time constants. We may, therefore, neglect all terms such as T_2^2 and T_2T_3 and write:

$$T_1^2 - 2nT_1(T_2 + T_3 + \ldots + T_r) = 0 \quad \ldots \quad (30)$$

or

$$T_1 = 2n(T_2 + T_3 + \ldots + T_r) \quad \ldots \quad \ldots \quad (31)$$

whence

$$C = \frac{2\alpha_0}{R_2}(T_2 + T_3 + \ldots + T_r) \quad \ldots \quad \ldots \quad (32)$$

which is seen to reduce to the form of equations (24) to (26) if all the time constants are equal.

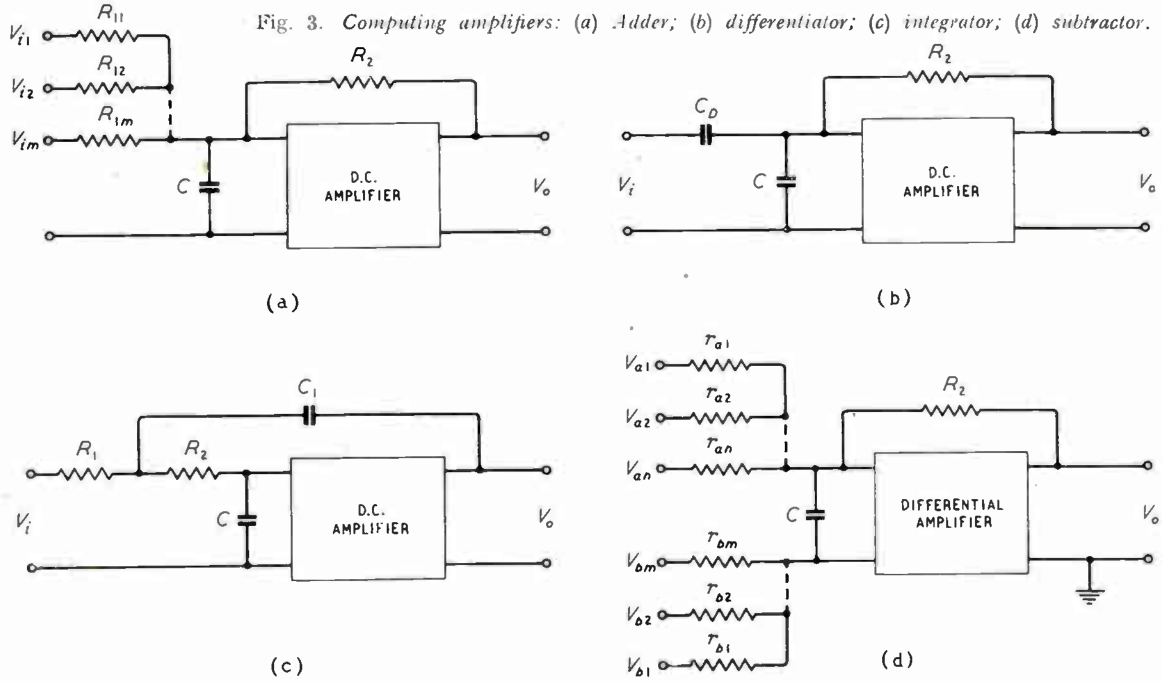

Fig. 3. *Computing amplifiers: (a) Adder; (b) differentiator; (c) integrator; (d) subtractor.*

5. Application to Computing Amplifiers

5.1. *Adder*

Fig. 3(a) shows the circuit of an adding amplifier. It is easily shown that the input voltages V_{i1}, V_{i2}, etc., and resistances R_{11}, R_{12}, etc., may be replaced by the single voltage V_i and single resistance R_1 where

$$V_i = V_{i1}\frac{R_1}{R_{11}} + V_{i2}\frac{R_1}{R_{12}} + \ldots + V_{im}\frac{R_1}{R_{1m}} \quad (33a)$$

and

$$\frac{1}{R_1} = \frac{1}{R_{11}} + \frac{1}{R_{12}} + \ldots + \frac{1}{R_{1m}} \quad \ldots \quad \ldots \quad (33b)$$

The conditions for stability and flat response are therefore exactly the same as for a normal voltage amplifier, and providing R_2 and C are left unchanged, any number of input resistors may be added without affecting the frequency response or stability.

5.2. *Differentiator*

The circuit is shown in Fig. 3(b), in which it is again assumed that the values of R_2 and C are unchanged. From the point of view of stability, it is readily seen that C_D is effectively in parallel with C thus increasing the time-constant and improving the stability.

The performance as a differentiator may be investigated by considering the response to a uniformly rising voltage commencing at $t = 0$

$$V_i = bt \,.\, \mathbf{1} \quad \ldots \quad \ldots \quad \ldots \quad (34)$$

It is readily shown by operational methods that the response is given by

$$V_o = \frac{b\alpha RC_D}{1+\alpha}\left\{1 - \exp.\frac{-(1+\alpha)t}{R(C+C_D)}\right\} \quad \ldots \quad (35)$$

It has been assumed in deriving this expression that the time constants of the amplifier stages are very small compared with $R(C + C_D)$ and that the gain may, therefore, be assumed independent of frequency. The only effect of C is to increase the time-constant of the error voltage, which, however, remains small so long as α is large.

It should be noted on the other hand that if a differentiating network is used with an amplifier having a large internal time-constant, there will be two integrating constants round the loop, and the response will be oscillatory unless these have very different values.

5.3. *Integrator*

The circuit is shown in Fig. 3(c). The components R_2 and C now form a low-pass input filter for the amplifier. Space does not permit a detailed investigation of the stability of this arrangement, but it is easily seen that R_1 and C_1 introduce additional attenuation and phase advance into the loop, and hence improve the stability.

Making suitable approximations on the assumption that α is very large, the step function response of the circuit may be shown to be

$$V_o = -V_i\alpha\left[1-\left(1+\frac{m}{n}\right)e^{-mt}+\frac{m}{n}e^{-nt}\right] \quad (36)$$

$$\text{where } m = \frac{1}{(1+\alpha)R_1C_1+(R_1+R_2)C} \quad (37a)$$

$$\text{and } n = \frac{(1+\alpha)R_1C_1+(R_1+R_2)C}{R_1R_2C_1C} \quad (37b)$$

The final term represents a transient effect of small amplitude and short time constant. Neglecting this term the expression may be expanded to

$$V_o \approx -V_i\alpha\left[-\frac{m}{n}+mt+\frac{mt^2}{2}+\ldots\right] \quad (38)$$

$$\text{or } V_o \approx \frac{-V_i}{R_1C_1}\left(t-\frac{R_2C}{\alpha}\right) \text{ if } mt \ll 1 \quad .. \quad (39)$$

The output is, therefore, of the required form but with a time-lag which is small provided α is large.

It should be noted that had the stabilizing network been placed between stages instead of at the input to the amplifier, the result would have been almost identical. A time delay of this order is, in fact, unavoidable in a stable integrator.

5.4. *Subtractor*

It has been shown by Goldberg[3] that a d.c. amplifier with a balanced input may be employed for many computing operations, including subtraction. The method of stabilization discussed above may be used with such a differential amplifier, provided the capacitor C is connected between the two inputs, rather than from one side to earth.

Fig. 3(d) shows the most general form of subtracting circuit, including the stabilizing capacitor. Using the notation shown on the diagram,

$$V_o = \frac{R_b(R_2+R_a)}{R_a}\left(\frac{V_{b1}}{r_{b1}}+\frac{V_{b2}}{r_{b2}}+\ldots+\frac{V_{bm}}{r_{bm}}\right) - R_2\left(\frac{V_{a1}}{r_{a1}}+\frac{V_{a2}}{r_{ag}}+\ldots+\frac{V_{an}}{r_{an}}\right) \quad .. \quad .. \quad (40)$$

$$\text{where } \frac{1}{R_a} = \frac{1}{r_{a1}}+\frac{1}{r_{a2}}+\ldots+\frac{1}{r_{an}} \quad .. \quad (41a)$$

$$\frac{1}{R_b} = \frac{1}{r_{b1}}+\frac{1}{r_{b2}}+\ldots+\frac{1}{r_{bm}} \quad .. \quad (41b)$$

It will be seen that the time constant of the stabilizing network is increased by R_b which should therefore be kept as small as possible. Various modifications of this circuit are described by Goldberg (loc.cit.) and need not be further discussed here.

6. Stability with Capacitive Load

The output stage of a computing amplifier usually consists of a cathode follower, which is assumed to have a negligible time constant. When feeding a capacitive load, however, the output time constant may easily become as great as, or greater than, others in the amplifier. Under these conditions the amplifier may become unstable.

Equation (32) shows that the amplifier may be re-stabilized by adding additional capacitance across the input, the required value being given by

$$C = \frac{2\alpha_0 R_0 C_L}{R_2} \quad .. \quad .. \quad .. \quad (42)$$

where R_0 is the output impedance and C_L the capacitance of the load.

7. Conclusion

It has been shown that the method developed by Mayr for the design of an amplifier of maximal flatness may be applied to the case of a d.c. amplifier with a low-pass feedback network. An amplifier so designed has the advantage that its gain may be varied over a wide range with negligible effect on the frequency response. The amplifier may also be used without modification as an adding, subtracting, integrating or differentiating element in a computing system, and will be perfectly stable under all these conditions. Any lack of stability when feeding a capacitive load can be readily corrected by increasing the capacitance in the feedback network.

A word of warning should perhaps be added on the subject of noise level. Owing to the presence of the low-pass filter in the feedback circuit, high-frequency noise originating in the early stages of the amplifier is not fed back, and the resultant noise level at the output may be excessive for some purposes. The circuit may not therefore have so wide a field of application as was at first hoped, but the principles developed are considered to be of sufficient interest to justify publication.

Acknowledgments

The author is indebted to the Ministry of Supply for permission to publish some of this material.

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MECHANICAL SYNTHESIS OF THE AMPLITUDE-MODULATED WAVE

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SUMMARY.—Apparatus is described which demonstrates the synthesis of a sinusoidal amplitude-modulated wave. The three component vibrations are separately generated by mechanical means and may be added together in any amplitude and phase relationship. The resultant oscillation is recorded on a travelling paper chart along with the components, and the apparatus, although constructed almost entirely from standard Meccano parts, is capable of giving results which are sufficiently accurate for teaching and demonstration.

The equipment is used to demonstrate the effect of a fixed or progressive phase difference between the carrier and side-frequency components, and the distortion of the modulation envelope occurring in single-sideband transmission under various conditions of locally added carrier.

1. Introduction

IN 1930 Sir Ambrose Fleming published an article in *Nature* entitled "The Waveband Theory of Wireless Transmission."[1] This article and the prolonged controversy which followed its publication make interesting reading more than 20 years later.

In his original communication Fleming made some surprising statements. After wrongly giving the expression for the complete modulated wave as $a = A \cos qt \sin pt$, and performing the trigonometrical transformation $a = A/2\{\sin(p + q)t + \sin(p - q)t\}$, he said, "... this, however, is a purely mathematical analysis, and this band of multiple frequencies does not exist, but only a carrier wave of one single frequency which is modulated in amplitude regularly or irregularly."

This edict from so eminent an authority was naturally followed by correspondence from several learned persons,* including Professor C. L. Fortescue,[2] Sir Oliver Lodge,[3] and Sir Richard Glazebrook.[4] The complete correspondence is summarized in the References for the convenience of those who wish to pursue it.

The publication of Colebrook's paper[6] on "The Physical Reality of Side-Bands" in 1931 appears to have been prompted by the topical controversy and this, too, was followed by further correspondence which became somewhat acrimonious when the principles of Robinson's highly selective 'Stenode' receiver[7] were called in question.

The discussion died out and the existence of sidebands appears at least to have been tacitly admitted by the opposition. The foundations of trigonometry remained unshaken.

It is hard to understand at this time how so futile a discussion should ever have arisen in the face of a plain mathematical identity. Perhaps there is now a growing tendency to acquiesce in the acceptance of a mathematical formulation of processes which are difficult to realize physically —a habit of thought common among engineers. As Fleming said, ".... the majority of persons are not able to see their way through complicated phenomena and so thankfully adopt any short-cut to a supposed comprehension of them without objection." It would appear from this that Fleming himself was unhappy without a satisfactory mental picture or, like Lord Kelvin, could understand nothing of which he could not make a model.

The more complex process of frequency modulation is practically impossible to visualize; yet, apart from early minor misunderstandings, there

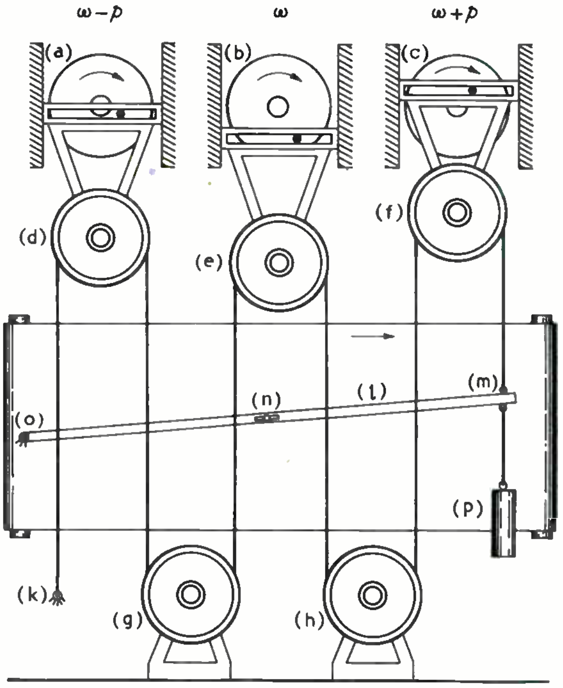

Fig. 1. *Outline of Ladner's wave synthesizer which embodies the principle of Kelvin's tide predictor.*

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* A trenchant criticism of Fleming's article was made by Professor G. W. O. Howe.[5]

MS accepted by the Editor, April 1952.

has been no doubt cast on the correctness of the mathematical statements first enunciated by Carson in 1922.[8] This is probably due to the fact that frequency modulation remained a laboratory curiosity almost until 1936, when Armstrong[9] advocated its adoption; and by 1936 engineers were well used to accepting the notion of sidebands—even an infinite number of them.

It appears to the author that the pendulum is now swinging rather too far in the other direction. Students tend to accept the mathematics without question. They are content to 'turn the mathematical handle' without attempting to form a mental picture, however imperfect, or showing much curiosity regarding orders of magnitude, unless the lecturer is able to devote a disproportionate time to the subject in an already overburdened engineering course.

Although the synthesis of the sinusoidal amplitude-modulated wave from its three components is comparatively easy to grasp, there are some more complicated aspects of the process in which the mathematical formulae certainly state the result correctly, but tend to obscure the actual

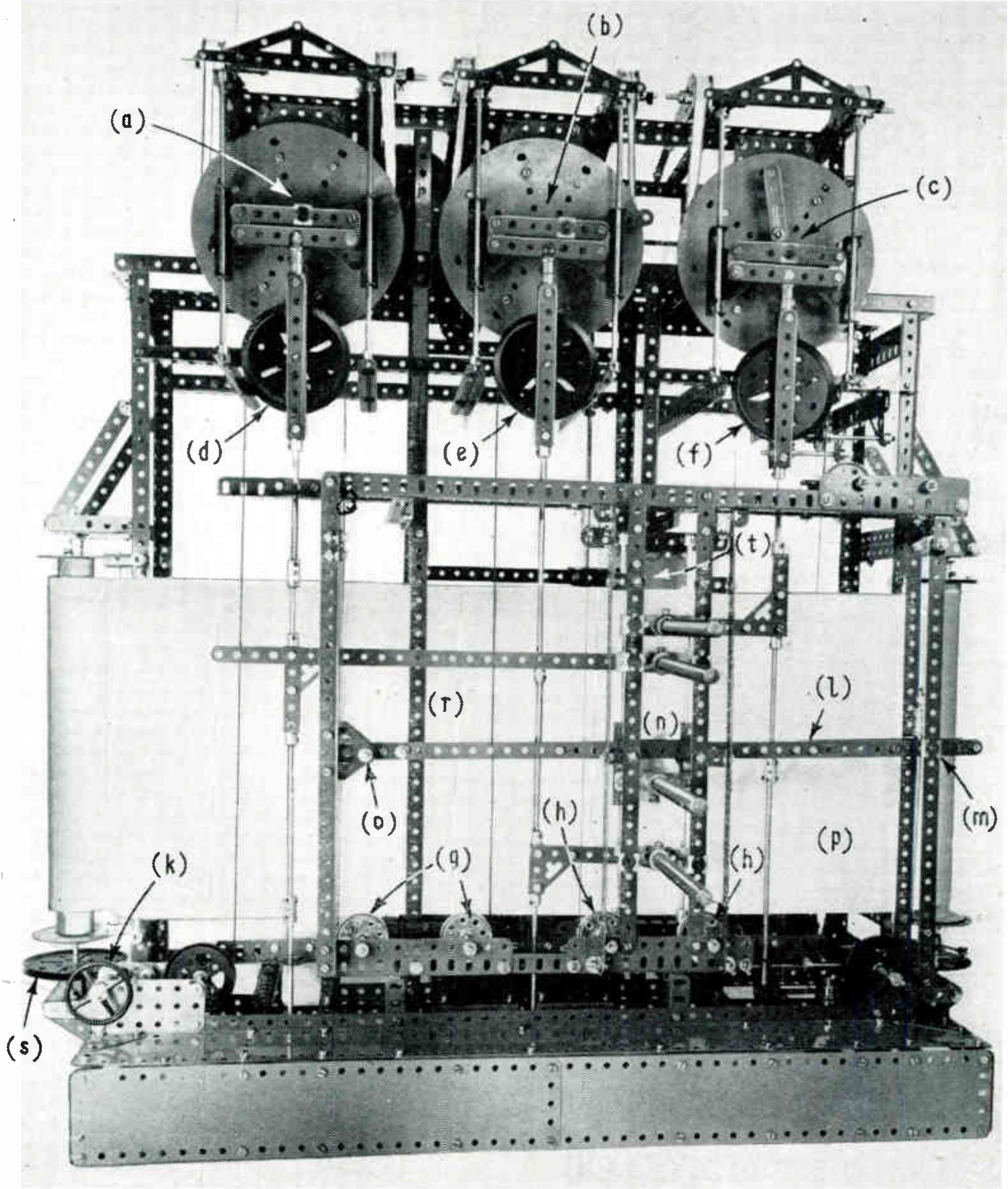


Fig. 2. *General view of the synthesizer.*

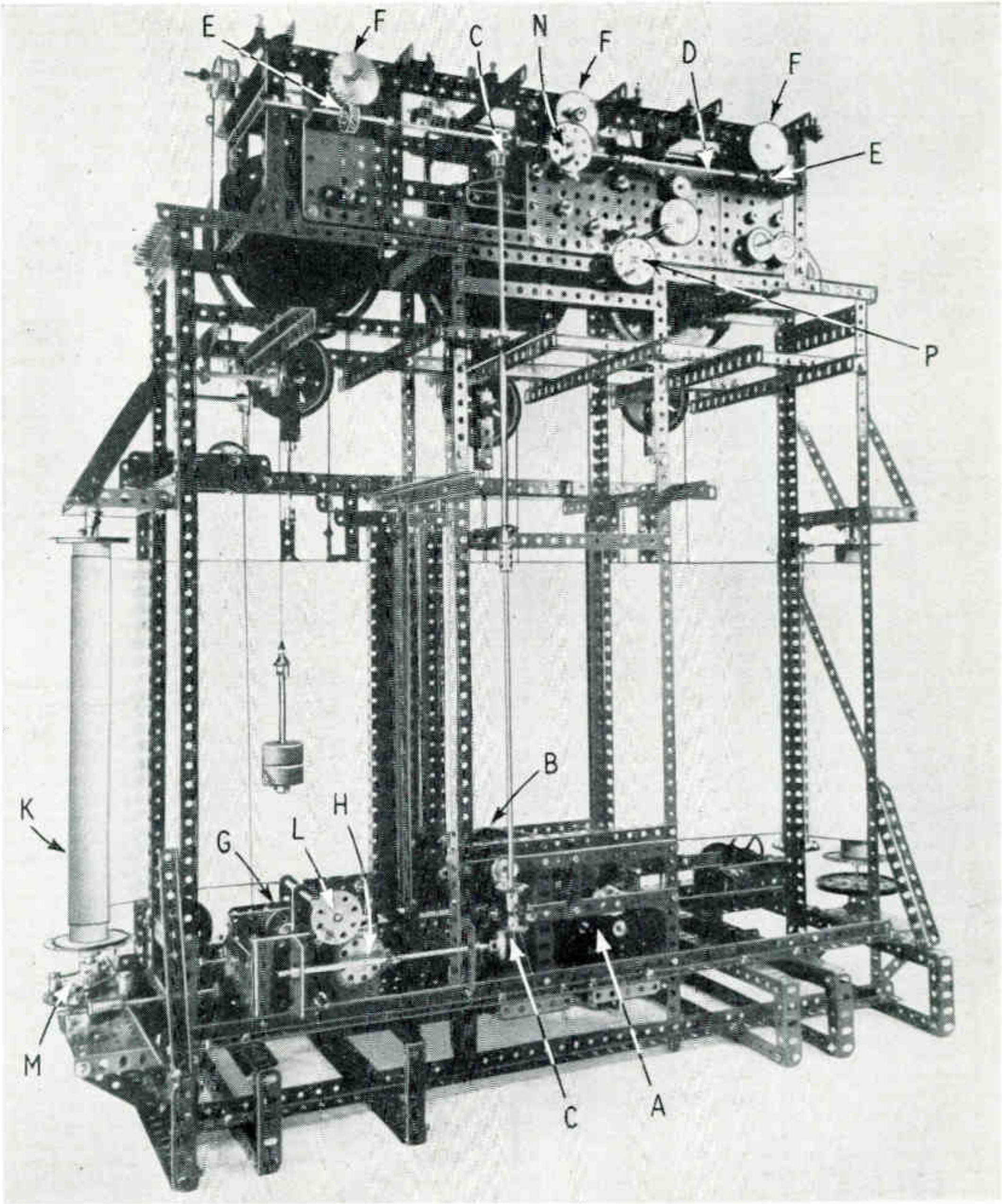


Fig. 3. *Rear view showing the drive to the frequency generators.*

mechanism of the process. The author has been conscious of this in teaching, more particularly in treating the forms of distortion due to a fixed or progressive phase displacement between the carrier and side-frequency components, and the necessity for a large amplitude local carrier in single-sideband reception.

An apparatus which performs mechanically the synthesis of an amplitude-modulated wave and slows down the mechanism of the process is most instructive, and the operation of such a device really fascinating to watch.

2. Description of Apparatus

In 1929 Ladner[10] published details of an elaborate general purpose 'Wave Synthesizer' which could also be used to demonstrate the formation of an amplitude-modulated wave from its components. Ladner's equipment employed the principle of Kelvin's tide predictor and is shown in outline in Fig. 1.

The component oscillations are generated by the crossheads (a), (b) and (c), driven by crank pins fixed in rotatable discs, giving simple harmonic motion in the vertical direction. The amplitudes and mutual phases of the motions are controlled by the crank pin pitch-circle radii and the relative angular positions of the discs.

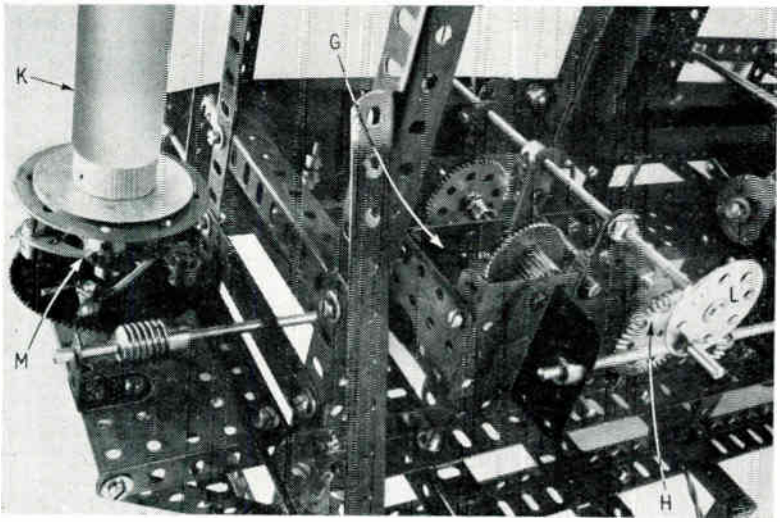
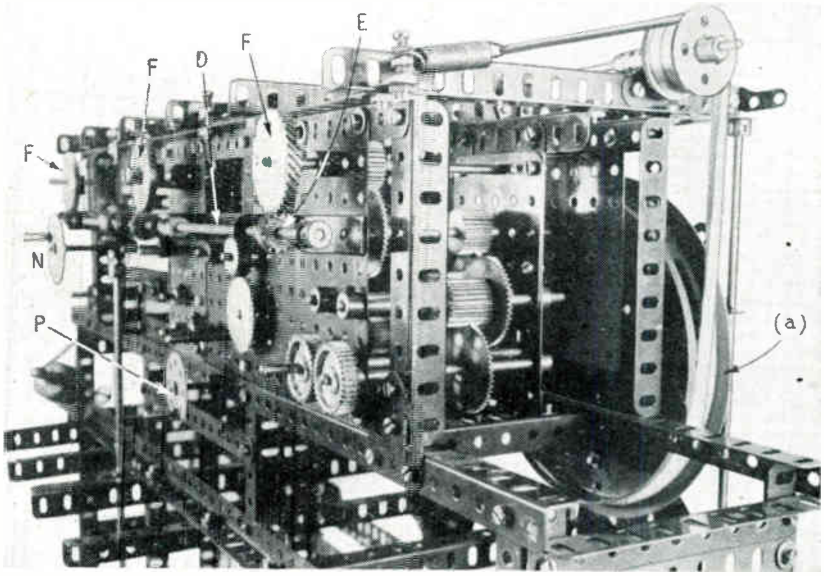


Fig. 4 (above). *Close-up of the paper-drive mechanism.*

Fig. 5 (right). *Close-up of helical drive and 16 : 1 reduction gear.*



The pulleys (d), (e) and (f) move with the crossheads while pulleys (g) and (h) are fixed. A light inextensible cord is fixed at (k) and after passing round all the pulleys is secured to the end of the arm (l) at (m). The arm (l) is pivoted at (o), and a small weight is attached at (m) to keep the cord taut. The point (m), assuming (l) to be infinitely long, describes the resultant motion of (a), (b) and (c) doubled in amplitude, since the pulley system is of the second order. A recording pen fixed at the mid-point (n), and travelling in suitable guides, reproduces the true resultant motion which is recorded on a slowly-moving paper chart (p).

In Ladner's apparatus there were six crossheads, the discs being driven at appropriate speeds by belts and interchangeable pulleys at the rear. All the component vibrations in addition to the resultant wave were recorded in the same vertical line so that a full graphical solution was obtained. The author's apparatus follows Ladner's in principle, but since it was primarily required to demonstrate sinusoidal amplitude modulation without harmonics of the modulating frequency, only three frequency generators were incorporated. A general view of the apparatus is given in Fig. 2, which is lettered to correspond with Fig. 1. Fig. 3 is a rear view which shows the drive to the frequency generators and the paper chart.

The motive power is provided by a standard Meccano electric motor A, Fig. 3, with a reduction gear train of 81 : 1 to a further chain reduction gear of 2 : 1 at B. The drive is then taken by bevel gears at C to the main driving shaft, D, of the frequency generators. This shaft carries three helical pinions, E, meshing with helical gears, F, on each frequency generator, so that all three helical gears rotate at the same speed—approximately 120 r.p.m. Trains of reduction gears then actuate the crank discs at the appropriate speeds.

The lower pair of bevel gears C transmits the drive to the 2-speed gear box, G, via the 3 : 1 bevel reduction gear, H. The gear box provides a further reduction of 9 : 1 or 6 : 1 before the drive is taken out to a 95 : 1 worm reduction gear on the paper mandrel, K. The required paper speed is selected by the control, L. An enlarged view of the paper drive is shown in Fig. 4. The paper mandrel is driven through a ratchet, M, which allows paper to be wound on the mandrel independently of the drive when setting up.

The paper chart is 10 in. wide and was obtained, as in Ladner's equipment, by cutting down a roll of 'detail' paper and mounting on two slightly-tapered mandrels pushed into either end and clamped between face plates.

Since the gear ratios available in the Meccano system are limited, particularly as regards even ratios, some care is necessary in choosing the disc speeds to give a reasonably well-defined 'audio' envelope. The reduction ratios chosen were 14 : 1 and 16 : 1 for the side frequencies [discs (c) and (a) respectively, Fig. 2] giving a mean of 224/15 : 1 for the 'carrier' component. This means that the discs revolve at 1/14, 1/16 and 15/224 of the speed of the helical driving gear. There are thus 15 'carrier' cycles within each 'audio' cycle.

These gear ratios are obtained by using standard Meccano gears in the following combinations:—

For 14 : 1 reduction:—$1/7 \times 1/2$

For 16 : 1 reduction:—$(1/2)^4$

For 224/15 : 1 reduction:—$5/1 \times 3/1 \times 1/7 \times (1/2)^5$

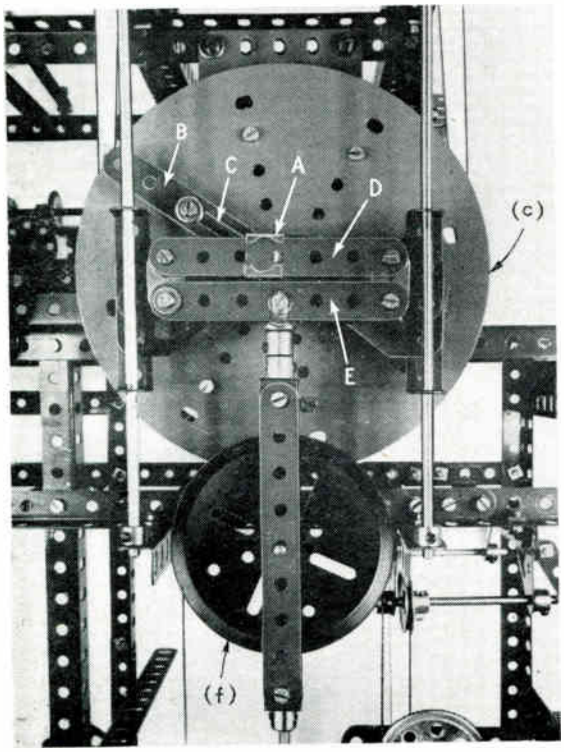


Fig. 6. *Detail of disc and cross-head.*

An enlarged view of the helical drive and the 16 : 1 reduction gear to disc (a) is shown in Fig. 5.

A progressive phase displacement between carrier and side frequencies is effected by changing the 224/15 : 1 reduction to a 225/15 : 1 or 15 : 1 reduction by means of a gear-change mechanism incorporated in the reduction train to disc (b). The appropriate reduction is now obtained by using $1/5 \times 1/3$, and the change is made by means of controls N and P (Fig. 3 and Fig. 5). Control N engages the required wheels, while P disengages the unused part of the normal reduction train in order to reduce rotational inertia.

A fixed angular phase displacement between carrier and side frequencies is easily obtained by loosening the set screws which secure the discs to their shafts, setting these to the correct starting position for normal operation and then phase advancing or retarding the carrier disc (b) by the required amount.

The disc (c) and crosshead arrangement are shown in detail in Fig. 6. The slide-piece, A, engages a pin secured to a hole in the slotted strip, B, so that the pin radius may be adjusted from zero to 1 in. by setting the position of the slotted strip on two threaded bosses, C. The second of these is just visible between the slide, D, and the member, E.

Since the weight of the moving parts is considerable, and the backlash in long gear trains by no means negligible, it was found that smoother operation resulted when each disc rotated under slight friction. This is provided by a length of tape passing round a flange at the rear of the disc and anchored by tension springs. These friction tapes are clearly shown in Fig. 2 and Fig. 5.

Although gearing restricts the scope of the equipment according to the gear ratios available, it is superior to belt drive which has a tendency to slip unless much care is taken in fitting, as Ladner found on his equipment. In any case, leather belting is too coarse to be incorporated in the Meccano system and the tension required would undoubtedly cause flexure of the shafting and other components.

The recording pens are commercial ball-pointed pens sliding in closely-fitting fibre tubes and spring-loaded to maintain a light and even pressure on the paper. This type of stylus has been found very satisfactory. The pens are secured by set screws in specially made brass holders (Fig. 2), these and the paper mandrels being, in fact, the only components which are non-standard. In order to avoid a curved record due to the finite length of the arm (l), the 'resultant' pen travels vertically in guides and a pin on the carrier engages a slot in the arm (l). The 'component' pens travel vertically, being coupled direct to their respective crossheads as Fig. 2.

The cord is a length of 'Cuttyhunk' line anchored at (k) (Fig. 2) to a rod with a pawl and ratchet, so that the setting of arm (l) is adjustable. The weight which keeps the cord taut is seen in Fig. 3 and is connected to point (m) (Fig. 2) by another cord passing over pulleys.

Friction control of the paper tension is obtained by passing the paper between two vertical strips (r), and a spring-loaded cord brake may be fitted to the pulley (s). The latter was not required.

At the recording position the paper passes over the plate (t), which provides a hard, smooth backing for the pens.

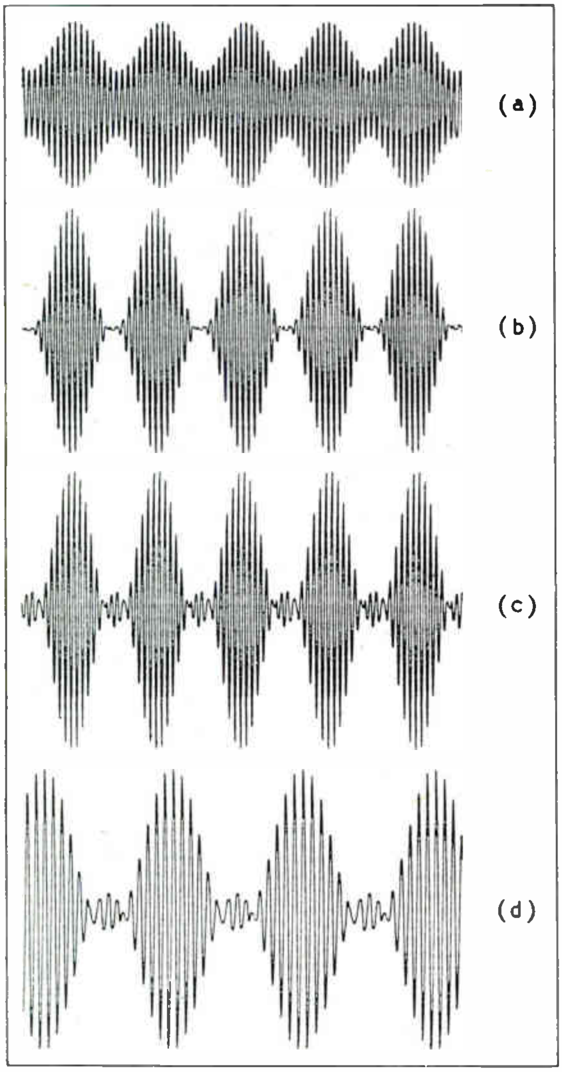


Fig. 7. *Amplitude-modulated wave;* (a) 40% *modulation,* (b) 100% *modulation,* (c) *overmodulation, and* (d) *overmodulation with higher paper speed.*

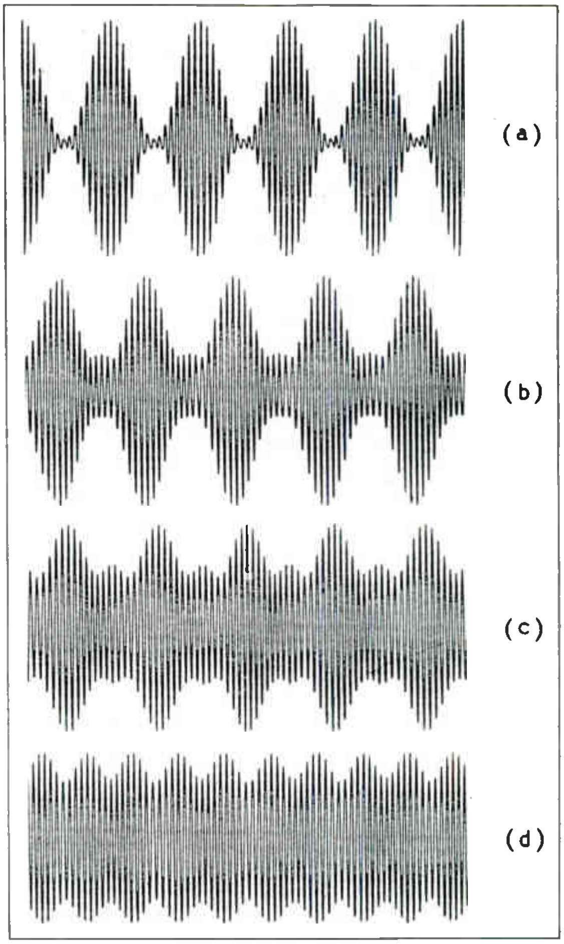


Fig. 8. *Effect of phase displacement between carrier and sidebands;* (a) *normal* 100% *modulation,* (b) 30°, (c) 60°, *and* (d) 90° *carrier phase shift, respectively.*

3. Operation of Equipment

(a) *Pure Amplitude-Modulated Wave*

Fig. 7 shows records of amplitude-modulated waves produced by the equipment with various modulation factors. The effect of changing the paper speed is shown at (d).

(b) *Effect of Fixed Phase Displacement between Carrier and Side-Frequency Components*

If C and $S/2$ are the carrier and side-frequency amplitudes and the fixed phase displacement of the carrier with respect to the side-frequency components is θ, the apparatus synthesizes the wave

$$y = C \sin(\omega t + \theta) + S \sin pt \sin \omega t, \quad .. \quad (1)$$

where $\omega/2\pi$ = carrier frequency, and $p/2\pi$ = modulating frequency.

This condition simulates the effect of a phase displacement of the locally-added carrier in a suppressed-carrier system.

Equation (1) may easily be transformed into

$$y = \sqrt{(C^2 + 2CS \cos \theta \sin pt + S^2 \sin^2 pt)} \sin (\omega t + \alpha), \quad .. \quad .. \quad (2)$$

where $\tan \alpha = \dfrac{C \sin \theta}{C \cos \theta + S \sin pt}$.

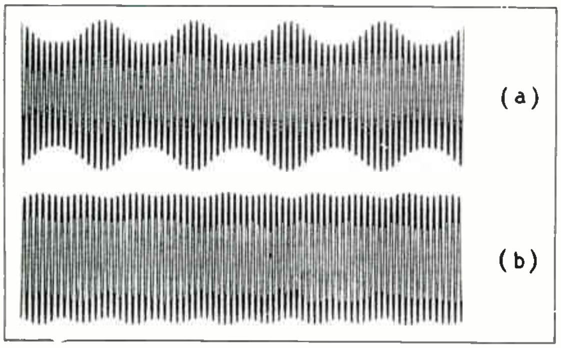


Fig. 9 (above). *Conditions as in Fig. 8, but the carrier amplitude is much greater than that of the side frequencies;* (a) *for* 60° *and* (b) *for* 90° *phase shift.*

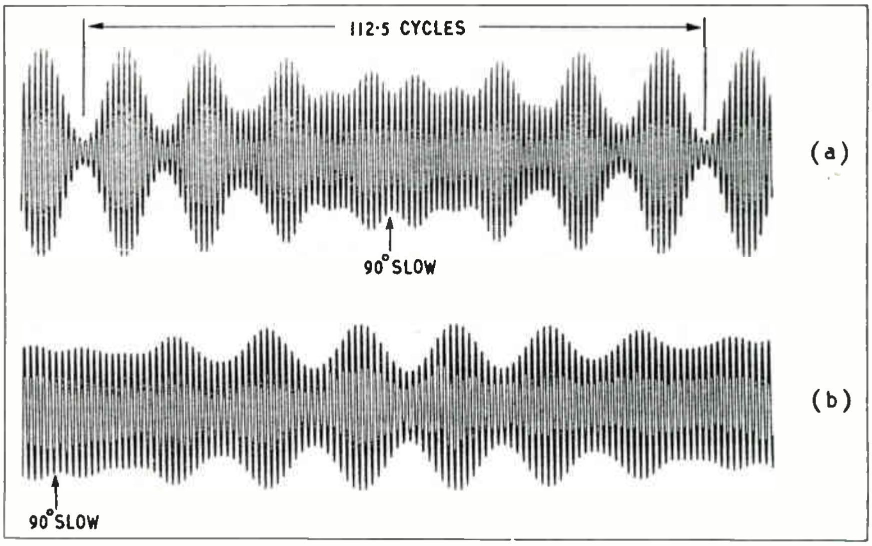


Fig. 10 (right). *Progressive phase shift of* 1·6° *per cycle of carrier;* (a) *for* 100% *modulation,* (b) *for shallow modulation.*

It is observed from equation (2) that there is envelope distortion due to the factor cos θ and some degree of phase modulation caused by variation of α with pt. The envelope distortion is illustrated by the records of Fig. 8 for various degrees of phase displacement. When $\theta = 90°$ the character of the modulation is radically altered. In this case equation (2) becomes

$$y = \sqrt{(C^2 + S^2 \sin^2 pt)} \sin (\omega t + \alpha)$$
$$= \sqrt{(C^2 + \tfrac{1}{2}S^2 - \tfrac{1}{2}S^2 \cos 2pt)} \sin (\omega t + \alpha) \quad (3)$$

The envelope therefore contains a double-frequency term arising from the $\sin^2 pt$ term in equation (2). This is clearly shown in the record of Fig. 8.

If the carrier amplitude is much greater than that of the side frequencies (i.e., if $C^2 \gg S^2$) then we have

$$y \approx (C + S \cos \theta \sin pt) \sin (\omega t + \alpha) \quad .. \quad (4)$$

and the envelope is practically undistorted but reduced in amplitude by the factor cos θ. This corresponds to the reintroduction of a large amplitude carrier in a suppressed-carrier system. If θ is fixed, then the system is workable, but if θ is increased towards 90° the intelligence is destroyed, since the term $S \cos \theta \sin pt$ containing the signal becomes zero. This is shown in Fig. 9.

(c) *Effect of Progressive Phase Displacement between Carrier and Side-Frequency Components*

A progressive phase displacement between the carrier and side-frequency components is caused by changing the carrier disc reduction gear from 224/15 : 1 to 15 : 1. The speeds of the discs (a), (b) and (c) are now in the ratio of 14 : 224/15 : 16 instead of 14 : 15 : 16. The carrier disc (b) now lags by 1/15 of a revolution every 15 revolutions, or by 1/225 of a revolution every revolution. The phase lag is thus 1/2 revolution, or 180° every 112·5 revolutions. The correct modulation envelope should thus appear every 112·5 cycles of the carrier frequency, and the envelope should be reversed in phase ; i.e., one 'audio' half-cycle should be 'slipped' during the intervening period of envelope distortion. The appearance of the correct envelope is naturally transitory.

If the rate of change of phase is constant, so that $d\theta/dt = p'$. then equation (2) becomes

$$y = \sqrt{(C^2 + 2CS \cos p't \sin pt + S^2 \sin^2 pt)} \sin (\omega t + \alpha) \quad .. \quad .. \quad (5)$$

or, if $C^2 \gg S^2$,

$$y \approx (C + S \cos p't \sin pt) \sin (\omega t + \alpha) \quad .. \quad (6)$$

The product term, $S \cos p't \sin pt$, may be resolved into sum and difference components, giving

$$y \approx \{C + \tfrac{1}{2}S \sin (p - p')t + \tfrac{1}{2}S \sin (p + p')t\} \sin (\omega t + \alpha) \quad .. \quad .. \quad .. \quad (7)$$

Beats now occur between the sum and difference frequencies, $(p - p')/2\pi$ and $(p + p')/2\pi$. The effect of a constant rate of phase displacement on the modulation may be regarded either as the production of a tone of frequency $p/2\pi$ and amplitude varying between zero and S, or the production of a beat tone from the sum and difference components. The modulation is itself modulated. See records of Fig. 10.

(d) *Suppression of One Side Frequency*

If the upper side frequency is suppressed, the apparatus now synthesizes the wave

$$y = C \sin \omega t + \tfrac{1}{2}S \cos (\omega - p)t \quad .. \quad (8)$$

which can be transformed into

$$y = \sqrt{(C^2 + \tfrac{1}{4}S^2 + CS \sin pt)} \sin (\omega t + \delta) \quad (9)$$

$$\text{where} \quad \tan \delta = \frac{\tfrac{1}{2}S \cos pt\cdot}{C + \tfrac{1}{2}S \sin pt}$$

It is perhaps more illuminating to leave equation (8) in the form

$$y = C \sin \omega t + \tfrac{1}{2}S \cos \omega t \cos pt + \tfrac{1}{2}S \sin \omega t \sin pt$$
$$= (C + \tfrac{1}{2}S \sin pt) \sin \omega t + \tfrac{1}{2}S \cos \omega t \cos pt \quad (10)$$

If C is not large in comparison with S, the envelope $(C + \tfrac{1}{2}S \sin pt)$ which contains the original modulation, is distorted by the additional product term of comparable amplitude, giving a resultant function (9) the envelope of which is not sinusoidal. There is also some degree of phase modulation since δ involves pt. That this is the case is easily seen by drawing a vector diagram in the usual way. If now $C^2 \gg S^2$, the resultant wave approaches the form

$$y = (C + \tfrac{1}{2}S \sin pt) \sin (\omega t + \delta) \quad .. \quad (11)$$

and the original modulation is practically undistorted.

The records of Fig. 11 show the above cases of small and large added carrier, corresponding to conditions in a suppressed-carrier single-sideband system.

(e) *Suppression of One Side Frequency: Carrier Phase Displaced*

The apparatus now synthesizes the wave

$$y = C \sin (\omega t + \theta) + \tfrac{1}{2}S \cos (\omega - p)t \, .. \quad (12)$$

which becomes

$$y = \sqrt{\{C^2 + \tfrac{1}{4}S^2 + CS \sin (pt + \theta)\}} \sin (\omega t + \epsilon) \quad .. \quad .. \quad (13)$$

$$\text{where} \tan \epsilon = \frac{C \sin \theta + \tfrac{1}{2}S \cos pt}{C \cos \theta + \tfrac{1}{2}S \sin pt}$$

If θ is fixed and $C^2 \gg S^2$, this becomes

$$y \approx \{C + \tfrac{1}{2}S \sin (pt + \theta)\} \sin (\omega t + \epsilon) \quad (14)$$

The phase displacement, θ, does not now reduce the modulation factor as in the double-side-frequency case [equation (4)], but merely alters the phase of the signal. If θ varies at a constant rate, let $d\theta/dt = p'$, as before. We now have

$$y \approx \{C + \tfrac{1}{2}S \sin (p + p')t\} \sin (\omega t + \epsilon) \quad (15)$$

so that the pitch of the signal is altered from $p/2\pi$ to $(p + p')/2\pi$. There is no periodic extinction of the modulation in this case.

Fig. 11(c) shows the condition $C^2 \gg S^2$ with a fixed phase displacement of 90°, while (d) shows the same condition with a progressive phase displacement of 1·60° per carrier cycle; i.e., 1/225 revolution lag for each revolution of the carrier disc (b). Unfortunately $(p + p')/2\pi$ differs by very little from $p/2\pi$ in this case, so that the change in the length of the modulation period is scarcely discernible over a few cycles. It can, however, be checked by measuring over many cycles and comparing the length of the record with that of the normal case.

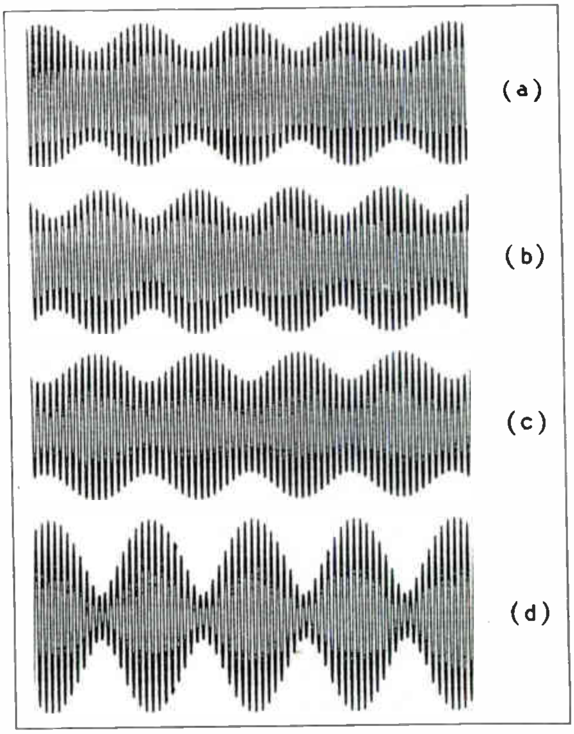


Fig. 11. *Waveforms with upper sideband suppressed; (a) for 100% modulation before removal of one sideband, (b) carrier much stronger than sideband, (c) as (b) but a fixed phase shift of 90° and (d) as (c) but progressive phase shift.*

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CORRESPONDENCE

Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

New Graphical Methods for Analysis and Design

SIR,—I should like to reply to Mr. Schneider's letter in the July issue of *Wireless Engineer* commenting on the article on graphical straight-line methods by myself and Miss Fosgate in the March issue.

With regard to Piloty's articles[1] quoted in Mr. Schneider's letter, it is certainly of interest that Piloty, in 1939, used 'elementary factors' for representing the rational function $E(x)$ (*our* notation) which occurs in the computation of symmetrical filters. As the straight-line method of representing $E(x)$ suggested by us is also based on the idea of splitting $E(x)$ into a number of simple factors, a reference in our article to Piloty's work quoted above would have been desirable. However, it is relevant to point out that

1. Piloty's elementary factors are quite different from our factors; the term of the form $(x/a - a/x)$ which is used in our method, does not occur in Piloty's quoted articles;
2. Piloty does not, in the articles quoted, describe any graphical method (neither of the conventional template nor of the straight-line type);
3. Piloty uses three different types of elementary factors all of which are necessary for his method of splitting $E(x)$ in the general case; but only one of these types would be suitable for a straight-line representation similar to that described by us.

Furthermore, in the 13 years after the publication of Piloty's articles, the splitting of rational network functions into elementary factors of various different types as a basis of graphical template methods has been described so often (see, e.g., Saraga,[2] Baum,[3] Linke[4]) that it can by now be regarded as a well-known and well-established technique. The main point of the discussion of $E(x)$ in our article—and it seems to us that Mr. Schneider, in trying to establish a relation between Piloty's and our article, has missed this point—is that we suggest the graphical representation of suitably chosen elementary factors and corresponding template methods by *single straight lines* and show a chart based on this suggestion. This, as far as we know, is novel, and from our point of view the advantages and disadvantages of this straight-line representation are the only questions at issue.

Mr. Schneider's remarks concerning an E,x curve which is maximally flat, namely that this curve "results as a border-line case where the attenuation peaks of the elementary factors happen to be at zero or infinite frequencies only", are in agreement with our discussion of the case "all $x_i = 0$" at the end of Section 8 of our article. However, the main point of our treatment of this problem is that by considering the curve which is maximally flat in the pass-band as a separate case—and not as a particular example of the general case—about half the number of straight lines (or templates, in a template version of the method) can be saved.

In the second part of his letter Mr. Schneider uses 'Feldtkeller's equation' for a reinterpretation of our graphical methods and he claims that a "greater clarity and a better physical explanation" can be achieved in this way. I cannot agree with Mr. Schneider. Feldtkeller's equation which relates the insertion loss of a filter to its return loss is, of course, of great practical and theoretical interest in problems which involve at the same time both kinds of losses. But in the problems discussed by us only the insertion loss of a filter—in the pass-band as well as in the stop-band—is being considered, and it seems to me basically wrong to complicate a perfectly straightforward insertion-loss problem by translating the insertion loss in part of the frequency band under consideration into its corresponding return loss. In my opinion this would violate the generally-accepted principle of economy of concepts, and as far as physical explanation is concerned, I fail to see why return loss should be preferable to insertion loss as basic concept of an explanation.

W. SARAGA.

Telephone Manufacturing Co., Ltd.,
St. Mary Cray, Kent.
3rd October 1952.

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Anti-Resonant H.F. Transmission Lines

SIR,—In his article in the June 1952 issue of *Wireless Engineer* about anti-resonant lines, Professor Barlow supposes that the characteristic impedance is purely real. That is true in first approximation but in second approximation this assumption involves that there is a relation between losses in dielectric and metal. Generally, at high frequency, losses in dielectrics are negligible and in this case the first approximation may lead to important errors. As far as losses are concerned, it is of no interest or dangerous to suppose the characteristic impedance real.

S. ALBAGLI.

Marseilles, France.
4th October 1952.

SIR,—In reply to Professor Albagli, it is very readily demonstrated that for any practical line operated at high frequency the effect of the imaginary part of the characteristic line impedance on the attenuation is negligible, but it is not quite so clear that the condition for maximum resistance and reactance remained unaffected in those circumstances. I have given special attention to that point, and I think it is fair to say that, within the limits of a reasonable approximation, my original analysis holds good.

In general, $$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \quad \ldots \quad \ldots \quad (1)$$

and this is real at any frequency if

$$\tan^{-1}\frac{\omega L}{R} = \tan^{-1}\frac{\omega C}{G}$$

or $$LG = CR \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Suppose we make precisely the same approximation in evaluating Z_0 at h.f. as is applied when calculating α.

We then find:—

$$Z_0 = \sqrt{\frac{L}{C}}\left[1 - \tfrac{1}{2}\left(\frac{G}{\omega C}\right)^2\right]\left[1 - j\tfrac{1}{2}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)\right] \quad (3)$$

But $\frac{G}{\omega C} = \tan\delta$ where $\delta =$ dielectric loss angle, and since $\tan\delta \ll 1$ in any practical case we can quite safely neglect the second-order term and write:—

$$Z_0 = \sqrt{\frac{L}{C}}\left[1 - j\tfrac{1}{2}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)\right] = Z_0'[1 - j\epsilon] \quad (4)$$

where $$Z_0' = \sqrt{\frac{L}{C}} \quad \ldots \quad \ldots \quad \ldots \qquad (5)$$

and $$\epsilon = \tfrac{1}{2}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right) \quad \ldots \quad \ldots \qquad (6)$$

We also have:—

$$\alpha = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} = \sqrt{\frac{L}{C}}\left(\frac{LG + CR}{2L}\right) \qquad (7)$$

Hence:—

$$\alpha = \frac{Z_0}{2L}(LG + CR)\left[1 + j\tfrac{1}{2}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)\right] =$$
$$\frac{Z_0}{2L}(LG + CR)(1 + j\epsilon) \quad \ldots \quad \ldots \qquad (8)$$

very nearly.

Thus a serious inaccuracy in assuming Z_0 real at h.f. can only arise when ϵ is comparable with unity.

If we take as an example a coaxial line for which radius of inner conductor = 0·05 cm, radius of outer conductor = 0·5 cm, and at a frequency of 100 Mc/s

$$\frac{R}{\omega L} = 3{\cdot}1 \times 10^{-3}$$

with $\frac{G}{\omega C} = \tan\delta = 5 \times 10^{-4}$, then $\epsilon = 1{\cdot}3 \times 10^{-3}$.

In this case there is clearly no significant error in assuming Z_0 real for the purpose of calculating α. At higher frequencies dielectric losses tend to become a larger proportion of the total loss so that the quantity ϵ will probably become still smaller.

If now we use the value

$$Z_0 = Z_0'(1 - j\epsilon) \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

in the expression for the input impedance

$$Z_s = R_s + jX_s = Z_0 \tanh Pl \quad \ldots \quad \ldots \qquad (9)$$

separate the resistive and reactive parts, then normalizing to Z_0' gives:—

$$\frac{R_s}{Z_0'} = \frac{\sinh \alpha l.\cosh \alpha l + \epsilon \sin \beta l.\cos \beta l}{\sinh^2\alpha l + \cos^2\beta l} \quad \ldots \qquad (10)$$

and $$\frac{X_s}{Z_0'} = \frac{\sin \beta l.\cos \beta l - \epsilon \sinh \alpha l.\cosh \alpha l}{\sinh^2\alpha l + \cos^2\beta l} \quad \ldots \qquad (11)$$

Putting $\sinh \alpha l = \alpha l$ with $\cosh \alpha l = 1$ we obtain after differentiating the above expressions with regard to l, and equating to zero:—

For maximum R_s/Z_0'

$$\left(1 + \frac{\alpha l}{\epsilon\beta l}\right)\cos^2\beta l - \alpha^2 l^2 + \left(\frac{2\alpha l}{\epsilon}\right)\sin\beta l.\cos\beta l = 0 \qquad (12)$$

For maximum X_s/Z_0'

$$\beta l(\cos^2\beta l - \alpha^2 l^2 \sin^2\beta l) - 2\alpha^2 l^2\left(1 + \frac{\epsilon\beta l}{\alpha l}\right)$$
$$\sin\beta l.\cos\beta l = 0 \quad \ldots \quad \ldots \quad \ldots \qquad (13)$$

To get the order of the different quantities in (12) and (13) we will suppose that the dielectric loss is small compared with the conductor loss.

We then find:—

$$\epsilon \approx \tfrac{1}{2}\frac{R}{\omega L} = \frac{1}{2Q} = \frac{\alpha}{\beta} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (14)$$

so that neglecting the higher-order terms (12) reduces to

$$\left(\frac{2\alpha l}{\epsilon}\sin\beta l\right)\cos\beta l = \alpha^2 l^2 \quad \ldots \quad \ldots \quad \ldots \qquad (15)$$

or with sufficient accuracy for most practical purposes to:—

$$2\beta l.\cos\beta l = \alpha^2 l^2 \quad \ldots \quad \ldots \quad \ldots \qquad (16)$$

Similarly, equation (13) reduces to:—

$$\pm \tan\beta l = \frac{1}{\alpha l} \quad \ldots \quad \ldots \quad \ldots \qquad (17)$$

It will be observed that (16) and (17) are equations (7) and (12) respectively in the original paper.

It would appear, therefore, that for any ordinary line the analysis previously given is substantially accurate.

It may also be of interest to record that my colleague, Dr. Cullen, has calculated the shift of the resonant frequency due to conductor resistance assuming dielectric losses to be negligible. He finds that $X_s = 0$ when:—

$$\alpha \sinh 2\alpha l = \beta \sin 2\beta l \quad \ldots \quad \ldots \qquad (18)$$

and he deduces therefrom that:—

$$f_0 \approx f_0'\left[1 - \frac{6\alpha^2 l^2}{\pi^2}\right] \quad \ldots \quad \ldots \qquad (19)$$

where f_0' = resonant frequency in the absence of resistance and

f_0 = actual resonant frequency.

Thus the frequency shift, which is proportional to $\alpha^2 l^2$ is of second order compared with the width of the resonance curve which varies directly as αl.

H. M. Barlow.

University College, London, W.C.1
14th October 1952.

BOOK REVIEWS

Short-Wave Radiation Phenomena

By August Hund. Pp. 1382 + xxi with 394 illustrations, in two volumes. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price £8 10s.

This addition to the literature of electromagnetic theory enters a field where there are already well-known and excellent texts. Stratton and Schelkunoff are the names which come naturally to the mind, and the range covered by their books is roughly that of the volumes under review. The first four chapters cover the fundamentals of electromagnetic theory, and are followed by chapters on transmission lines, radiation, diffraction and waveguides.

In a 1300-page text one would expect the treatment to be detailed, as indeed it is, but it is also repetitive and, to many minds, prolix. The author admits in the preface that there is overlapping because "the various subjects are all *self-contained*", but there appears to be no advantage in this arrangement. Thus, values of Bessel zeros required in waveguide theory are repeated in four different places.

Another reason for the length is that all mathematical steps are fully detailed. Readers able to cope with a large amount of advanced mathematics might safely be trusted to supply mentally many of the intermediate steps. An extreme example noted gave the following as successive steps in an argument: ... = $\sqrt{x + y}$ = $(x + y)^{\frac{1}{2}}$ = ... Again, after dealing with the theory of skin effect, the author says in an illustrative calculation "we find δ = 6·42 × 10^{-6} m = 6·42 × 10^{-3} mm, where 1 mm is about the thickness of a pencil line", a statement more suited to a "Radiation for Everyman".

Another criticism is lack of continuity. This is emphasized by many section headings being of the form "Notes on . . . " or "General Remarks on . . . ". Chapter IV, indeed, starts with four "General Remarks" sections.

Nevertheless the book does contain much good material. In particular, the habit of indicating in words the significance of each term in a complicated expression will be welcome to many, and is one for which the author deserves commendation. The leavening of the mathematics by a large number of illustrative examples will go a long way towards clarifying the results for those to whom the older works are rather too forbidding.

Finally, the reviewer cannot resist saying how refreshing he finds it to see an American publication in which the abbreviation for megacycles per second is Mc/sec.

H. R. L. L.

Television

By F. Kerkhof and W. Werner. Pp. 475 with 360 illustrations. Cleaver-Hume Press, Ltd., 42a South Audley Street, London, W.1. Price 50s.

The authors of this book are principals of the television development laboratory of Philips Industries of Eindhoven. The book is a translation, Dutch and German editions having already appeared and a French edition being in course of preparation.

The book deals mainly with television reception but there is a certain amount of information about the transmitting side. Chapter 3, for instance, on "Pick-Up and Picture Tubes" has about 12 pages on camera tubes to about eight on receiving tubes. Then a good deal of Chapter 5 on "The Excitation and Application of Electrical Relaxation Phenomena" is devoted to multivibrators, flip-flops, mixers, etc., for sync-pulse generation in the transmitter.

The main body of the text is substantially non-mathematical and explains in quite simple language how the various circuits operate and what their characteristics are. More complete explanations in mathematical form are frequently included as well and are presented as interpolations to the main text. They are set in smaller type and can be omitted on a first reading.

There is little point in enumerating the subjects dealt with, nor even the chapter headings; it is sufficient to say that the book covers more-or-less fully most aspects of the receiving side of television. The fact that most matters are covered does not mean that they are all treated adequately, however, and there are actually very great variations in the way in which the various subjects are dealt with. Some are discussed almost from the designer's point of view; for example, wideband amplifiers, ringing-choke e.h.t. systems and, but rather less fully, scanning circuits. Other subjects are treated as being of a trivial nature and receive only the barest elementary explanation; among these are things like deflector coils, sound-channel rejector and pick-out circuits, power supplies, and station-selecting methods.

The form of treatment is not tied to one system of television standard. It is so arranged as to be applicable to both the British 405-line positive-modulation system and the Continental 625-line negative-modulation, while the French 819-line is mentioned. The references to the British system seem to have been written a long time ago and are almost all to the London double-sideband transmissions. On p. 77, it is said that "These stations (i.e., the British) will come into use one after the other. Contrary to the London television station they will work on the vestigial sideband system."

The use of the future tense dates this paragraph as being written prior to December 1949 when Sutton Coldfield was opened, and now, of course, all five high-power stations are in operation and only the original London station is double-sideband. On the next page, there is a reference to a conference held in July 1950 and in the bibliography there are some references to papers published in 1951.

No technical book ever can be right up to date, of course, for development does not wait on authors nor on printers, nor yet on translators. A book of this size necessarily takes a long time in preparation.

Considering the book as a whole, it is a good one for the man with a sound knowledge of ordinary radio but to whom television is something rather new. Its diligent study will certainly give him a good grounding in principles.

W. T. C.

I.E.E. MEETINGS

10th December. Discussion on "The B.B.C. School, Evesham" and "The Post Office School, Stone", to be opened by K. R. Sturley, Ph.D., B.Sc., and H. R. Harbottle, O.B.E., B.Sc.(Eng.).

11th December. "The Royal Festival Hall: Electrical Installation", by J. G. Hunter.

15th December. Discussion on "How to Plan a Radio Project", to be opened by J. Thomson, M.A., Ph.D., D.Sc.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2, and, with the exception of the meeting on 10th December, which commences at 6 o'clock, will start at 5.30.

BRIT.I.R.E. MEETING

10th December. "The Production of Television Receivers", by Frank Allen, to be held at the London School of Hygiene and Tropical Medicine, Keppel St., Gower St., London, W.C.1, at 6.30.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for October 1952

Date 1952 October	Frequency deviation from nominal: parts in 10^8		Lead of MSF impulses on GBR 1000 G.M.T. time signal in milliseconds
	MSF 60 kc/s 1029-1130 G.M.T.	Droitwich 200 kc/s 1030 G.M.T.	
1	+ 0·4	0	− 43·8
2	+ 0·5	0	− 42·7
3	+ 0·6	0	− 41·1
4	+ 0·6	− 1	− 39·7
5	+ 0·6	0	− 39·4
6	+ 0·6	0	− 37·9
7	+ 0·6	+ 1	− 36·3
8	+ 0·6	0	− 33·8
9	+ 0·8	+ 1	− 32·5
10	+ 0·8	+ 1	− 30·9
11	+ 0·9	+ 1	− 30·1
12	+ 0·9	+ 2	− 29·3
13	+ 0·7	+ 3	− 27·6
14	+ 0·9	+ 1	− 26·5
15	+ 0·8	+ 1	− 26·3
16	+ 0·9	+ 2	− 26·5
17	+ 0·9	+ 1	− 25·7
18	+ 1·0	+ 1	− 24·9
19	+ 1·0	+ 3	− 24·0
20	+ 0·9	+ 2	− 24·2
21	+ 1·1	+ 3	− 24·3
22	+ 1·1	+ 3	NM
23	+ 1·2	+ 3	− 24·1
24	− 0·7	+ 3	− 24·9
25	− 0·5	+ 3	− 27·6
26	− 0·5	+ 3	− 26·6
27	− 0·2	+ 3	− 28·7
28	− 0·3	+ 3	− 30·1
29	− 0·2	+ 4	− 31·0
30	− 0·4	+ 3	− 30·8
31	− 0·4	+ 2	− 31·5

The values are based on astronomical data available on 1st November 1952.

NM = Not Measured.

ABSTRACTS and REFERENCES

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research and published by arrangement with that Department.

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to it.

ACOUSTICS AND AUDIO FREQUENCIES

016 : 534 **3298**

References to Contemporary Papers on Acoustics.—R. T. Beyer. (*J. acoust. Soc. Amer.*, July 1952, Vol. 24, No. 4, pp. 421–426.) Continuation of 2675 of October.

534.2 **3299**

Sound Scattering by Thin Elastic Shells.—M. C. Junger. (*J. acoust. Soc. Amer.*, July 1952, Vol. 24, No. 4, pp. 366–373.) Theory previously developed by Faran (2611 of 1951) for scattering by solid cylinders and spheres is extended to take account of the modification of the scattering pattern due to the forced vibrations excited in the elastic shell by the incident wave. The influence of the ambient medium is discussed.

534.231 : 621.3.018.78† **3300**

Two Applications of the Concept of Spatial Distortion.—J. Bernhart. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 334–343.) Spatial distortion is regarded as including all defects of reproduction which detract from the directional effect, whether they originate in the pickup of a sound or in its transmission or reproduction. Two cases are considered: (*a*) the distortion introduced at the origin of a transmission chain by classical methods of sound pickup, stereophonic reproduction being treated as a particular case, (*b*) the spatial distortion in the reproduction of sound. A detailed study is presented of the Elipson 'radiation transformer'; its use for directing the maximum amount of sound energy toward an audience is explained. See also 2108 of August (Forestier).

534.232 + 621.395.612.4 **3301**

The Radiation Impedance of Ribbon-Type Sound Radiators, and the Vibro-motive Force on Them.—T. Nimura & K. Shibayama. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, Sept. 1951, Vol. 3, No. 1, pp 77–85.) Mathieu functions are used to derive formulae for the acoustic radiation from a ribbon with a baffle of finite width, and for the acoustic scattering by a rigid ribbon. The analysis is applicable to ribbon microphones.

534.232 **3302**

Calculation of the Directivity Index for Various Types of Radiators.—H. Stenzel. (*J. acoust. Soc. Amer.*, July 1952, Vol. 24, No. 4, pp. 417–418.) Discussion on 3289 of 1948 (Molloy).

534.232 **3303**

Observations on Edge-Tones.—M. Mokhtar & H. Youssef. (*Acustica*, 1952, Vol. 2, No. 3, pp. 135–139.) The mechanism of edge-tone production is studied from the following aspects, (*a*) distribution of wind velocity between slit and edge, (*b*) paths of the vortices, (*c*) velocity/frequency relation. Particular attention is paid to the frequency-jump stage.

534.232 : 537.228.1 **3304**

On the Characteristics of Miscellaneous Piezoelectric Vibrators in Stiffness Control.—S. Honda. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, March 1952, Vol. 3, No. 2, pp. 95–114.) Investigation of the characteristics of electromechanical transducers of the longitudinal- and shear-vibration types and of twin-plate flexure and torsion types. Formulae for the electrical and mechanical constants of the different types are tabulated.

534.232 : [537.228.2 + 538.652 **3305**

On the Effective Attenuation of Some Electroacoustic Transducers at their Conjugate Electrical Matching.—Y. Kikuchi & H. Shimizu. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, Sept. 1951, Vol. 3, No. 1, pp. 13–18.)

534.232 : 538.652 **3306**

On the Effective Attenuation of Ring-Type Magnetostriction Transducer.—Y. Kikuchi & H. Shimizu. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, Sept. 1951, Vol. 3, No. 1, pp. 1–5.)

534.24 **3307**

The Reflection of a Transient [sound] **Pulse by a Parabolic Cylinder and a Paraboloid of Revolution.**—W. Chester. (*Quart. J. Mech. appl. Math.*, June 1952, Vol. 5, Part 2, pp. 196–205.) An adaptation of Lamb's analysis for the case of an incident harmonic wave train is used to derive the corresponding transient solutions.

534.321.9 **3308**

Linear Magnetostrictive Ultrasonic-Wave Generation using Crossed Magnetic Fields.—H. H. Rust & E. Bailitis. (*Acustica*, 1952, Vol. 2, No. 3, pp. 132–135. In German.)

With linear magnetostrictive generators the actual maximum elongation is given by the difference of the elongations in the remanence and the saturation states. If the vibrating body, a cube of ferromagnetic material, is enclosed in two pairs of coils at right angles to each other, one of each pair providing a permanent magnetic field, the other carrying alternating current, an alternation of maximum elongation and contraction will take place in the direction of the wave vector. At these maxima the Weiss vectors will be normal to each other, and remanence will temporarily vanish. The expected increase in elongation with the above arrangement is $\sim 45 \cdot 10^{-6}$ for Ni, and it should thus be possible to use less costly materials, e.g., Fe-Ni alloy with 4% Ni content, as magnetostrictive elements.

534.321.9 **3309**

Considerations and Suggestions on the Concentration of Ultrasonic Energy.—A. Barone. (*Ricerca sci.*, April 1952, Vol. 22, No. 4, pp. 679–684.) Reflection types of concentrator, two of which are described, are preferable to acoustic lenses. One equipment uses a parabolic reflector to obtain a converging beam; the other makes use of reflections at the surfaces of two conical holes bored in the ends of a metal cylinder arranged in front of the ultrasonic generator. By suitable design of cone lengths and angles, and the internal diameter where the holes meet, the energy can be concentrated, within certain limits, over a prescribed area.

534.321.9 : 534.22 : [546.264 + 547.313.2 **3310**

Propagation of Ultrasonic Waves in Vapours near the Critical Point.—H. D. Parbrook & E. G. Richardson. (*Proc. phys. Soc.*, 1st June 1952, Vol. 65, No. 390B, pp. 437–444.) An experimental study of the velocity and absorption of ultrasonic waves at frequencies of 0·5, 1 and 2 Mc/s in CO_2 and C_2H_4 at pressures up to 100 atm, using a variable-path acoustic interferometer.

534.414 **3311**

Multiple Helmholtz Resonators.—C. S. McGinnis & V. F. Albert. (*J. acoust. Soc. Amer.*, July 1952, Vol. 24, No. 4, pp. 374–379.) The equations of motion for the fluid in any resonator network are obtained by application of Lagrange's method. The number of resonances found is equal to the number of distinct cavities. Calculated values of resonance frequency agree with values found experimentally. The work is relevant to investigations of the mechanism of voice production.

534.612.4 **3312**

A Simplified Technique for the Pressure Calibration of Condenser Microphones by the Reciprocity Method.—A. K. Nielsen. (*Acustica*, 1952, Vol. 2, No. 3, pp. 112–118.) Calibration technique is much simplified if the transfer impedance is determined, the open-circuit voltage of the receiver microphone and the current through the source microphone being measured directly. A suitable method and precautions necessary are explained. Discussion shows that the noise level of the cathode-follower pre-amplifier used can be reduced to a tolerable value by suitable circuit design.

534.613 : 534.321.9 **3313**

Absolute Method of Measurement of Acoustic Power in an Ultrasonic Beam in a Liquid, based on the Radiation Pressure exerted on a Liquid/Gas Interface.—C. Florisson. (*C. R. Acad. Sci., Paris*, 7th July 1952, Vol. 235, No. 1, pp. 27–28.)

534.78 : 519.271 **3314**

An Experimental Study of Speech-Wave Probability Distributions.—W. B. Davenport, Jr. (*J. acoust. Soc. Amer.*, July 1952, Vol. 24, No. 4, pp. 390–399.)

534.833.4-13/-14 **3315**

General Theory of the Absorption of Sound in Gases and Liquids taking Account of Transport Phenomena.—J. Meixner. (*Acustica*, 1952, Vol. 2, No. 3, pp. 101–109. In German.)

534.84 **3316**

Recent Progress in Architectural Acoustics.—A. C. Raes. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 321–330.) Review of methods of determining the acoustic properties of rooms or halls, and of test methods for sound-absorbent materials.

534.84 : 621.396.619.13 **3317**

Frequency Modulation in Architectural Acoustics.—J. Pujolle & R. Lamoral. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 331–333.) An investigation of the optimum values of frequency and frequency swing of a warble-tone generator for room-acoustics measurements.

534.84 : 621.396.712.3 **3318**

New Studios of Radiodiffusion Française.—J. Pujolle. (*Ann. Télécommun.*, July/Aug. 1952, Vol. 7, Nos. 7/8, pp. 305–309.) Description of studios at Nancy, Lille and Nice, and at the Centre Bourdan, Paris, with particular reference to the acoustic treatment of walls, ceilings, etc.

534.843 **3319**

The Acoustic Significance of the Amplitude and Phase of Harmonics Present in a Source of Sound in a Room.—J. G. Robbins. (*J. acoust. Soc. Amer.*, July 1952, Vol. 24, No. 4, pp. 380–383.) Report of a study of the acoustic properties of a rectangular room, using both subjective listener-response tests and objective measurements of the modulation of the sound-decay curve. The sound source covered the fundamental frequency range 50–3 000 c/s, the amplitude and phase of the first four harmonics being adjustable. A large majority of listeners cannot distinguish between two steady-state sounds differing only in the relative phase of a harmonic.

534.844.1/.2 **3320**

The Reverberation Times of Ten British Concert Halls.—P. H. Parkin, W. E. Scholes & A. G. Derbyshire. (*Acustica*, 1952, Vol. 2, No. 3, pp. 97–100.) Measurements at frequencies of 125, 500, 2 000 and 4 000 c/s are tabulated and are discussed with reference to the opinions of 42 professional musicians regarding the acoustic quality of the halls. In general, the reverberation times of the 'good' halls lie on or near the Knudsen optimum line.

534.844.2 **3321**

Reverberation Times in Baroque Churches.—W. Lottermoser. (*Acustica*, 1952, Vol. 2, No. 3, pp. 109–111. In German.) Measurements for five churches in Upper Swabia and one in Alsace are reported. The many bays in the side-walls and the stucco ornamentation combine to 'mix' the sound waves thoroughly, so that good intelligibility of speech and music results. A significant feature is the maximum reverberation time occurring between 500 and 1 000 c/s.

534.861 : 534.322.1 **3322**

Quadratic and Cubic Distortion in the Transmission of Music.—G. Haar. (*Frequenz*, July 1952, Vol. 6, No. 7, pp. 199–206.) Report of tests to find how much distortion can be introduced in a transmission system before listeners notice a deterioration of musical quality. Results are shown graphically. Cubic distortion has a greater effect than quadratic distortion.

534.861 : 534.843.2 **3323**

The Effect of the Direct and the Reflected Sound on the Sound Pattern.—J. Grunert. (*Tech. Hausmitt. Nordw-*

Dtsch. Rdfunks, July/Aug. 1952, Vol. 4, Nos. 7/8, pp. 138–141.) Discussion of the characteristics of the sound picked up by a single microphone in a studio, as affected by reflection from the interior, and of problems of balance when two microphones are used, as in the case of a soloist and orchestra.

534.861 : 621.396.8 **3324**

Use of Electronic Sound Sources in Broadcasting.—W. Meyer-Eppler. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, July/Aug. 1952, Vol. 4, Nos. 7/8, pp. 130–135.) Discussion of the technical possibilities of sound film, electronic organs, and similar devices.

534.861 : 782/785 **3325**

The Musical Work of Art in Electrical Transmission.—H. Husmann. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, July/Aug. 1952, Vol. 4, Nos. 7/8, pp. 135–137.) General discussion of technical and physiological problems connected with the faithful transmission of music.

621.395.623.7 **3326**

Studies on Cone-Type Loudspeakers: Part 1 — On the Extensional Vibration of a Conical Shell.—T. Nimura & K. Shibayama. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, Sept. 1951, Vol. 3, No. 1, pp. 56–75.) Theoretical and experimental investigations are reported.

621.395.623.73 **3327**

Studies on Cone-Type Loudspeakers: Part 2 — On the Inextensional Vibration of a Conical Shell.—T. Nimura & K. Shibayama. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, March 1952, Vol. 3, No. 2, pp. 189–198.) Resonance modes of vibration of conical diaphragms in which bending is chiefly involved are analysed. Theoretical and experimental results are in good agreement with those of Bordoni (1976 of 1947) and McLachlan. Part 1: 3326 above.

621.395.623.73 **3328**

Studies on Cone-Type Loudspeakers: Part 3 — The Upper Frequency Limit of Cone-Type Loudspeakers.—T. Nimura & E. Matsui. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, March 1952, Vol. 3, No. 2, pp. 199–213.) Discussion of effects depending on cone edge conditions and derivation of a formula for the upper limiting frequency. Part 2: 3327 above.

621.395.623.74 : 537.58 **3329**

The Ionophone.—S. Klein. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 314–320.) An account of the principles of operation of the ionophone, its construction and associated receiver circuits, with results of performance tests as a microphone and as an ultrasonic transmitter. See also 896, 897 and 898 (Bonhomme) of April.

621.395.625 **3330**

Comparison of Sound-Recording Methods.—H. Schiesser. (*Elektrotech. Z.*, 1st June 1952, Vol. 73, No. 11, pp. 366–371.) Review of the development and application of photoelectric, mechanical and magnetic recording techniques. Features of modern equipment are noted.

621.395.625.2 **3331**

Disk Recording and Reproduction.—P. Gilotaux. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 289–294.) Further discussion of modern techniques. See also 2970 of 1950.

621.395.625.3 **3332**

Progress and Trends in High-Fidelity Magnetic Recording.—F. Gallet. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 295–301.) Discussion of harmonic distortion, background noise, tape characteristics, etc., with a view to the choice of optimum recorder adjustments.

621.395.625.3 : 539.23 : 538.221 **3333**

Experiments on the Anisotropy of the Magnetization of Magnetic-Recorder Tapes.—J. Greiner. (*NachrTech.*, July 1952, Vol. 2, No. 7, pp. 197–201.) Investigation of the influence of particle material, shape and arrangement on the properties of magnetic tapes. A considerable increase in remanence was obtained by applying, prior to drying, a d.c. field of 500 oersted to a tape coated with a mixture of ferromagnetic particles and insulating material.

621.395.625.3 : 539.23 : 538.221 **3334**

Crystalline Structure and Electroacoustic Properties of Magnetic Tapes.—A. Lovichi & J. P. Deriaud. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 275–288.) A comparison is made between the properties of high-speed and low-speed tapes. The differences are attributed to differences of crystalline structure of the iron oxides used for the tape coatings. From relations established for the magnetic properties of these oxides predictions of the electroacoustic characteristics of the two types of tape can be made.

621.395.92(083.74) **3335**

The Problem of the Standardization of Hearing Aids and their Test Methods.—P. Chavasse & R. Lehmann. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 302–313.) A review of the special problems of bone-conduction and air-conduction types of hearing aid, and of standard equipment and test methods adopted in various countries, together with a proposed scheme of standard methods for testing complete hearing-aid apparatus of the air-conduction type. 34 references. See also *Acustica*, 1952, Vol. 2, No. 3, pp. 119–131.

AERIALS AND TRANSMISSION LINES

621.3.018.78† : 621.315.212 **3336**

Distortion of a Signal Transmitted by a Perfectly Uniform Coaxial Line.—R. Cazenave. (*Câbles & Transmission*, July 1952, Vol. 6, No. 3, p. 264.) Corrections to paper abstracted in 1194 of May.

621.315.212.2 : 621.315.687.1 **3337**

Reflectionless Joints for Coaxial Pairs.—R. J. Turner. (*P.O. elect. Engrs' J.*, July 1952, Vol. 45, Part 2, pp. 72–76.) Design theory is given for joints producing no reflection of signals transmitted along a cable, with practical details for a 0·375-in. coaxial-pair cable with polythene-disk spacers.

621.392.09 **3338**

Surface-Wave Transmission Lines.—A. C. Grace & J. A. Lane. (*Wireless Engr*, Sept. 1952, Vol. 29, No. 348, pp. 230–231.) An account is given of experiments at frequencies of 3·3 and 9·4 kMc/s, using single-conductor lines of 18 s.w.g. copper wire bare, tinned or enamelled, with launching and receiving horns of small flare angle. Oscillator output power and received power were measured by a bolometer bridge method. The results are in good agreement with values calculated from Goubau's theory (812 and 2636 of 1951). The effect of bending the line was investigated.

621.392.09 **3339**

Propagation of Electromagnetic Waves along a Conducting Wire with Thin Dielectric Covering.—A. Fromageot & B. Louis. (*Bull. Soc. franç. Élect.*, June 1952, Vol. 2, No. 18, pp. 349–353.) Discussion of paper abstracted in 317 of February.

621.392.09 : 621.396.611.31 **3340**

Interaction between Surface-Wave Transmission Lines.—A. A. Meyerhoff. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1061–1065.) Interaction may occur between two surface-wave transmission lines or between one line and a near-by conductor. Analysis is presented for the case of two parallel lossless lines whose separation is large compared with their diameters. Interaction is found to be a maximum when the two lines are identical, and complete power transfer from one line to the other is possible under suitable conditions. Numerical examples are discussed.

621.392.21 **3341**

An Approach to the Standard Equations for a Uniform Transmission Line.—H. R. Harbottle. (*P.O. elect. Engrs' J.*, April & July 1952, Vol. 45, Parts 1 & 2, pp. 30–34 & 80–82.) The standard equations for a uniform line are derived without the use of the differential calculus. The propagation of voltage and current through a chain of similar symmetrical resistance sections is first considered. The results obtained are applied to the general case of propagation through a chain of impedance sections simulating a uniform transmission line.

621.392.26 **3342**

Waveguide Systems with Negative Phase Velocities.—L. B. Mullett & B. G. Loach. (*Nature, Lond.*, 14th June 1952, Vol. 169, No. 4311, p. 1011.) A fundamental wave with genuinely negative phase velocity is possible in the case of the helix and folded-strip transmission line. A diagram shows how the propagation constant of a rectangular waveguide loaded on one broad face with a reactive sheet changes with the loading reactance; to obtain a slow wave with negative phase velocity the reactive sheet must be capacitive. The abnormal behaviour below cut-off for the H_{01} mode is confirmed in two experimental arrangements.

621.392.26 **3343**

Theory of Waveguide-Fed Slots Radiating into Parallel-Plate Regions.—H. Gruenberg. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 733–737.) A formula is derived for the conductance of a longitudinal slot in a rectangular waveguide when the slot is radiating into a space bounded by parallel plates. The influence of plate spacing and slot position is discussed. Theoretical and experimental results are in good agreement.

621.392.26 **3344**

The Principle of Limiting Absorption in a Waveguide.—A. G. Sveshnikov. (*C. R. Acad. Sci. U.R.S.S.*, 21st Sept. 1951, Vol. 80, No. 3, pp. 345–347. In Russian.)

621.392.26 **3345**

Notes on Methods of Transmitting the Circular Electric Wave around Bends.—S. E. Miller. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1104–1113.) Theory and results concerning the propagation of TE_{01} waves in round guides, published by various authors, are reviewed and three alternative solutions of the problem of transmitting these waves round bends in the guide are discussed in detail.

621.392.26 **3346**

Study of Obstacles in Rectangular Waveguides and of Waveguide Filters.—J. Dockès. (*Câbles & Transmission*, July 1952, Vol. 6, No. 3, pp. 221–242.) A method is described for determining the susceptance of a waveguide diaphragm from measurements of the reflection or the transmission coefficient, and a theoretical and experimental study is presented of resonant cavities enclosed between diaphragms in rectangular waveguides. Band-pass filters constituted by a series of such resonant cavities coupled by $\lambda_g/4$ (or $3\lambda_g/4$) lines are discussed and design formulae derived. Application is made to the design of (*a*) a 3-cavity filter with a pass band of 52 Mc/s centred on 3·92 kMc/s, (*b*) a 5-cavity filter with a similar pass band centred on 3·69 kMc/s.

621.392.26 **3347**

Completeness Relations for Loss-Free Microwave Junctions.—T. Teichmann. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 701–710.) Using a method which is the electromagnetic analogue of the scattering-matrix formalism in the theory of nuclear reactions, two 'sum rules' are derived for the frequency-independent coefficients occurring in the admittance matrix relating the currents and voltages in a loss-free microwave junction. The results are used to estimate the effect on the admittance matrix of the higher modes, both of the guides, and of the junction proper.

621.392.26 **3348**

A Compact Broad-Band Microwave Quarter-Wave Plate.—A. J. Simmons. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1089–1090.) Theory is presented for a device using three capacitive pins in a round waveguide to obtain a 90° phase difference between two orthogonal TE_{11} waves. With an experimental X-band unit only 1 in. long, a voltage ellipticity ratio $< 1\cdot1$ and a voltage s.w.r. $< 1\cdot2$ is maintained over a 12% frequency band.

621.392.5 **3349**

Cable Operating Parameters in the Transmission of Energy in the Decimetre and Metre Wavebands.—H. Ebert. (*Fernmeldetech. Z.*, May 1952, Vol. 5, No. 5, pp. 239–240.) Quadripole theory is applied to determine the equivalent circuit of a lossy transmission line, attenuation and phase coefficients being accounted for by separate networks in a symmetrical arrangement. The dependence of the transfer ratio on the line attenuation coefficient and the terminal mismatch is hence derived.

621.396.67 : 621.392.076.12 **3350**

Increase of Aerial Bandwidth by means of Compensation Circuits.—R. Goublin. (*Rev. tech. Comp. franç. Thomson-Houston*, July 1952, No. 17, pp. 61–73.) The problem of bandwidth increase reverts to that of finding a quadripole which, when terminated on the aerial, has an impedance lying within a certain circle in the complex plane. A detailed discussion is given of various methods of compensation by circuits or transmission-line sections. Methods of calculation for certain types of auto-compensated aerial, such as folded dipoles, are outlined.

621.396.677 **3351**

An Improved Theory of the Receiving Antenna.—R. King. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1113–1120.) "The theory of the center-loaded receiving antenna is improved by introducing the expansion parameter of King and Middleton, and generalized to take account of a load consisting of a two-wire line with finite spacing. First-order formulas for the distribution of current are obtained, together with approximate second-order formulas for the complex effective length of the antenna. Theoretical results are compared with experiment."

621.396.677 **3352**

A Design Method for a Directive Antenna consisting of Two Elements, Projector and Reflector.—R. Sato & K. Nagai. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, March 1952, Vol. 3, No. 2, pp. 125–133.) Methods used in the measurement of aerial input impedance, power gain and directional characteristic are described. The data thus determined have been applied to the construction of a chart from which design details can be derived for aerials with specified characteristics.

621.396.677 **3353**

A Directive Aerial with Increased Line-Wavelength.—U. Finkbein. (*Frequenz*, July 1952, Vol. 6, No. 7, pp. 206–213.) Discussion of a system of two conductors in line, fed at the inner ends and with capacitors inserted at regular intervals which are small compared with the wavelength used. The line wavelength is in this case greater than the free-space wavelength. The radiation diagram for such an aerial is determined, and also the radiation resistance and power gain.

621.396.677 **3354**

Wide-Band Aerial for U.S.W. Beam Links.—H. Körner & W. Stöhr. (*Frequenz*, May/June 1952, Vol. 6, Nos. 5/6, pp. 154–162. Corrections, *ibid.*, July 1952, Vol. 6, No. 7, p. 215.) A detailed account of the development of directive aerials for a radio link, of length 213 km, between Berlin and the Harz mountains, about 90 km of the path being beyond the limit of vision. Two methods of measuring the input impedance of dipoles are described and the results obtained on different types of dipole assembly are compared with theoretical results. The aerial arrays finally adopted consist of groups of four or six units, each unit including four stacked whole-wavelength dipoles fed in phase, with reflectors. Satisfactory operation has been maintained with these aerials over a period of 1½ years, even under conditions of severe icing.

621.396.677 **3355**

Experimental Results for a Lattice Lens for Centimetre Waves.—J. Moussiegt. (*C. R. Acad. Sci., Paris*, 4th June 1952, Vol. 234, No. 23, pp. 2263–2265.) Report of preliminary tests of a rough model of a lattice lens (3004 of November), made up of 312 resonant elements cut from 0·05-mm Al foil and of length 16 mm and breadth 4 mm, arranged in three parallel planes 16 mm apart, at their intersections with four paraboloids, the largest nodal circle having a diameter of 37·5 cm. Power is reduced by a half at 3·5° on either side of the axis, and the gain relative to that of an isotropic source is 42.

621.396.677 : 538.566 : 513.433 **3356**

Laws of Propagation of Electromagnetic Waves in a Conical Horn.—H. Buchholz. (*Arch. Elektrotech.*, 1952, Vol. 40, No. 6, pp. 346–362.) Analysis of the propagation of any partial wave of the infinite system of TM and TE waves. The phase velocity, complex energy flow, and the e.m. energy stored in a thin conical capsule within the horn, are calculated. Calculation of the group velocity by the usual formula, assuming an exponential law of propagation, gives satisfactory results for large values of rk, where r is the distance from the apex of the cone and k the wave-equation constant. For medium and small values of rk, however, the usual formula fails completely and even gives negative group velocities. A formula is derived which can be used throughout the range $0 < rk < \infty$. For large values of rk it agrees, to a first approximation, with the usual formula. The attenuation is also calculated and the dependence of the amplitude on the value of rk determined.

621.396.677.3 **3357**

Sharpness of Aerial Beam Cut-Off.—L. G. Chambers. (*Wireless Engr*, May 1952, Vol. 29, No. 344, p. 142.) A note suggesting that the angle required for the field distribution at infinity to fall from $1/\sqrt{2}$ of its value to 1/10 of its peak value, i.e., for the gain to fall from 1/2 to 1/100 of its peak value, a drop of nearly 17 db, affords a practical basis for specifying the sharpness of cut-off.

621.392.26 **3358**

Waveguide Handbook. [Book Review]—N. Marcuvitz (Ed.). Publishers: McGraw-Hill, London, 1951, 428 pp., 64s. (*Nature, Lond.*, 28th June 1952, Vol. 169, No. 4313, p. 1071.) No. 10 of the M.I.T. Radiation Laboratory Series. ". . . it may certainly be recommended as a standard text of reference."

CIRCUITS AND CIRCUIT ELEMENTS

621.3.012.3 **3359**

The Resolution of Complex Quantities.—N. H. Crowhurst. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp. 426–428.) A chart using logarithmic scales is presented for facilitating calculations involving complex quantities; its use is illustrated by examples.

621.3.015.3 : 517.942.82 **3360**

Treatment of Transient Phenomena by means of the Laplace Transformation.—U. Kirschner. (*Funk u. Ton*, July 1952, Vol. 6, No. 7, pp. 369–373.) A simple explanation of the essential steps in applying the Laplace transform to the determination of the transient response of a system.

621.3.015.7 : 621.392.5 **3361**

A Transmission-Line Pulse Inverter.—R. W. Rochelle. (*Rev. sci. Instrum.*, June 1952, Vol. 23, No. 6, pp. 298–300.) Description and theory of a device for reversing the polarity of pulses with rise times of the order of 10^{-9} sec. It consists of two coaxial cables joined so that the inner conductor of one is connected to the outer conductor of the other and vice versa, the junction being shielded. Normalized design graphs aid in the calculation of inverter characteristics.

621.314.3† **3362**

Magnetic Amplifiers.—W. Schilling. (*Arch. tech. Messen*, June 1952, No. 197, pp. 139–142.) Review of the properties of basic types in reference to their use for control purposes in industry.

621.314.634 : 621.314.222 **3363**

The Characteristics of the New Siemens Flat Se Rectifier, and the Internal Resistance of the Associated Transformer.—R. Kühn. (*Funk u. Ton*, July 1952, Vol. 6, No. 7, pp. 337–350.) Description of the construction of Type-SSF rectifiers, with a table of dimensions and ratings, derivation of approximate formulae and curves for the internal resistance of transformers using standard M-type or E-I-type stampings, and examples of their application in the design of half-wave and full-wave rectifiers.

621.316.86 **3364**

Nonlinear Resistors with Sintered-Semiconductor Base.—N'Guyen Thien-Chi & J. Suchet. (*Ann. Radioélect.*, April 1952, Vol. 7, No. 28, pp. 106–114.) Complementary to paper abstracted in 1219 of May. Two recently developed types of thermistor are described: Type RD (1-W rating) and Type RH (15- or 25-W rating). Their d.c. and a.c. characteristics are discussed and their applications are illustrated.

621.318.4 : 621.318.3 **3365**

Rapid Coil Calculations for Magnetic Devices.—A. E. Maine. (*J. Brit. Instn Radio Engrs*, July 1952, Vol. 12, No. 7, pp. 403–410.) The equations and charts presented are primarily for designing coils associated with solenoid-operated devices, but are not restricted in their scope.

621.392.4/.5 **3366**

Realization of Positive Reactance Functions for Practical Use.—P. Behrend & K. Scheuermann. (*Frequenz*, July 1952, Vol. 6, No. 7, pp. 190–199.) The realization of positive reactance functions has applications in all sections of quadripole theory. The general problem is here treated by a symbolism which a practical engineer can use without elaborate mathematics. The rational positive function corresponding to the impedance of a 2-pole network is first obtained and the result is extended to the case of a quadripole. Essential matrix and function theory is given. A scheme for realizing reactance functions in the form of 2-pole and 4-pole networks is explained and illustrated by practical examples, including the realization of (*a*) a positive matrix as the resistance matrix of a quadripole, (*b*) a quadripole equivalent to a 10·5-km length of wide-band cable.

621.392.4.014.8.015.4 **3367**

Electrical Resonance.—W. Alexander. (*Electrician*, 6th June 1952, Vol. 148, No. 3860, pp. 1857–1861.) General discussion of resonance conditions in series and parallel RLC circuits, with correction of some common mis-statements and loose or ambiguous definitions. Relevant formulae are collected in two tables.

621.392.5 **3368**

Synthesis of Shunt-Reactance Networks with Given Resonance and Antiresonance Frequencies by the Partial-Network Method.—T. O'Callaghan. (*Frequenz*, July 1952, Vol. 6, No. 7, pp. 185–190.) The use of the method is explained for extension of a given network to one with new resonance and antiresonance frequencies, and for the synthesis of a network from elements with assigned resonance and antiresonance frequencies. See also 66 of January.

621.392.5 **3369**

The Transfer Function of General Two-Terminal-Pair RC Networks.—A. Fialkow & I. Gerst. (*Quart. appl. Math.*, July 1952, Vol. 10, No. 2, pp. 113–127.) The present study is completely general in relation to the types of network treated, in contrast to an earlier paper (350 of February) which deals with particular types. The investigation establishes the properties characteristic of the transfer functions of this class of network, and indicates how to synthesize the network being given a transfer function having these properties. The adaptation of the analysis to RL and LC networks is indicated.

621.392.5 **3370**

Network Analysis by Least-Power Theorems.—F. L. Ryder. (*J. Franklin Inst.*, July 1952, Vol. 254, No. 1, pp. 47–60.) Theorems relating to electrical power, analogous to the theorem of least work applicable to mechanical deformation, are applied to the solution of the general linear network (*a*) without use of Kirchhoff's second law in the mesh-analysis case, (*b*) without use of Kirchhoff's first law in the nodal-analysis case. The theorems are put into a form suitable for practical network analysis and are extended to a.c. networks including transformers and complex impedances.

621.392.5 **3371**

Approximations in Network Design.—W. Saraga. (*Wireless Engr*, Oct. 1952, Vol. 29, No. 349, pp. 280–281.) The relation between the Taylor and Tchebycheff approximations is demonstrated. See also 2461 of September (Linvill).

621.392.5 **3372**

Positive Feedback Operator Networks.—A. W. Keen. (*J. Brit. Instn Radio Engrs*, July 1952, Vol. 12, No. 7, pp. 395–402.) A feedback system using a passive bilateral shaping network in the forward path and a unidirectional unit-gain transformer in the return path can be made to perform a prescribed mathematical operation on an input quantity. This generalized network is basic to certain hitherto uncorrelated circuits, including Beale & Stansfield's integrator/differentiator (British Patent No. 453887), Schmitt & Tolles' feedback differentiator (2174 of 1942) and Newsam's 'bootstrap' integrator (British Patent No. 493843). Instability is prevented by including local negative feedback in the main return path. The system is compared with a more conventional arrangement using negative feedback.

621.392.5 **3373**

'Non-canonical' Symmetrical Lattice Networks.—R. Leroy. (*Câbles & Transmission*, July 1952, Vol. 6, No. 3, pp. 193–210.) In 'canonical' lattice networks the opposite impedances are equal for both pairs of branches, while in 'non-canonical' units the impedances of only one pair are the same. The solution of the general equation for such networks is considered particularly for networks comprising reactive elements, which enable the number of elements required for a filter to be reduced. The design is discussed of filters (*a*) passing neither zero nor infinite frequency, (*b*) passing either zero or infinite frequency and rejecting the other, (*c*) passing both zero and infinite frequency. Filters with a single pass-band, comprising reactances (*a*) with zeros both at the origin and at infinity, (*b*) with zeros at the origin and poles at infinity, are also dealt with and the necessary design formulae derived.

621.392.5 : 512.94 **3374**

Quaternion Calculus and Chain Arrangements of Quadripoles.—J. A. Ville. (*Câbles & Transmission*, July 1952, Vol. 6, No. 3, pp. 211–220.) The elements of quaternion calculus are explained. A quadripole can be represented by a matrix, and its image-impedance attenuation by the logarithm of a matrix. A method is described for deriving the image parameters of a chain of quadripoles by a particular form of addition of the image parameters of the constituent units.

621.392.5 : 621.396.645 **3375**

Networks with Maximally Flat Delay.—W. E. Thomson. (*Wireless Engr*, Oct. 1952, Vol. 29, No. 349, pp. 256–263.) Discussion of the application of these networks (310 of 1950) to the design of low-pass and band-pass multistage wide-band amplifiers and pulse-shaping networks. The treatment is more general and complete than that of Laplume (951 of April) which deals with 2-, 3- and 4-stage amplifiers. The impulse response can be made more and more symmetrical and free from overshoot by increasing the order *n* of the system, the Gaussian curve being approached as *n* tends to infinity. Numerical examples are worked out.

621.392.52 **3376**

On the Redundant Information Supplied in Practical Applications by the Time and Frequency/Phase Responses of a System.—M. Levy. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 801–802.) In determining the transient response of a system from its frequency/phase characteristics, or vice versa, curves are obtained which include redundant information whose elimination simplifies the problem. Three main cases are discussed in relation to low-pass systems. See also *Proc. nat. Electronics Conf., Chicago*, 1951, Vol. 7, p. 73 (abstract only) and 2750 of October.

621.392.52 **3377**

Formulation of the Characteristic Functions and Calculation of the Attenuation of Symmetrical and Antimetrical Filters.—K. H. Haase. (*Frequenz*, May/June 1952, Vol. 6, Nos. 5/6, pp. 168–176 . . 182.) The term 'characteristic function' is applied to the quotient of two polynomials determining the transmission properties of a quadripole. The different forms of these functions are tabulated for low-pass, high-pass, band-pass and band-stop filters of both the symmetrical and the antimetrical type, the latter being such as are changed into the dual form on exchange of input and output [see 959 of 1940 (Piloty)]. The normalized characteristic functions are applied to determine the overall attenuation, for which approximate tolerances for the transmission and blocking regions can be derived. Numerical calculations for a practical band-pass filter illustrate the theory.

621.396.611.21.029.3 **3378**
Quartz Vibrators for Audio Frequencies.—J. E. Thwaites. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 83–91.) Full paper. See 2472 of September.

621.396.611.3 **3379**
Theory of Pull-In Effect.—H. Fack. (*Frequenz*, May/June 1952, Vol. 6, Nos. 5/6, pp. 141–145.) An approximate solution is obtained of the system of nonlinear differential equations for the oscillations in an oscillatory circuit subjected to an applied alternating voltage of frequency different from the natural circuit frequency, a simplified type of characteristic being assumed.

621.396.611.3 : 621.392.26 **3380**
Multi-element Directional Couplers.—S. E. Miller & W. W. Mumford. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1071–1078.) Theory is presented that facilitates the treatment of directional couplers using any number of coupling elements from two up to infinity. The backward wave in a directional coupler is related to the shape of the function describing the coupling between transmission lines by the Fourier transform. This facilitates the design of directional couplers with arbitrary directivities over any prescribed frequency band. Directional couplers with tight coupling are analysed in simple terms; any desired loss ratio, including complete power transfer between lines, can be achieved. The theory is verified by experiments on waveguide models at frequencies of 4, 24 and 48 kMc/s.

621.396.615 **3381**
RC Tuned Oscillators.—H. Stibbé : P. Kundu. (*J. Brit. Instn Radio Engrs*, July 1952, Vol. 12, No. 7, pp. 392–393.) Discussion on 2955 of 1951, with analysis of the oscillator shown in Fig. 5(*a*).

621.396.615 **3382**
Cascade LCR Phase-Shift Oscillators.—F. Butler. (*Wireless Engr*, Oct. 1952, Vol. 29, No. 349, pp. 264–268.) By including inductance in the feedback network the energy dissipation can be reduced in comparison with that for a RC network producing the same phase shift, thus facilitating the sustaining of oscillations. Several one-valve and transistor oscillator circuits are described, intended primarily for operation at audio and low radio frequencies: some of them incorporate quartz crystals for frequency control. A simplified theory of operation is presented.

621.396.615.17 : 537.533.9 : 530.12 **3383**
Possibility of Frequency Multiplication and Wave Amplification by means of Some Relativistic Effects.—K. Landecker. (*Phys. Rev.*, 15th June 1952, Vol. 86, No. 6, pp. 852–855.) Discussion of the possibility of converting the frequency of an e.m. wave to a higher frequency by reflection from an electron cloud moving with relativistic velocity. Such a cloud can be realized by compressing all or part of the beam of an electron accelerator into one or more groups. A gain of wave energy should result from such reflection. It is estimated that a 1-mm wave, with a power of at least 1 mW, can be generated by reflecting a 3-cm wave from the beam of a small betatron. Equipment to test this is being designed.

621.396.615.18 **3384**
A New Frequency Divider.—J. A. Fitzgerald. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp 413–415.) The divider described is a development of the balanced-modulator type. A single valve is used, having in its anode circuit the tuned primary of a transformer whose secondary is connected back to the modulator bridge. Satisfactory operation is obtained with division ratios from 2:1 to 5:1. By modifying the circuit slightly, fractional ratios are also obtainable.

621.396.645 **3385**
The Effective Bandwidth of Video Amplifiers.—F. J. Tischer. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, p. 1060.) See 3050 of November.

621.396.645 **3386**
Amplifier Frequency Response.—A. E. Ferguson : D. A. Bell. (*Wireless Engr*, Oct. 1952, Vol. 29, No. 349, pp. 281–282.) Comment on 2482 of September and author's reply.

621.396.645 **3387**
Amplifiers and Superlatives.—D. T. N. Williamson & P. J. Walker. (*Wireless World*, Sept. 1952, Vol. 58, No. 9, pp. 357–361.) Requirements of a good amplifier [2715 of 1947 (Williamson)] are first listed. Amplifier efficiency and trouble-free production are important factors in design. The operation and the merits of different output circuits are discussed. A triode-connected tetrode and a distributed-load tetrode give about the same quality, the efficiencies being 27% and 36% respectively. Similar quality can be obtained with a conventional tetrode circuit if appropriate feedback is applied, preferably by way of multiple loops in order to avoid instability.

621.396.645 : 621.314.7 **3388**
Transistor Power Amplifiers.—R. F. Shea. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 106–108.) Discussion of the best methods of obtaining maximum power gain and efficiency from junction-type transistors when used in class-A and class-B a.f. amplifiers, with illustrations of practical circuits for gramophone and speech amplifiers and for intercommunication systems.

621.396.645 : 621.314.7 : 621.396.822 **3389**
Noise Figures of Transistor Circuits.—Y. Watanabe. (*Sci. Rep. Res. Inst. Tokohu Univ., Ser. B*, March 1952, Vol. 3, No. 2, pp. 151–187.) An alternative definition of noise figure is proposed, based on the relation between source power and output power on load. Comparison is made between the values of noise figure thus defined and the values in terms of available power for some simple amplifier circuits, cascade types of network, and for a circuit including a valve amplifier. Reasons are given for preferring the author's alternative definition, and on this basis noise figures are determined for transistor amplifiers with either base, emitter or collector electrode grounded, and the variation of noise figure with load resistance is considered.

621.396.645 : 621.396.619 **3390**
On the Theory of Doherty's Power-Amplifier Circuit.—A. Simon. (*Fernmeldetech. Z.*, May 1952, Vol. 5, No. 5, pp. 201–210.) The operation of the circuit is analysed. Expressions for voltage, efficiency etc. of the individual amplifier chains and their typical values for an 80-kW power stage are listed. The latter are based on the characteristics of a Siemens Type-RS566 valve which

does not operate with grid secondary emission. Two methods of reducing distortion are discussed: (*a*) insertion of a correction circuit in the input, (*b*) using a grounded-grid circuit for the main amplifier.

621.396.645.029.42 **3391**

Low-Pass RC Amplifier for Very Low Frequencies.—G. Hoffmann. (*Frequenz*, May/June 1952, Vol. 6, Nos. 5/6, pp. 162–165.) Description, with full circuit details, of an a.c. amplifier with a fixed lower frequency limit of about 0·3 c/s and upper limit adjustable stepwise to 1, 2, 4, 8, 16 or 32 c/s. The amplifier is particularly suitable as a balance indicator in bridge measurements at frequencies down to 1 c/s.

621.396.645.36 **3392**

The Differential Amplifier with a Useful Modification.—B. F. Davies. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp. 404–407.) An analysis is given of the manner in which an amplifier comprising a cathode-coupled pair of triodes discriminates between push-pull and push-push signals. By suitably adjusting the input to one of the pair, via a potentiometer, the discrimination is made infinitely great without an inconveniently high value of h.v. being required.

621.396.645.371 : 621.396.61 : 621.396.712 **3393**

C.F.T.H. Applications of Negative Feedback.—Warnier. (See 3590.)

621.396.662 **3394**

Saturable Reactors as R.F. Tuning Elements.—E. Newhall, P. Gomard & A. Ainlay. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 112–115.) New ferrite materials are used in saturable reactors for remote tuning of r.f. circuits, the inductance of the coils wound on the ferrite cores being varied by changing the d.c. producing the magnetizing field.

GENERAL PHYSICS

06.055.5 (45) : 53 : 538.56.029.6 **3395**

Centre for the Study of the Physics of Microwaves [Florence, Italy].—N. Carrara. (*Ricerca sci.*, April 1952, Vol. 22, No. 4, pp. 643–647.) Director's report for the year 1951.

535.22 **3396**

A Check Determination of the Velocity of Light.—E. Bergstrand. (*Ark. Fys.*, 3rd July 1952, Vol. 3, Nos. 4/5, pp. 479–490. In English.) Further measurements, using improved equipment, termed a 'geodimeter', were made to check the determination previously reported (324 of 1951). The final value deduced is $c =$ 299 793.1 ± 0·2 km/s.

535.43 **3397**

Scattering of Plane Waves by Soft Obstacles: Part 3—Scattering by Obstacles with Spherical and Circular Cylindrical Symmetry.—E. W. Montroll & J. M. Greenberg. (*Phys. Rev.*, 15th June 1952, Vol. 86, No. 6, pp. 889–898.) A new variational method is devised for obtaining the 'best' parameters for trial wave functions of a given type for insertion in the integral equation for the scattering by soft obstacles. The differential and total scattering cross-sections for scattering by Gaussian, exponential, and screened Coulomb potentials are obtained in simple closed forms. Part 1: 2139 of 1951 (Hart & Montroll). Part 2: 2317 of 1951 (Hart).

537.226 : 546.391.85 **3398**

On the Theory of the Dielectric, Piezoelectric, and Elastic Properties of $NH_4H_2PO_4$.—T. Nagamiya. (*Progr. theor. Phys., Osaka*, March 1952, Vol. 7, No. 3, pp. 275–284.)

537.226.2/.3 : [546.212 + 547.261 + 547.262 **3399**

Dielectric Dispersion in Pure Polar Liquids at Very High Radio Frequencies: Part 1—Measurements on Water, Methyl and Ethyl Alcohols.—J. A. Lane & J. A. Saxton. (*Proc. roy. Soc. A*, 8th July 1952, Vol. 213, No. 1114, pp. 400–408.) Measurements were made at wavelengths of 6·2 mm, 1·24 cm and 3·21 cm by a waveguide technique similar to that of Collie et al. (2508 of 1948). The temperature range covered was from −10° to +50°C and results were obtained for water in the supercooled state. Values of the absorption coefficient and refractive index for the three liquids are tabulated. The electrical characteristics of water vary in a continuous manner down to at least −8°C. The results for the alcohols indicate that both, like water, have relatively high atomic polarizations. Part 2: 3400 below.

537.226.2/.3 : [546.212 + 547.261 + 547.262 **3400**

Dielectric Dispersion in Pure Polar Liquids at Very High Radio Frequencies: Part 2—Relation of Experimental Results to Theory.—J. A. Saxton. (*Proc. roy. Soc. A.*, 22nd July 1952, Vol. 213, No. 1115, pp. 473–492.) Analysis of the results given in part 1 (3399 above) indicates that a single relaxation time as a function of temperature is sufficient to account for the observed dielectric properties of water, at any rate for wavelengths greater than a few millimetres. The results for methyl and ethyl alcohols for wavelengths near to 1 cm, which apparently indicate a distribution of relaxation times, can be explained in terms of resonance absorption, with postulated bands centred at wavelengths of 2·5 mm and 5 mm in methyl and ethyl alcohol respectively. Further measurements at wavelengths between 1 mm and 1 cm are required. The close relation between dipole rotation and viscous flow in the three liquids is discussed.

537.311.33 **3401**

The Influence of Surface [energy] **Levels on the Chemical Potential and Work Function of a Semiconductor.**—G. E. Pikus. (*Zh. eksp. teor. Fiz.*, Nov. 1951, Vol. 21, No. 11, pp. 1227–1238.) A discussion based on the assumption of a surface zone in which the number of levels is equal to the number of surface cells of the crystal.

537.311.33 **3402**

On the Diffusion Theory of Rectification.—P. T. Landsberg. (*Proc. roy. Soc. A*, 24th June 1952, Vol. 213, No. 1113, pp. 226–237.) The Einstein relation $eD = \mu kT$ between the mobility μ and diffusion coefficient D has not so far been established theoretically or experimentally for rectifiers. Analysis of experimental results for a copper-oxide rectifier in terms of a Schottky barrier on the basis of the diffusion equation in which μ and D are retained, suggests that the values of μ and D differ for forward and reverse characteristics. The diffusion equation is developed from the formal theory of conduction using Fermi-Dirac statistics; the μ and D of this equation are to be regarded as average values throughout the barrier, as both depend on the concentration distribution of conduction electrons in the barrier.

537.523.4 **3403**

Mechanism of Positive Spark Discharges with Long Gaps in Air at Atmospheric Pressure.—H. Norinder & O. Salka. (*Ark. Fys.*, 3rd July 1952, Vol. 3, Nos. 4/5, pp. 347–386. In English.) Report of experiments made to determine to what extent the streamer theory is applicable in the case of long gaps. A sphere-to-plane or point-to-plane arrangement was used, with the point or sphere always at the positive potential; gap lengths ranged from 5 to 155 cm. 41 references.

537.523.4 : 546.17-1 **3404**

Electrical Breakdown of Gases: Part 2 — Spark Mechanism in Nitrogen.—J. Dutton, S. C. Haydon & F. L. Jones. (*Proc. roy. Soc. A*, 24th June 1952, Vol. 213, No. 1113, pp. 203–214.) The growth of the pre-breakdown ionization currents in uniform fields in nitrogen was measured for various field strengths, pressures, gap widths and sparking potentials. The sparking distance and potentials measured were found to be exactly in accordance with those predicted by the Townsend equation. There were strong indications that the secondary ionization is a cathode process. Possible effects of space charge are considered. Part 1: 3405 below.

537.523.4 : 546.217 **3405**

Electrical Breakdown of Gases: Part 1 — Spark Mechanism in Air.—F. L. Jones & A. B. Parker. (*Proc. roy. Soc. A*, 24th June 1952, Vol. 213, No. 1113, pp. 185–202.) Experimental investigations show that the pre-breakdown growth of small ionization currents in air in uniform electric fields can, for certain conditions, be represented by the well-known Townsend relation. This indicates the existence of a secondary mechanism throughout the complete breakdown process. Measurement of the primary and secondary ionization coefficients gave agreement between the calculated and observed sparking potentials.

537.533 **3406**

The Dispersion of Electron Beams in Gases.—P. F. Little & A. von Engel. (*Proc. phys. Soc.*, 1st June 1952, Vol. 65, No. 390B, pp. 459–460.) Discussion of the mechanism of dispersion based on the discovery that an electron beam accelerated at 3–10 kV in nitrogen remains well concentrated at pressures of about 1 mm Hg. The ultimate cause of beam concentration is the presence of positive ions in and around the beam.

537.533 : 519.21 **3407**

Probabilities relating to a Continuous Electron Beam.—P. Mourmant. (*Radio franç.*, June 1952, No. 6, pp. 19–24.) In the case of currents involving the movement of a very large number of electrons, simple statistical methods of treatment result in theories of practical value for engineers. For feeble currents, however, where the number of electrons concerned may be relatively small, statistical methods are not satisfactory and discussion of certain probabilities concerning individual electrons appears preferable. The probable number of electrons passing across a certain section of an electron beam in a given time interval, and the probable time interval between the passage of consecutive electrons, are discussed, with numerical examples. Application of certain probability invariants in the case of modulated or unmodulated beams is also considered.

537.533.7 : 537.226 **3408**

Free Paths of Electrons in Crystals, Electroluminescence Effects and Phenomena of Dielectric Breakdown.—D. Curie. (*J. Phys. Radium*, June 1952, Vol. 13, No. 6, pp. 317–325.)

537.533.8 **3409**

A Note on Wooldridge's Theory of Secondary Emission.—E. M. Baroody. (*Phys. Rev.*, 15th June 1952, Vol. 86, No. 6, pp. 915–916.) Re-examination of Wooldridge's theory shows that the broad maximum which he obtained in the curve of secondary-emission coefficient against primary energy is a result of inconsistency in approximations, rather than an essential result of his theory. See also 107 and 110 of January, and 108 and 109 of January (Brophy).

537.562 **3410**

Wave Theory of Plasmas.—D. Gabor. (*Proc. roy. Soc. A*, 5th June 1952, Vol. 213, No. 1112, pp. 73–86.) A critical review is given of various theories. The spectral law of energy distribution in plasma waves is discussed and a thermodynamical upper limit is shown to exist for the energy. The momentum and energy interchange of electrons with plasma waves is very weak, and quite insufficient to explain the existence of the Maxwellian energy distributions in low-pressure arcs observed by Langmuir, for which a fresh interpretation is required.

537.562 : 538.566 **3411**

High-Frequency Oscillations in an Electron Plasma.—A. I. Akhiezer & Ya. B. Faynberg. (*Zh. eksp. teor. Fiz.*, Nov. 1951, Vol. 21, No. 11, pp. 1262–1269.) If a beam of charged particles enters an electron plasma, the fluctuations of density and velocity in the beam are propagated in the form of waves with increasing amplitude.

537.562 : 538.566 **3412**

On Magneto-hydrodynamic Waves in Gases.—V. L. Ginzburg. (*Zh. eksp. teor. Fiz.*, July 1951, Vol. 21, No. 7, pp. 788–794.) Formulae are derived which for high frequencies are transformed into corresponding expressions determining the propagation of radio waves in the ionosphere, taking account of the effect of the magnetic field. At low frequency, below the gyromagnetic frequency for ions, the results obtained coincide with those derived from the hydrodynamic approximation. See also 2152 of 1951 (Åström).

538.114 **3413**

Molecular-Field Treatment of Ferromagnetism and Antiferromagnetism.—J. S. Smart. (*Phys. Rev.*, 15th June 1952, Vol. 86, No. 6, pp. 968–974.) A modified Weiss treatment of magnetism in crystals in which both first and second nearest-neighbour interactions, with all four combinations of signs, are considered.

538.221 **3414**

Antiferromagnetic Arrangements in Ferrites.—Y. Yafet & C. Kittel. (*Phys. Rev.*, 15th July 1952, Vol. 87, No. 2, pp. 290–294.) Néel's molecular-field treatment is extended to take into account the exchange interactions within the two magnetic sublattices.

538.3 **3415**

A Method for determining the Electromagnetic Field inside a Closed Spherical Envelope with Nonuniform Permittivity.—R. G. Mirimanov. (*C. R. Acad. Sci. U.R.S.S.*, 21st Sept. 1951, Vol. 80, No. 3, pp. 361–364. In Russian.) An equation (10) is derived establishing the relation between the total fields on both sides of the envelope. The total field in this case is made up of the field due to the external sources, which induce corresponding currents in the envelope, and the field excited by these currents in space. Methods are indicated for determining the secondary field, and a linear differential equation (22) is derived from which the required solution can be found.

538.3 **3416**

Matrix and Tensor Form of the Fundamental Relations of Magneto-ionic Theory.—H. Arzeliès. (*C. R. Acad. Sci., Paris*, 16th June 1952, Vol. 234, No. 25, pp. 2430–2432.) Matrix relations are developed from Maxwell's equations which give all the characteristics of waves, including phase velocity and polarization. Formulae such as the Appleton-Hartree formula are included as particular cases. The system can be put into tensor form.

538.521 **3417**

The Dromgoole Effect.—R. H. Frazier. (*Wireless Engr*, Sept. 1952, Vol. 29, No. 348, p. 253.) Comment on 2491 of September, indicating the relation between the Dromgoole effect and the well-known Wiedemann effect.

538.56 : 535.42 **3418**

Diffraction by a Semi-infinite Metallic Sheet.—T. B. A. Senior. (*Proc. roy. Soc. A*, 22nd July 1952, Vol. 213, No. 1115, pp. 436–458.) "In spite of the considerable attention which has been focused on diffraction by perfectly conducting structures, little success has so far been achieved when finite conductivity is introduced. It is now shown that with the assumption of suitable boundary conditions, the problem of diffraction at a metal sheet is capable of exact solution. Corresponding to each of two fundamental polarizations, a pair of Wiener-Hopf integral equations is derived from which to determine the electric and 'magnetic' currents present in the sheet. One of these equations is subjected to a rigorous solution, and from it the solutions of the other three are deduced by symmetry considerations. Use of the generalized method of steepest descent then serves to determine the diffracted fields. The case of a circularly polarized incident wave is also briefly discussed and a comparison presented between the theoretical and experimental forms of the scattered field; good agreement is obtained."

538.56 : 621.3.011.21 : 523.14 **3419**

The Characteristic Impedance of Vacuum, an Important Universal Constant.—E. Hallén. (*Bull. Soc. franç. Élect.*, June 1952, Vol. 2, No. 18, pp. 377–380.) Discussion of basic formulæ of electromagnetic theory. See also 1397 of 1950 (Tanasescu: Brylinski) and back references.

538.566.2 **3420**

The Concept of Group Velocity.—P. Poincelot. (*C. R. Acad. Sci., Paris*, 16th June 1952, Vol. 234, No. 25, pp. 2426–2427.) Discussion for the case of propagation from one medium to another with different refractive index, justifying the methods applied to the study of the ionosphere. See also 2179 of August.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.72 + 523.85] : 621.396.822.029.6 **3421**

Cosmic Radio-Noise Intensities in the V.H.F. Band.—H. V. Cottony & J. R. Johler. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1053–1060.) Results of continuous observations made at the National Bureau of Standards during 1948 and 1949 on frequencies in the range 25–110 Mc/s are reported. A regular daily variation in noise was found to correspond with the movement of the principal sources of cosmic r.f. noise across the receiving aerial system. The results are presented in terms of the observed daily maxima and minima. Periods of abnormally high noise levels, generally associated with periods of unusual solar activity, were also recorded.

523.752 : 523.746.5 **3422**

Prominence Activity and the Sunspot Cycle.—R. Ananthakrishnan. (*Nature, Lond.*, 26th July 1952, Vol. 170, No. 4317, pp. 156–158.) Analysis of solar-prominence records at Kodaikanal from 1905 to 1950 shows a marked correlation with the sunspot cycle. The region of most intense prominence activity on the sun is at about latitude 50°–55° in both hemispheres some three or four years before sunspot maximum.

523.854 : 621.396.822.029.62 **3423**

Measurements of the Radiation from the Milky Way on 255 Mc/s.—I. Atanasijević. (*C. R. Acad. Sci., Paris*, 16th July 1952, Vol. 235, No. 2, pp. 130–132.) Preliminary report of results obtained with the 7·5-m paraboloid of the Institut d'Astrophysique, Paris, with a diagram showing the 255-Mc/s radio-isophotes for the region of the Milky Way investigated.

537.311 + 537.226.2] : 546.331.31-145.1 **3424**

Electrical Properties of Sea Water.—J. A. Saxton & J. A. Lane. (*Wireless Engr*, Oct. 1952, Vol. 29, No. 349, pp. 269–275.) The results of recent measurements of the dielectric properties of aqueous NaCl solutions at frequencies between 9·4 and 48 kMc/s are applied to the calculation of the electrical properties of sea water. The static dielectric constant has values of about 75 and 69 respectively at 0° and 20°C, the corresponding values for pure water being 88 and 80. The reflection coefficient of sea water is given as a function of the angle of incidence at frequencies between 30 Mc/s and 30 kMc/s, and it is shown how the dipolar and ionic conductivities govern the attenuation of pure, fresh and sea water at radio frequencies.

550.386 : 523.78 **3425**

Micro-magnetic Variations during the Solar Eclipse of February 25, 1952.—N. F. Astbury. (*Nature, Lond.*, 12th July 1952, Vol. 170, No. 4315, pp. 68–69.) A preliminary account of observed variations of the horizontal component of the geomagnetic field at Khartoum. A region of minimum disturbance occurred about 10 minutes after totality; recovery to the pre-eclipse level was prolonged for 4–5 hours after the last contact. It is suggested that the magnetic variations are largely due to plasma oscillations in the lower levels of the ionosphere.

551.510.535 **3426**

Nocturnal Disturbances of Ionization in the Lower Ionosphere.—E. A. Lauter & K. Sprenger. (*Z. Met.*, June 1952, Vol. 6, No. 6, pp. 161–173.) The observations made on 245-kc/s sky waves, reported previously [1377 of 1951 (Lauter)], are analysed statistically and the types of disturbance are classified. Though there is generally close correlation with geomagnetic activity, some of the phenomena observed cannot be explained by accepted corpuscular-radiation theories. Observations on long waves should yield useful information not only about the mechanism of disturbances in the lower ionosphere, but also about the wind systems in the upper atmosphere.

551.510.535 : 621.396.11.029.53 **3427**

Weak Echoes from the Ionosphere with Radio Waves of Frequency 1·42 Mc/s.—S. Gnanalingam & K. Weekes. (*Nature, Lond.*, 19th July 1952, Vol. 170, No. 4316, pp. 113–114.) Note of results obtained by a sensitive f.m. method suitable for detecting echoes at times of high absorption. In January and February, reflections were obtained from heights between 75 and 80 km. The effective reflection coefficient was found to be $< 3 \times 10^{-4}$. In days when the absorption was less, discrete reflection heights were noted near 90, 96 and 112 km. From mid-March the reflection height was consistently in the range 102–105 km.

551.54 : 550.386 **3428**

Atmospheric Pressure and Geomagnetic Disturbance.—R. P. W. Lewis & D. H. McIntosh. (*Nature, Lond.*, 21st June 1952, Vol. 169, No. 4312, pp. 1059–1060.) Discussion of possible relations between geomagnetic disturbances and atmospheric pressure variations in the light of results for selected days in years of low sunspot number between 1900 and 1945.

551.594.6 : 551.515.3 3429

Identification of Tornadoes by Observation of Atmospherics Waveform.—H. L. Jones & P. N. Hess. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1049–1052.)

LOCATION AND AIDS TO NAVIGATION

621.396.9 3430

Narrow-Band Link relays Radar Data.—J. L. McLucas. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 142–146.) Description, with detailed circuit diagrams, of equipment for scanning the p.p.i. display on a radar c.r. tube at a slow rate, thus integrating the display data and enabling a video signal, of bandwidth 2·3 kc/s, to be derived for transmission over telephone lines or a radio link to any desired point, where an adapter unit generates the signals necessary to operate a display which is a reasonably good reproduction of the original.

621.396.9 3431

A Survey of Requirements for Port Radar.—L. S. Le Page. (*J. Inst. Nav.*, July 1952, Vol. 5, No. 3, pp. 285–295.) General discussion of the advantages and limitations of a port radar system, based on the results of an official investigation. The trial equipment set up at Sunderland (1388 of 1951) and now permanently installed is described. Details are given of the operating procedure. Other existing and projected shore installations in various parts of the world are listed, with descriptive notes.

621.396.9 3432

Operational Requirements for the Harbour Radar Installation at Ijmuiden.—E. Goldbohm. (*Tijdschr. ned. Radiogenoot.*, July 1952, Vol. 17, No. 4, pp. 156–167. Discussion, p. 167.) The special problems introduced by local weather and tidal conditions are indicated. Design features discussed include choice of wavelength (3·26 cm) and resolving power (17 m radial, 0·7° half beam-width), screen excitation, ranges (10 km maximum), scale of display and accuracy. Details are given of the parabolic-cylinder aerial with offset horn feed; rotation rate is 20 r.p.m. Communication is effected by f.m. radiotelephone operating in the 160-Mc/s band.

621.396.9 : 621.317.75 3433

The Indicator of the Harbour Radar Installation at Ijmuiden.—J. A. Grosjean. (*Tijdschr. ned. Radiogenoot.*, July 1952, Vol. 17, No. 4, pp. 182–190. Discussion, p. 190.) The indicator comprises two similar independent units each equipped with a 16-in. metal-cone c.r. tube for panoramic display. A direct indication of bearing and distance of object is provided. The sweep is performed by a rotating-coil mechanism driven from the aerial by a servo link. Permanent magnets of ferroxdure are used to offset the display to give bearing and distance from the harbour mouth rather than from the transmitter. See also 3432 above.

621.396.9 : 621.396.61/.62 3434

The Transmitter and Receiver of the Harbour Radar Installation at Ijmuiden.—J. Verstraten. (*Tijdschr. ned. Radiogenoot.*, July 1952, Vol. 17, No. 4, pp. 168–180. Discussion, p. 181.) A magnetron transmitter with a peak power of 7 kW is used in conjunction with a heterodyne receiver including Si detector and klystron oscillator with a.f.c. The i.f. is 30 Mc/s and the pulse repetition frequency 3 kc/s. Circuit design details for attaining the required resolution, range and accuracy of location are discussed. Some notes on the mechanical construction are included. See also 3432 above.

621.396.9 : 621.396.8 3435

Fluctuations of Ground Clutter Return in Airborne Radar Equipment.—T. S. George. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 92–99.) Full paper. See 2514 of September.

621.396.932/.933 3436

Decca Navigator.—(*Wireless World*, Sept. 1952, Vol. 58, No. 9, p. 338.) A map shows the locations of European Decca stations, including those of the South-West British chain opened on 29th July 1952, with its central station near Plymouth.

621.396.932/.933].1 + 621.396.97 3437

Common-Wave Broadcasting and Hyperbolic Navigation: Part 2.—M. Pohontsch. (*Telefunken Ztg*, June 1952, Vol. 25, No. 95, pp. 93–97.) Discussion of the accuracy of hyperbolic navigation systems and of the possibility of using the transmissions of the German Decca stations as frequency standards for common-wave transmitters in the medium-wave range and even for the control of u.s.w. transmitters. 37 references. Part 1: 2515 of September.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.37 3438

Induced Conductivity and Light Emission in Different Luminescent Type Powders.—H. Kallmann & B. Kramer. (*Phys. Rev.*, 1st July 1952, Vol. 87, No. 1, pp. 91–107.) Experimental and theoretical investigation of various (Zn:Cd)S phosphors.

535.37 3439

Electroluminescence of Single Crystals of ZnS : Cu.—W. W. Piper & F. E. Williams. (*Phys. Rev.*, 1st July 1952, Vol. 87, No. 1, pp. 151–152.) Application of direct or alternating voltage causes luminescence. Observations are explained on the basis of semiconductor theory.

535.371 : 546.472.21 3440

A Study of the Electron Traps in Zinc Sulfide Phosphor.—A. W. Smith & J. Turkevich. (*Phys. Rev.*, 15th July 1952, Vol. 87, No. 2, pp. 306–308.)

535.376 3441

Recent Research on Radio-luminescence.—G. F. J. Garlick. (*Brit. J. appl. Phys.*, June 1952, Vol. 3, No. 6, pp. 169–172.) Investigations of the excitation of single crystals by single particles, using sensitive photomultipliers, indicate much simpler relations between luminescence intensity and particle energy than those previously found for phosphors of complex structure. In many inorganic crystals the luminescence is proportional to the energy absorbed; deviations from proportionality provide indications of the nature of the processes involved. Further theoretical research is needed on the nature of the nonradiative processes which consume at least 80% of the energy absorbed by ordinary phosphor screens.

535.376 : [546.41.786-31 + 546.47-31 3442

The Decay of Calcium-Tungstate and Zinc-Oxide Phosphors after Electron-Beam Excitation.—H. Gobrecht, D. Hahn & H. Dammann. (*Z. Phys.*, 23rd June 1952, Vol. 132, No. 3, pp. 239–247.) Oscillograms of the decay characteristics are examined. That of $CaWO_4$ is exponential, of ZnO hyperbolic. Luminescence is assumed to be a monomolecular process in $CaWO_4$, and to be due to a recombination mechanism in ZnO.

537.224 3443

Investigation of the Thermal Conductivity of Electrets.—J. van Calker & R. Arnold. (*Z. Phys.*, 23rd June 1952, Vol. 132, No. 3, pp. 318–329.)

537.226 **3444**

Thermodynamic Theory of the Ferroelectric Properties of Crystals of the Barium Titanate Type.—M. Ya. Shirobokov & L. P. Kholodenko. (*Zh. eksp. teor. Fiz.*, Nov. 1951, Vol. 21, No. 11, pp. 1239–1249.)

537.226 **3445**

The Ferroelectric Properties of Crystals of the BaTiO$_3$ Type near the Curie Point in the Presence of Elastic Stresses.—L. P. Kholodenko & M. Ya. Shirobokov. (*Zh. eksp. teor. Fiz.*, Nov. 1951, Vol. 21, No. 11, pp. 1250–1261.)

537.228.2 : 538.652 **3446**

On the Theory of Electrostriction Vibration — Substitution of Magnetostriction Theory.—Y. Kikuchi. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, Sept. 1951, Vol. 3, No. 1, pp. 7–12.)

537.311.3 **3447**

The Electrical Resistance of Binary Metallic Mixtures.—R. Landauer. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 779–784.) A theory is developed which assumes a random mixture of the two components, conduction proceeding as if each crystal is surrounded by a homogeneous medium whose properties are those of the mixture. The variation of resistivity with composition as computed from the theory is compared with curves obtained experimentally; agreement is satisfactory for one group of mixtures, but totally unsatisfactory for another group.

537.311.33 : 537.565 **3448**

Effects of Dislocations on Mobilities in Semiconductors.—D. L. Dexter & F. Seitz. (*Phys. Rev.*, 15th June 1952, Vol. 86, No. 6, pp. 964–965.) The scattering of electrons or holes in semiconductors by the dilatation of the lattice around rigid randomly arranged edge-type dislocations is treated by the method of the deformation potential. The contribution of this scattering to the electrical resistance is determined from the Boltzmann transport equation.

537.311.33 : 537.58 **3449**

Thermal Ionization of Trapped Electrons.—R. Kubo. (*Phys. Rev.*, 15th June 1952, Vol. 86, No. 6, pp. 929–937.) The rate of thermal ionization of electrons trapped on impurity atoms is treated on a quantum mechanical basis. Approximate formulae based on an Einstein model are derived for the total ionization rate. Reasons are given for expecting much greater rates than those given by Goodman, Lawson & Schiff (2453 of 1947).

537.311.33 : 546.24-1 **3450**

Semiconducting Properties of Tellurium.—P. Aigrain, C. Dugas, J. Legrand des Cloizeaux & B. Jancovici. (*C. R. Acad. Sci., Paris*, 16th July 1952, Vol. 235, No. 2, pp. 145–146.) Measurements of the conductivity and Hall effect of single crystals, of dimensions several millimetres, were made at different temperatures between that of liquid N and 50°C The results show that Te is a *p*-type semiconductor with intrinsic activation energy of 0·34 eV and impurity activation energy of about 0·039 eV. At room temperature the mobility of electrons was found to be 910 cm/s per V/cm, and that of holes 570 cm/s per V/cm.

537.311.33 : 546.28-1 **3451**

Study of the Conductivity of Silicon.—M. Perrot & J. Tortosa. (*C. R. Acad. Sci., Paris*, 16th July 1952, Vol. 235, No. 2, pp. 143–145.) Films of Si were deposited by evaporation on to glass between two Ag electrodes 100–300 μ apart. For thicknesses $>$ 300 mμ the resistance was nearly constant for applied voltages up to 1·5 kV/cm, but the thinnest films showed considerable departures from Ohm's law, the resistance of 70-mμ and 160-mμ films being 15 times greater at 1·5 kV/cm than at zero voltage.

537.311.33 : 546.289 **3452**

The ABC's of Germanium.—J. P. Jordan. (*Elect. Engng, N.Y.*, July 1952, Vol. 71, No. 7, pp. 619–625.) Discussion of mechanisms governing the properties and applications of Ge crystals.

537.311.33 : 546.289 : 537.568 **3453**

Electron-Hole Recombination in Germanium.—R. N. Hall. (*Phys. Rev.*, 15th July 1952, Vol. 87, No. 2, p. 387.) Measurements show that the rate of recombination varies linearly with carrier concentration over a wide range of concentration and of temperature. This can be explained on the assumption that recombination takes place largely through the agency of recombination centres distributed throughout the Ge. The Fermi level of these centres is estimated as about 0·22 eV above valence band or below the conduction band.

537.311.33 : 546.772.21 **3454**

Semiconductor Properties of Molybdenite.—F. Regnault, P. Aigrain, C. Dugas & B. Jancovici. (*C. R. Acad. Sci., Paris*, 7th July 1952, Vol. 235, No. 1, pp. 31–32.) Measurements of conductivity and Hall effect were made at temperatures between that of liquid H and 300°C. The curve showing the logarithm of the number of free carriers plotted against the reciprocal of absolute temperature is not a straight line in all cases, indicating the presence of both types of impurity.

538.221 **3455**

New Magnetic Material.—(*Elect. Rev., Lond.*, 6th June 1952, Vol. 150, No. 3889, p. 1246.) A few details are given of a new Ni-Fe alloy, developed by Standard Telephones, to be known as 'Permalloy F'. It has a very nearly rectangular hysteresis loop, low coercive force, and is very suitable as a core material for all types of saturable reactor. A flux density of nearly 14 000 gauss can be obtained with magnetizing fields $<$ 0·1 oersted. A list of proposed core sizes is given.

538.221 **3456**

The Magnetic Structure of Alnico 5.—E. A. Nesbitt & R. D. Heidenreich. (*Elect. Engng, N.Y.*, June 1952, Vol. 71, No. 6, pp. 530–534.) Revised text of A.I.E.E. Winter General Meeting paper, January 1952. Detailed discussion of (*a*) the mechanism which enables the alloy to respond to heat treatment in a magnetic field, (*b*) the mechanism resulting in the high coercive force of 600 oersted. See also 2530 and 2531 of September.

538.221 **3457**

Rare-Earth Ferrites with Two Curie Points.—H. Forestier & G. Guiot-Guillain. (*C. R. Acad. Sci., Paris*, 7th July 1952, Vol. 235, No. 1, pp. 48–50.) Continuation of work noted previously (2532 of 1950).

538.221 : 534.232 : 538.652 **3458**

Magnetostrictive Vibration of Prolate Spheroids. Ni-Fe and Ni-Cu Alloys.—J. S. Kouvelites & L. W. McKeehan. (*Phys. Rev.*, 15th June 1952, Vol. 86, No. 6, pp. 898–904.) A study of various magnetic properties of Ni-Fe and Ni-Cu alloys determined from longitudinal magnetostrictive vibrations of spheroidal samples. See also 1929 of July (Beck et al.).

538.221 : 537.226.2/.3 **3459**

Dielectric Investigations on Ferrites.—G. Möltgen. (*Z. angew. Phys.*, June 1952, Vol. 4, No. 6, pp. 216–224.) Measurements of dielectric constant ϵ_r and dielectric loss between 50 c/s and 20 Mc/s indicate an inhomogeneous structure. Extremely high values of ϵ_r at low frequencies are attributed to very thin air layers between the ferrite crystals. At frequencies of a few kc/s ϵ_r falls to a constant value of about 10; this is maintained up to 4 kMc/s.

538.221 : 621.318.2 **3460**

A New Permanent-Magnet Material of Nonstrategic Material.—F. G. Brockman. (*Elect. Engng, N.Y.*, July 1952, Vol. 71, No. 7, pp. 644–647.) An account of the properties of the Philips material ferroxdure. See also 2824 of October (Went et al.).

538.221 : 621.318.2 **3461**

Determination of the Characteristics of Permanent-Magnet Materials.—E. Meyer. (*Arch. Elektrotech.*, 1952, Vol. 40, No. 6, pp. 363–366.) A graphical method is described for determining the maximum induction that can be obtained in the air-gap of a magnet made from specified material.

538.221 : 621.318.2 **3462**

A Graphical Method for Determining the Optimum Working Point of Permanent-Magnet Systems.—W. Breitling. (*Arch. Elektrotech.*, 1952, Vol. 40, No. 6, pp. 366–369.)

538.221 : 669.14.018.582-15 **3463**

The Influence of Heat Treatment on Magnetic Viscosity in Permanent-Magnet Alloys.—R. Street, J. C. Woolley & P. B. Smith. (*Proc. phys. Soc.*, 1st June 1952, Vol. 65, No. 390B, pp. 461–462.)

538.221 : 669.15.782 **3464**

Low Remanence and the Temperature Variation of Permeability of Silicon-Iron Alloys.—E. W. Lee. (*Proc. phys. Soc.*, 1st June 1952, Vol. 65, No. 390B, pp. 455–456.)

538.221.029.5/.6 **3465**

The Magnetic Spectra of the Ni-Zn Ferrites at Radio Frequencies.—L. A. Fomenko. (*Zh. eksp. teor. Fiz.*, Nov. 1951, Vol. 21, No. 11, pp. 1201–1208.) The influence of frequency on the elastic and viscous permeabilities of ferrites is considered. The Ni-Zn ferrites have a continuous magnetic spectrum with sharply defined dispersion bands of elastic permeability and absorption bands of viscous permeability at frequencies from 0·75 to 360 Mc/s.

546.23-161 : 621.317.335.3 **3466**

The Dielectric Constant and Loss of Amorphous Selenium at a Wavelength of 3 cm.—H. A. Gebbie & D. G. Kiely. (*Proc. phys. Soc.*, 1st July 1952, Vol. 65, No. 391B, p. 553.) Results of waveguide measurements are in good agreement with values previously found for infrared wavelengths.

546.26-1 : 537.582 **3467**

The Thermionic Constants of Metals and Semiconductors: Part 1 — Graphite.—S. C. Jain & K. S. Krishnan. (*Proc. roy. Soc. A*, 24th June 1952, Vol. 213, No. 1113, pp. 143–157.) Experimental determination of the saturation vapour pressure of the electron gas from graphite as a function of temperature T by an effusion method, yielding a value for the work function of 4·62 eV and for the effusion constant of 60 $A/cm^2/T^2$.

546.47-31 **3468**

The Photoconductivity of Zinc Oxide.—H. Weiss. (*Z. Phys.*, 23rd June 1952, Vol. 132, No. 3, pp. 335–353.) An investigation of the photoconductivity of evaporated ZnO films as a function of temperature and of the wavelength of the incident light. The quantum efficiency is determined from the initial rise of current. Normal relations connecting dark and light current and rate of current change hold at temperatures down to 87°K.

546.47-31 : [537.533.9 + 535.215.2 **3469**

The Energy Conversion in Light or Electron Irradiation of Thin Zinc-Oxide Films.—G. Heiland. (*Z. Phys.*, 23rd June 1952, Vol. 132, No. 3, pp. 367–383.) A simple model is proposed which affords a theoretical explanation of the effects previously described (3470 below).

546.47-31 : 537.533.9 **3470**

Conductivity Variations of Thin Zinc-Oxide Films due to Electron Irradiation.—G. Heiland. (*Z. Phys.*, 23rd June 1952, Vol. 132, No. 3, pp. 354–366.) Irradiation by electrons of energy 1–6 keV produced a reversible increase of the conductivity; a quantitative estimation of the energy conversion was made from the initial increase of current.

621.3.042.143 **3471**

Tape-Wound Magnetic Cores.—A. L. Morris. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp. 416–417.) The advantages of tape-wound cores for use in transformers and magnetic amplifiers are indicated, and various constructions are discussed. Flux distribution can be made satisfactorily uniform by means of series, parallel or tertiary compensating windings.

621.314.63 **3472**

Further Results in the General Theory of Barrier-Layer Rectifiers.—P. T. Landsberg. (*Proc. phys. Soc.*, 1st June 1952, Vol. 65, No. 390B, pp. 397–409.) Formulae are derived for the temperature variation of the zero-voltage resistance of a rectifier with an arbitrary distribution of impurity centres. These formulae are applied to interpret experimental results and to determine the dependence on temperature of (*a*) the effective mass of current carriers in Ge rectifiers and (*b*) the mobility of current carriers in Se rectifiers. Thermal instability and current creep are discussed.

621.314.632 : 549.328.1 **3473**

Rectification Phenomena exhibited by Natural and Sulphurized Galena.—A. L. Reimann & J. V. Sullivan. (*Proc. phys. Soc.*, 1st July 1952, Vol. 65, No. 391B, pp. 480–487.) According to the sulphurization treatment given, either the rectification properties of specimens of *n*-type galena were improved, or the polarity was changed to *p*-type. The results of tests with d.c. and at 3 kMc/s were discussed in the light of present-day theory.

621.314.634 + 621.383.42] : 546.49-13 **3474**

The Influence of Mercury Vapour on Selenium Rectifiers and Selenium Photoelements.—P. Selényi. (*Proc. phys. Soc.*, 1st July 1952, Vol. 65, No. 391B, p. 552.) If Se rectifiers are exposed to Hg vapour, they lose their high resistance in the blocking direction and become useless. A similar destructive effect has been observed with Se photocells. The effect, which is due to the formation of mercuric selenide, an excess semiconductor of high conductivity, is discussed with reference to Schottky's barrier-layer theory.

621.315.61 : 537.311.1 **3475**

Electronic Conduction in Crystalline Insulating Materials.—W. Franz. (*Z. Phys.*, 23rd June 1952, Vol. 132, No. 3, pp. 285–311.) Systematic development of a theory of conduction and breakdown.

621.315.612.6 : 666.1 **3476**

Dielectric Losses in Glass.—J. M. Stevels. (*Philips tech. Rev.*, June 1952, Vol. 13, No. 12, pp. 360–370.) Losses at different temperatures due to (*a*) conduction, (*b*) after effect and (*c*) resonance are discussed. The influence of chemical composition and structure is investigated, with special attention to the borate glasses. Methods of reducing the losses in certain frequency ranges are described.

621.315.612.6 : 677.021/.024 **3477**

Fibreglass in Electrical Insulation.—A. R. Henning. (*Distrib. Elect.*, July 1952, Vol. 25, No. 193, pp. 154–158.) An account of modern methods of producing, spinning and weaving glass fibres, and of the application of glass-fibre yarn, braid, cloth, etc., for cable insulation and other purposes.

621.315.616.9 : 621.396.822 **3478**

Random Noise in Dielectrics.—H. Bauss & R. F. Boyer. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 802–803.) The fluctuating currents previously observed [2550 of 1950 (Boyer)], on applying direct voltage across thin films of certain polymers, tend to disappear on cooling the sample below the second-order transition temperature. This is interpreted as supporting the theory that the fluctuations are due to the diffusion of ions.

621.318.1 **3479**

Magnetodynamics of Cores and Sheaths with Air-Gaps.—P. M. Prache. (*Câbles & Transmission*, July 1952, Vol. 6, No. 3, pp. 265–277.) Continuation of a previous paper (2246 of August). A physical explanation is given of the action of air-gaps in increasing the frequency at which skin effects begin to cause a decrease of coil inductance and Q factor. Formulae and charts are given which enable quantitative estimation of the improvement due to the use of air-gaps; experiments confirm their validity.

621.318.2 **3480**

Permanent Magnets for Spectrographs and Nuclear Physical Research.—D. Hadfield & D. L. Mawson. (*Brit. J. appl. Phys.*, June 1952, Vol. 3, No. 6, pp. 199–202.) Descriptions are given of recently designed permanent-magnet systems for producing constant strong fields in large air gaps; modern anisotropic alloys are used. Where small variations can be tolerated, auxiliary electromagnets are used to facilitate adjustment of field strength; alternatively control may be effected by artificial aging.

621.396.611.21 : 621.3.018.41(083.74) **3481**

High-Frequency Crystal Units for Primary Frequency Standards.—A. W. Warner. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1030–1033.) Description of the characteristics of and production methods for a new type of crystal unit suitable for mass-production techniques. An AT cut is used and one face of the crystal has a spherical contour whose radius is chosen to give minimum series-resonance resistance. Both faces are polished, with gold-film electrodes of limited area. Overtone operation is used, final frequency adjustment to within 1 c/s per megacycle/sec being effected by control of the final stage of the gold-film deposition. Such crystals operate in the range 3–20 Mc/s, have very high Q values and very low temperature coefficients, and are highly stable under conditions of vibration or shock.

MATHEMATICS

517.942.93 **3482**

Separability Conditions for the Laplace and Helmholtz Equations.—P. Moon & D. E. Spencer. (*J. Franklin Inst.*, June 1952, Vol. 253, No. 6, pp. 585–600.) The necessary and sufficient conditions are deduced for separation of the variables in the Helmholtz and Laplace equations. The wave equation and the damped-wave equation can be reduced to the Helmholtz equation by separation of the time term, and Poisson's equation can be reduced to the Laplace equation by change of variable. Results are tabulated for Euclidean n-space and for Euclidean 3-space.

681.142 **3483**

Modern Computing Machines.—G. T. Hunter. (*J. Franklin Inst.*, June 1952, Vol. 253, No. 6, pp. 567–583.) A review of some American digital computers, with particular reference to the I.B.M.-Harvard calculators and their operation. Practical applications are mentioned.

681.142 : 512.37 **3484**

A New Construction Principle for Electrical Machines for Determination of the Roots of Algebraic Equations.—D. Mitrovic. (*C. R. Acad. Sci., Paris*, 23rd June 1952, Vol. 234, No. 26, pp. 2519–2521.) Voltages defined by certain relations among the coefficients of the equation are applied in the various branches of a ladder type of network comprising a set of simultaneously variable impedances μ in series and a set of equal fixed-value impedances λ in parallel. By adjusting to obtain zero current in the first mesh of the network, the roots of the equation can be directly determined from the ratio μ/λ.

MEASUREMENTS AND TEST GEAR

531.76 : 621.318.572 **3485**

A Dekatron Timer.—J. McAuslan & K. J. Brimley. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp. 408–409.) A circuit including a 1-kc/s crystal-controlled oscillator is used to measure detonator delay times from 25 ms to 12 sec. The counting is done by four Type-GC10/B dekatrons which display the result in decimal form.

621.3.018.41(083.74) : 621.396.611.21 **3486**

High-Frequency Crystal Units for Primary Frequency Standards.—Warner. (See 3481.)

621.316.726.078.3 : 538.569.4.029.64 **3487**

The Application of Molecular Resonance to Microwave Frequency Stabilization.—H. R. L. Lamont & E. M. Hickin. (*Brit. J. appl. Phys.*, June 1952, Vol. 3, No. 6, pp. 182–188.) A description is given of apparatus for stabilizing an oscillator at wavelengths near 1·25 cm; the method is based on that of Hershberger & Norton (2953 of 1948 and 2140 of 1950), making use of the absorption lines of ammonia. Factors affecting performance are discussed. An N.P.L. test gave a measured stability figure of ± 6 parts in 10^7; it should be possible to improve on this by using a larger waveguide and a lower temperature, and especially by finding substances with sharper absorption lines.

621.317.015.33 **3488**

Parameters and Operation Constants of Surge Waves with Different Time Characteristics.—R. Höfer. (*Elektrotech. Z., Edn A*, 11th July 1952, Vol. 73, No. 14, pp. 461–462.) The different forms of surge waves are discussed and the theoretical relations between their parameters are explained, numerical results being tabulated and shown graphically.

621.317.32.029.64 : 621.396.611.4 : 537.52 **3489**

Methods of Measuring the Properties of Ionized Gases at High Frequencies: Part 2 — Measurement of Electric Field.—D. J. Rose & S. C. Brown. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 719–722.) Three cavity-resonator methods are described, the field being determined in terms of the power incident on the cavity and the standing-wave pattern on the input line. Two of the methods are applicable to high-Q cavities, with simple and complex field configurations respectively, while the third is applicable to low-Q cavities. Part 1 : 3496 below.

621.317.329 : 621.392.26 **3490**

The Electric Polarizability of Apertures of Arbitrary Shape.—S. B. Cohn. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1069–1071.) Report of further electrolyte-tank measurements. See also 725 of March.

621.317.335.3 **3491**

The Effect of Reactance in a λ/4 Lecher System on Measurements of Dielectric Constant.—I. V. Zhilenkov & A. N. Efremov. (*Zh. eksp. teor. Fiz.*, July 1951, Vol. 21, No. 7, pp. 839–844.) Results are given of an experimental investigation of the effects of the inductance of the capacitor leads, the shunting action of the coupling loop, bending of the leads, etc., on measurements of capacitance and dielectric constant. The advantages of direct immersion of the open end of the system in the dielectric and of the use of a three-plate capacitor are indicated.

621.317.335.3 + 621.317.374] : 621.392.2 **3492**

The Tuned Coaxial λ/2 Lecher Line as Measurement Line for Determination of Loss Angle and Dielectric Constant at Decimetre and Centimetre Wavelengths.—E. Löb. (*Arch. elekt. Übertragung*, July 1952, Vol. 6, No. 7, pp. 288–298.) A method is described for determining dielectric properties from the resonance curve of a coaxial λ/2 line provided with short-circuiting disks. The loss angle is found in the usual way from the width of the resonance curve at half the maximum height, and the dielectric constant by comparison of the resonance frequencies for the air-filled and the dielectric-filled resonator. The losses occurring in the resonator itself are calculated for different ratios of the diameters of the inner and outer conductors, minimum losses occurring for a ratio of 3·6. Numerical results are given for the losses in a brass resonator of optimum dimensions, for wavelengths of 40 cm and 55 cm.

621.317.335.3.029.64 : 546.217 **3493**

An Airborne Microwave Refractometer.—C. M. Crain & A. P. Deam. (*Rev. sci. Instrum.*, April 1952, Vol. 23, No. 4, pp. 149–151.) An account of the adaptation of the equipment previously described [2565 of 1950 (Crain)] to measurements in aircraft. Results are to be published later.

621.317.335.3.029.64 : 551.578.4 **3494**

The Dielectric Properties of Ice and Snow at 3·2 Centimeters.—W. A. Cumming. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 768–773.) Report of an investigation to establish the relation between the reflection coefficients of snow-covered surfaces and the dielectric properties of ice and snow. Permittivity and loss-tangent measurements were made using waveguide techniques; values of reflection coefficient calculated from these measurements are compared with values found from measurements of the radiation pattern of a slotted-waveguide aerial mounted at a variable height above a snow-covered surface.

621.317.336 : 621.315.212 **3495**

Reflections in a Coaxial Cable due to Impedance Irregularities.—G. Fuchs. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 121–136.) Full paper. See 2554 of September.

621.317.337.029.64 : 621.396.611.4 : 537.52 **3496**

Methods of Measuring the Properties of Ionized Gases at High Frequencies: Part 1 — Measurement of *Q*.—S. C. Brown & D. J. Rose. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 711–718.) Measurements of the field associated with a gas discharge at microwave frequency commonly involve prior determination of the power absorbed in a resonant cavity. Methods are described for determining the impedance, *Q* and resonance wavelength of such cavity systems from measurements of the voltage distribution on the line terminated by the cavity; the series losses in the coupling between cavity and transmission line are taken into account.

621.317.35 : 621.396.61 **3497**

A Method to Estimate Attenuation of Spurious Emission of Very-High-Frequency Transmitter.—H. Uchida. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, Sept. 1951, Vol. 3, No. 1, pp. 87–94.)

621.317.35 : 621.396.615.17 **3498**

Synthetic Waveforms speed Wave Analysis.—A. A. Mahren. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 132–135.) Description with circuit details, of a generator for producing particular waveforms by addition of harmonics to a fundamental whose frequency can be varied from 25 c/s to 3 kc/s. Both the amplitudes and phases of the individual harmonics up to the fifth are variable over very wide ranges. Typical synthetic waveforms are reproduced.

621.317.443 **3499**

Some Developments and Simplifications in Permeameters.—A. M. Armour, A. J. King & J. W. Walley. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 74–82.) Problems of strains in specimens and nonuniformity of field are solved for a precision-type instrument. One of the simplified instruments described uses a rotatable permanent magnet to vary the magnetization of the specimen. The associated magnetometer, covering a range 1–3 000 oersted, has a low-permeability moving magnet of silmanal, 3 mm^3 in volume.

621.317.723 **3500**

The Vibrating-Condenser-Type Electrometer.—S. Hamada, E. Takagi & A. Sato. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, March 1952, Vol. 3, No. 2, pp. 233–249.) Description of the instrument used in the Research Institute of Tohoku University. Minimum difference of potential measurable is about 0·1 mV.

621.317.725 **3501**

A Differential Voltmeter using a Temperature-Limited Diode.—V. H. Attree. (*J. sci. Instrum.*, July 1952, Vol. 29, No. 7, pp. 226–229.) A type-29C1 diode forms one arm of a resistance bridge. A centre-zero instrument in the anode circuit gives an accurate indication of the supply voltage. A typical instrument has a range 215–245 V and consumes 10 W.

621.317.725 **3502**

Mean-Square Vacuum-Tube Voltmeter.—L. A. Rosenthal & G. M. Badoyannis. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 128–131.) Description, with full circuit details, of an instrument which uses a nonlinear thyrite element in a rectifier bridge circuit for squaring the input signal. A suitable resistive shunt across the thyrite element results in a square-law characteristic accurate to within ± 2·5% for a current range of 50 : 1. The upper frequency limit of the meter is 500 kc/s. A thermostat may be used to reduce the temperature error of the thyrite element.

621.317.725 **3503**

Valve Voltmeter TVL25.—A. V. J. Martin. (*Télévision*, July/Aug. 1952, No. 25, pp. 161–168.) Constructional details of an inexpensive linear-scale instrument with a range 3 V–1 kV. Probe fittings extend the range to 30 kV and adapt the instrument for measurement of alternating voltages with an upper frequency limit of 250 Mc/s.

621.317.733 **3504**

The Elimination of Errors due to Stray Capacitances in certain Schering-Bridge Measurements.—H. C. Hall. (*J. sci. Instrum.*, July 1952, Vol. 29, No. 7, pp. 224–225.) The simple circuit is modified to include three variable capacitors and a switch connecting the junction of the resistive arms either to earth E or to the high-voltage terminal A. The value of stray capacitance included in the equation for balance with the switch at E is unaltered when measurement is made with the switch at A. A Wagner earth is not required.

621.317.733 : 621.311.6 **3505**

Precision Voltage Source.—V. H. Attree. (*Wireless Engr*, Sept. 1952, Vol. 29, No. 348, pp. 226–230.) A tungsten-lamp nonlinear bridge, run from a mains transformer, provides an a.c. source for the rapid and accurate checking of amplifier gain. The bridge is switched to d.c. for calibrating.

621.317.733.011.22 **3506**

A Note on the Sensitivity of Electrical Bridge Networks.—M. Romanowski & A. F. Dunn. (*Canad. J. Phys.*, July 1952, Vol. 30, No. 4, pp. 342–347.) An analytical solution is presented of the problem of determining accurately the value of a resistance when the bridge used for its measurement is very nearly but not quite balanced. Application is made to the use of the Kelvin double bridge for the comparison of precision standard resistors.

621.317.733.011.5 **3507**

A High-Voltage Schering Bridge for Dielectrics Research.—B. Salvage & T. R. Foord. (*Distrib. Elect.*, July 1952, Vol. 25, No. 193, pp. 160–162.) Description of a doubly screened bridge with automatic compensation of stray capacitance by use of a cathode-follower circuit to maintain the inner screen at the potential of one of the detector terminals, thus avoiding the need for balance by successive approximations, as with the Wagner circuit. An amplifier and moving-coil rectifier instrument are used as detector. A new h.v. standard capacitor for the bridge, with units of 200, 350 and 700 pF, is described.

621.317.733.029.62 **3508**

A Bridged-T Impedance Bridge for the V.H.F. Waveband.—R. F. Proctor. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 47–50.) Full paper. See 2557 of September.

621.317.755.029.51/.62 **3509**

High-Frequency Curve Tracer for 100 kc/s–230 Mc/s.—A. Klemt. (*Funk u. Ton*, July 1952, Vol. 6, No. 7, pp. 357–362.) Description of signal generator and c.r.o. equipment for display of the response curves of amplifiers, oscillatory circuits, filters, etc. Ranges of 100 kc/s–110 Mc/s and 170–230 Mc/s, with frequency marker pips derived from a quartz-crystal oscillator, are provided. A frequency wobble of 0–20 Mc/s can be applied.

621.317.77 **3510**

A Simple Variable-Frequency Phase-Measuring Device.—J. C. West & J. Potts. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp. 402–403.) The phase shift produced by the network under test is compared oscillographically with that produced by a calibrated 4-valve phase-shifting network with a frequency-independent response over the range 100 c/s–25 kc/s. The error in the phase-angle measurement is $< \frac{3}{4}°$.

621.317.794 **3511**

Accuracy of Bolometric Power Measurements.—H. J. Carlin & M. Sucher. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1042–1048.) When a bolometer is calibrated at l.f., errors of measurements at r.f. are minimized by using a convectively cooled wire with a large length/diameter ratio. Analysis shows that the error for a Wollaston wire in air is less than that for a corresponding wire mounted in vacuo, and that the advantage of the air-mounted wire increases as the wire length becomes an appreciable fraction of the wavelength. Wollaston-wire bolometers, if properly designed and mounted, can be used to measure c.w. power over a range of wavelengths down to millimetre waves with an accuracy approaching that of l.f. measurements.

621.396.615.029.426/.51 **3512**

A Note on 'A Precision Decade Oscillator'.—J. A. B. Davidson. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1124–1125.) Comment on 2237 of 1951 (Edwards), pointing out that Muirhead & Co. have been producing precision decade oscillators since 1940 with a frequency accuracy within 0·1–0·2% over the range 1 c/s–100 kc/s, four decade dials giving 1-c/s steps up to 10 kc/s and 10-c/s steps up to 100 kc/s. Special features of these oscillators are mentioned. Other types with ranges of 100 c/s–40 kc/s and 0·1 c/s–20 kc/s respectively are also noted.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.321.9 : 620.179.16 **3513**

Thickness Gauge.—(*Overseas Engr*, July 1952, Vol. 25, No. 295, p. 440.) Oscillations from a variable-frequency ultrasonic generator are transmitted into the plate or other structure whose thickness is to be measured, a film of oil or grease being used to give good coupling. When the wave reflected from the back face is in phase with the transmitted wave, a maximum signal is picked up by a probe. The thickness is at once obtained as the quotient of the speed of sound in the material by twice the fundamental frequency, which is read directly. Accuracy is within about 1%. The complete equipment weighs only 23 lb.

534.321.9 : 620.179.16 : 625.8 **3514**

An Apparatus for Determining the Velocity of an Ultrasonic Pulse in Engineering Materials.—E. N. Gatfield. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp. 390–395.) A detailed description of equipment for investigating road materials, particularly concrete. The time of propagation between quartz transducers separated by the thickness of the material is measured and indicated on a c.r.o. The frequency used is 200 kc/s and the pulse repetition rate 50 per sec.

535.336.2.071 : 621.316.728 **3515**

Power Supply for a Thermionic Ion Source.—C. Reuterswärd. (*J. sci. Instrum.*, June 1952, Vol. 29, No. 6, pp. 184–185.) Stabilized power is supplied to emissive filaments investigated in mass spectroscopy by means of regulated oscillation generators; the laboratory unit described delivers 15 W.

537.228.1 : 531.768.087 **3516**

The Reciprocity Calibration of Piezoelectric Accelerometers.—M. Harrison, A. O. Sykes & P. G. Marcotte. (*J. acoust. Soc. Amer.*, July 1952, Vol. 24, No. 4, pp. 384–389.) Theoretical and experimental evaluation of an absolute technique for the frequency range 100 c/s–10 kc/s.

621.384.6 : 621.319.3.027.89 **3517**

Tested Construction of Electrostatic Generator for Nuclear Research, giving Very High Voltage and using a Dust Stream.—M. Morand, A. Raskin & L. Winand. (*C. R. Acad. Sci., Paris*, 16th June 1952, Vol. 234, No. 25, pp. 2450–2452.) Discussion of problems in the development of a generator giving a current of the order of 1 mA at over 1 MV. Very finely powdered glass is used for the dust stream. A generator of this type has been in regular use for over five years without giving trouble. For the first description and theory of such generators see 3451 of 1937 (Pauthenier & Moreau-Hanot), 3725 and 4117 of 1939 (Pauthenier).

621.384.622.2 **3518**

Axial Motion of an Electron in a Constant-Wave-Velocity Section of a Linear Accelerator.—D. Caplan & E. Akeley. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 774–778.)

621.385.833 **3519**

The Derivation of Paraxial Constants of Electron Lenses from an Integral Equation.—H. Bremmer. (*Appl. sci. Res.*, 1952, Vol. B2, No. 6, pp. 416–428.)

621.385.833 **3520**

The Current in the Electron Immersion Objective.—L. Jacob. (*Proc. phys. Soc.*, 1st June 1952, Vol. 65, No. 390B, pp. 421–425.) Analysis showing that the emission current under conditions of constant cut-off voltage is uniquely defined by the cross-over potential.

621.385.833 **3521**

The Reliability of Internal Standards for Calibrating Electron Microscopes.—J. H. L. Watson & W. L. Grube. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 793–798.)

621.385.833 **3522**

Specimen Charging in the Electron Microscope and some Observations on the Size of Polystyrene Latex Particles.—S. G. Ellis. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 728–732.)

621.385.833 **3523**

A Method for the Electron and Optical Microscopic Examination of Identical Areas.—E. D. Hyam & J. Nutting. (*Brit. J. appl. Phys.*, June 1952, Vol. 3, No. 6, pp. 173–176.)

621.387.4.087.6 **3524**

A Printing Recorder for use in Conjunction with Scaling Units.—A. R. Lang. (*J. sci. Instrum.*, June 1952, Vol. 29, No. 6, pp. 176–178.) Description of a machine designed for use with an automatic X-ray counter spectrometer. The counts, together with an angle given in degrees and minutes, are recorded on a paper roll 6-in. wide.

621.387.42 **3525**

The Parallel-Plate Counter as a Self-Quenching Particle-Counting Apparatus.—E. Bagge & J. Christiansen. (*Naturwissenschaften*, July 1952, Vol. 39, No. 13, p. 298.)

621.387.462 : 549.211 **3526**

Electrical Counting Properties of Diamonds.—F. C. Champion. (*Proc. phys. Soc.*, 1st July 1952, Vol. 65, No. 391B, pp. 465–472.) About 25 out of 200 gem-quality diamonds responded to both α- and β-particles. Pulse heights given by 5-MeV α-particles were only about three times those for 1-MeV β-particles. Results are discussed.

621.387.462 : 549.211 **3527**

Electrical Counting Response of Two Large Diamonds under Beta-Irradiation.—K. Stratton & F. C. Champion. (*Proc. phys. Soc.*, 1st July 1952, Vol. 65, No. 391B, pp. 473–480.) Report and discussion of tests on removal of space charge, variation of counting rate with time, variation of pulse height with applied field, and comparison with a Geiger counter.

621.387.464 **3528**

Characteristics of Scintillation Counters.—G. F. J. Garlick & G. T. Wright. (*Proc. phys. Soc.*, 1st June 1952, Vol. 65, No. 390B, pp. 415–421.) Experimental study to determine the factors responsible for the pulse-amplitude distribution in α-particle counters.

771.36 : 537.228.4 : 531.557 **3529**

Electro-optical Shutters for Ballistic Photography.—B. J. Ley & P. Greenstein. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 123–125.) Equipment for operating Kerr-type shutters gives either a single 1-μs pulse or ten identical pulses spaced 25, 50 or 100 μs apart, with amplitudes up to 50 kV.

PROPAGATION OF WAVES

621.396.11 **3530**

Sweep-Frequency Oblique-Incidence Ionosphere Measurements over a 1 150-km Path.—P. G. Sulzer & E. E. Ferguson. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, p.1124.) Preliminary account of results obtained in simultaneous transmission and reception experiments at both Sterling, Virginia, and St. Louis, Missouri, as well as in vertical-incidence virtual-height/frequency recordings at the midpoint of the path. Values of m.u.f. determined from the oblique-incidence records are in good agreement with those calculated from midpoint data by the transmission-curve method [3042 of 1939 (Smith)].

621.396.11 **3531**

On the Propagation of Electric Waves behind a Mountain.—Y. Nomura. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, March 1952, Vol. 3, No. 2, pp. 115–124.) Formulae for the field strength are derived on the assumption that the mountain can be regarded as a vertical screen (*a*) with upper edge horizontal and inclined at 90° or any other angle to the vertical plane through transmitter and receiver, (*b*) with upper edge not horizontal.

621.396.11 + 535.222] : 535.417 **3532**

Determination of the Velocity of Short Electromagnetic Waves by Interferometry.—K. D. Froome. (*Proc. roy. Soc. A*, 5th June 1952, Vol. 213, No. 1112, pp. 123–141.) A full account of the equipment used and the method of measurement, an outline of which has previously been given (2313 of August).

621.396.11.029.51 **3538**

The Ionospheric Propagation of Radio Waves with Frequencies near 100 kc/s over Short Distances.—K. Weekes & R. D. Stuart. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 29–37.) Full paper. See 2577 of September.

621.396.11.029.51 **3534**

The Ionospheric Propagation of Radio Waves with Frequencies near 100 kc/s over Distances up to 1000 km.—K. Weekes & R. D. Stuart. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 38–46.) Full paper. See 2578 of September.

621.396.11.029.55 **3535**

Investigations of High-Frequency Echoes: Part 3.—H. A. Hess. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1065–1068.) See 3139 of 1950. Part 2: 3523 of 1949.

621.396.81 **3536**

Ionospheric-Propagation Predictions for Any Two Points on the Earth's Surface by the 'Spanish Method'.—R. Gea Sacasa. (*Rev. Telecomunicación, Madrid*, June 1952, Vol. 8, No. 28, pp. 11–26.) Graphs are given for the month of June and N-S direction of propagation showing the optimum working frequency for any latitude at any time of day for four distances, viz., 400, 1 000, 1 300 and 2 000 km. From these the optimum working frequencies for the E-W direction of propagation and/or for distances > 2 000 km can be simply determined. Similar curves can be constructed for other months.

621.396.812.029.62 **3537**

Cross Polarization of Scattered Radio Waves.—A. H. LaGrone. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1120–1123.) Extension of analysis previously given (1412 of May) to include study of the polarization of the scattered waves. Formulae are derived for the response of dipole aerials oriented horizontally, vertically, or axially relative to a linearly polarized source. Numerical calculations for selected values of the scattering parameters are compared with measurements on 102·9-Mc/s signals, initially horizontally polarized, arriving over a 147-mile path.

621.396.812.5 **3538**

Analysis of Observed Variations of Absorption of Electromagnetic Waves in the Ionosphere.—G. Lange-Hesse. (*Naturwissenschaften*, July 1952, Vol. 39, No. 13, pp. 297–298.) Published absorption figures have been analysed by Bartels' method (883 of 1951). In equatorial latitudes (Singapore) monthly mean values of absorption correlate closely with the relative sunspot number. For temperate latitudes (Slough) such correlation exists only for the summer months. Prediction of monthly mean absorption is possible in principle. The mean variation during the sun's 27-day cycle is far greater than that of the monthly means from month to month. Frequent marked increases of absorption of 2 to 20 hours duration occurring in polar latitudes show correlation with geomagnetic disturbances and are limited to the auroral zone.

RECEPTION

621.396.62 + 621.397.62] : 061.4 **3539**

19th National Radio Exhibition [London, 1952]: **State of Development in Television and Sound Receivers.** —(*Wireless Engr*, Oct. 1952, Vol. 29, No. 349, pp. 275–279.)

621.396.621.54 **3540**

Approximate Formulae for Alignment of Superheterodyne Receivers.—H. W. Paehr. (*Frequenz*, May/June 1952, Vol. 6, Nos. 5/6, pp. 133–138.) Formulae are derived for three-point alignment of circuits with ganged capacitors of the same plate area; their use is illustrated by a worked-out example.

621.396.813 : 621.396.97 **3541**

Quality of Broadcasting Transmissions.—H. Kösters. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, July/Aug. 1952, Vol. 4, Nos. 7/8, pp. 127–130.) General discussion of problems associated with faithful transmission and reproduction, in particular of original sound patterns such as are provided by orchestral music.

621.396.822 **3542**

On the Evaluation of Noise Samples.—A. J. F. Siegert. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 737–742.) Criteria are developed for use in deciding whether a given noise sample can reasonably be assumed to have come from a Gaussian noise with predetermined parameters.

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 **3543**

Channel Capacity and Transmission Time.—K. Küpfmüller. (*Arch. elekt. Übertragung*, July 1952, Vol. 6, No. 7, pp. 265–268.) The capacity of a transmission channel depends in general on the channel transmission time. Only in the case of transmission times greater than a certain value can the limiting value of channel capacity given by Shannon's formula be approximately reached. This minimum transmission time is about equal to twenty times the reciprocal of the bandwidth. A formula is derived for the channel capacity corresponding to a given finite transmission time.

621.39.001.11 **3544**

Information Theory.—"Cathode Ray". (*Wireless World*, Sept. 1952, Vol. 58, No. 9, pp. 365–370.) An outline of the subject in simple terms, indicating its significance and application.

621.39.001.11 : 621.397.5 **3545**

Quantized Signals in Communications Technique.—F. Schröter. (*Bull. schweiz. elektrotech. Ver.*, 14th June 1952, Vol. 43, No. 12, pp. 497–508. In German.) Practical means for using the equivalence of bandwidth and the logarithm of the signal/noise ratio in the Hartley-Shannon theory are discussed, and the principles of quantization for the reduction of bandwidth are illustrated. A 'double-amplitude' system giving a further reduction of bandwidth is proposed. This is a form of binary coding of the quantized signal so that the final pulse amplitude represents $kx+y$, where k is a constant defined by the number of quantum stages, and x, y are the partial amplitudes of the quantized signal. Examples of quantization processes discussed include the coding of text and of colour television. See also *Telefunken Ztg*, June 1952, Vol. 25, No. 95, pp. 115–127.

621.394.14 **3546**

A Method for the Construction of Minimum-Redundancy Codes.—D. A. Huffman. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1098–1101.)

621.394.14 : 621.392.5 **3547**

Coding with Linear Systems.—J. P. Costas. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1101–1103.)

621.394.441 : 621.396.619.13 **3548**

Two New Voice-Frequency Telegraphy Systems.—H. Gardère. (*Câbles & Transmission*, July 1952, Vol. 6, No. 3, pp. 243–264.) A system using ph.m. has been described previously (1100 of April). A similar account is here given of a f.m. system. A subsequent paper will give results of a comparison of the two systems.

621.395.44 : 622 **3549**

'Montavox', Equipment for High-Frequency Telephony in Mining.—H. Ukrow. (*Telefunken Ztg*, June 1952, Vol. 25, No. 95, pp. 98–104.) Description of a transmitter-receiver housed, together with its efficient Ag-Zn alkaline accumulator, in a cylindrical watertight container which can be carried in one hand. Communication is effected by coupling with a flexible loop to any continuous metal system such as compressed-air pipes, tramway lines or lighting cables. Operating frequency is about 200 kc/s, power 0·1–0.2 W. The locally generated oscillation of the 5-valve heterodyne receiver serves, after frequency transformation, to control the power stage of the transmitter. A signal lamp, whose switch is operated by a magnetic device in the receiver, indicates when the carrier of the 'called' station is being received. Ranges up to 1 000 m are practicable.

621.396 : 061.3 **3550**

The Extraordinary Administrative Radio Conference, Geneva, 1951.—C.F.B. (*P.O. elect. Engrs' J.*, July 1952, Vol. 45, Part 2, pp. 85–86.) A brief outline of the main provisions of the agreement reached at the conference, 15th August–3rd December 1951. See also 2599 of September (Pressler).

621.396.4 : 621.396.619.13 **3551**

Theoretical Performance of Simple Multichannel Systems using Frequency Modulation.—E. G. Hamer. (*J. Brit. Instn Radio Engrs*, July 1952, Vol. 12, No. 7, pp. 411–415.) Frequency-sharing and time-sharing systems using small numbers of channels are considered, formulae commonly used for systems with large numbers of channels being adapted. The same basic assumptions are made regarding signal bandwidth and noise as those made by Feldman & Bennett (454 of 1950). Advantages obtainable with the frequency-sharing system due to nonsimultaneous loading, and with the time-sharing system by use of companding, are discussed and illustrated by practical examples.

621.396.41 **3552**

Fundamental Aspects of Linear Multiplexing.—L. A. Zadeh & K. S. Miller. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1091–1097.) In a linear multiplex system the channel separation is achieved by the use of linear time-variant or time-invariant filters. The sets of signals associated with the different channels are linear and disjoint, and the signals belonging to such sets can be transmitted simultaneously and separated at the receiving end by means of linear, generally time-variant, filters. Frequency-band compression cannot be effected with linear systems. Analysis of the filtering process is based on resolution of signals into a set of complex exponential component signals. Methods of synthesis of linear multiplex systems are indicated for types other than those using frequency or time division. See also 3028 of November (Zadeh).

621.396.5 : 621.396.932 **3553**

Portable Radiotelephony Equipment for Communication between Ship and Port.—W. A. Krause. (*Frequenz*, May/June 1952, Vol. 6, Nos. 5/6, pp. 146–149.) Port facilities such as those for Liverpool, where a single radar station suffices, are quite unsuitable for the long approach up the Elbe to Hamburg, where there are five radar stations with overlapping ranges and a similarly distributed set of h.f. telephony stations. Illustrations are given of portable send-receive equipment as used at Liverpool and Sunderland, and of several German types, one of which weighs only 3·1 kg. All operate in the range 156–174 Mc/s.

621.396.619.13 : 517.564.3 **3554**

Spectrum of a Frequency-Modulated Wave.—W. C. Vaughan. (*Wireless Engr*, Sept. 1952, Vol. 29, No. 348, p. 254.) Corrections to paper noted in 2892 of October.

621.396.619.16 : 621.396.4 **3555**

Nonsynchronous Time Division with Holding and with Random Sampling.—J. R. Pierce & A. L. Hopper. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1079–1088.) A detailed description of the system of which a shorter account has been given by Hopper (3231 of November).

621.396.619.16 : 621.396.41 : 621.396.822.1 **3556**

Crosstalk in Time-Division-Multiplex Communication Systems using Pulse-Position and Pulse-Length Modulation.—J. E. Flood. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 64–73.) Full paper. See 2606 of September.

621.396.712 : 623.98 **3557**

Project 'Vagabond'.—J. W. Seymour. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 120–122.) Description of some of the equipment installed in the U.S. Coastguard cutter *Courier* for relaying Voice-of-America programmes. One 150-kW transmitter operates anywhere in the range 540–1 600 kc/s and there are also two 35-kW s.w. transmitters.

621.396.932/.933].1 + 621.396.97 **3558**

Common-Wave Broadcasting and Hyperbolic Navigation: Part 2.—Pohontsch. (See 3437.)

621.396.97 : 621.396.8 **3559**

Quality in Broadcasting, and Compressor-Expandor Systems.—A. Warnier. (*Onde élect.*, July 1952, Vol. 32, No. 304, pp. 261–274.) A survey of the performance achieved in broadcasting as regards musical quality indicates that in the reception, e.g., of orchestral music, the results obtained are definitely inferior, even with a high-fidelity receiver, to those obtained from modern gramophones. Improvement is practicable by the use of compressor-expandor systems, the characteristics of which are discussed. Equipment is described which has given results comparable with studio quality.

621.396.97.029.62 + 621.397.61.029.62] : 061.3 **3560**

The European Broadcasting Conference [C.E.R.], **Stockholm, 1952.**—W. Stepp. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, July/Aug. 1952, Vol. 4, Nos. 7/8, pp. 144–145.) An outline of the proceedings, with analysis of the standards adopted for u.s.w. broadcasting and television. For a fuller account, in Danish, see *Teleteknik, Copenhagen*, Aug. 1952, Vol. 3, No. 3, pp. 149–155.

SUBSIDIARY APPARATUS

621-52 : 621.316.728 **3561**

A Device for the Automatic Control of Electrical Power up to 2 kW.—W. T. Bane & J. S. Appleby. (*J. sci. Instrum.*, June 1952, Vol. 29, No. 6, pp. 174–176.) Description of a closed-loop control system in which a voltage proportional to the consumed power is continuously compared with a voltage representing the desired power consumption. Control to within ±¼% has been achieved.

621.311.62 **3562**

Variable-H.T. Power Pack.—A. H. B. Walker. (*Wireless World*, Sept. 1952, Vol. 58, No. 9, pp. 374–376.) Details are given of an easily constructed unit providing continuously variable output up to about 400 V. The rectifier circuit comprises two triodes with a centre-tap cathode-follower connection. The control voltage applied to the grids is derived from one half of the centre-tapped mains-transformer secondary via a miniature metal rectifier.

621.311.62 : 621.316.722.1 **3563**

New Constant-Voltage Source of High Control Accuracy.—E. Helmes. (*Elektrotech. Z.*, *Edn A*, 11th July 1952, Vol. 73, No. 14, p. 458.) Description of equipment for supplying heater currents at voltages from 2·5 to 6 V, constant to within ±0·1%. Variation of output voltage produces a deflection in a mirror galvanometer controlling the illumination of a photocell, which, in turn, governs a valve anode current feeding the primary of the output transformer.

621.313.323.029.3 **3564**

The Theory of the Operation of a Phonic Motor.—D. E. Caro. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 51–63.) "A mathematical analysis of the operation of a phonic motor is presented. Expressions are developed for the motor currents and voltages, power output, efficiency, etc. Both polarized and unpolarized motors are treated, and operation from high- and low-impedance sources is considered. A method for obtaining the motor constants experimentally is given and the predicted power output is compared with experimental results. Power ripple and motor hunting are both analysed. The possibility of multiphase motors is discussed and some applications of phonic motors are described."

621.314.63 **3565**
Special Rectifier Circuits.—D. B. Corbyn. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp. 418–419.) Some new h.v. circuits with improved regulation are described, and 'centre-tapped' circuits are discussed briefly.

621.314.63 **3566**
The High-Frequency Properties of the Boundary-Layer Rectifier.—W. Schottky. (*Z. Phys.*, 23rd June 1952, Vol. 132, No. 3, pp. 261–284.) In dry rectifiers with specific impurity-centre semiconductivity, delay in achieving an equilibrium condition can only affect the impedance characteristic if the impurity centres remain largely undissociated. This is the condition for a reserve boundary layer to be formed. The total boundary layer capacitance for small a.c. loads decreases with increasing frequency to a value many times smaller and finally corresponding to the thickness of the reserve layer. The 'kinetic' frequency ω_{kin} characterizing the transition from conductive to capacitive action is given by the product of the recombination coefficient α and the electron density. Since the dielectric relaxation frequency ω_{rel} can be represented as the product of the electron density and a constant factor dependent on mobility μ and permittivity ϵ, the ratio $\omega_{kin} : \omega_{rel}$ is determined completely in terms of α, μ and ϵ, and is apparently in every case $\ll 1$. The capacitive shunt appearing across the reserve layer as frequency increases, is due to lack of the necessary rapid transfer of charge by the impurity centres. Values of α of about 5×10^{-10} cm³ sec⁻¹ obtained from impedance measurements on Cu_2O rectifiers support the theory. This is extended by considering a two-stage recombination process. The effect of reaction inertia on the rectification process is discussed. The effective increase of boundary-layer thickness at high frequencies can greatly improve the performance of a rectifier with a poor static characteristic.

621.314.63 : 546.824-3 **3567**
Titanium-Dioxide Rectifiers.—(*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 164, 166.) Short note on rectifiers, developed at the National Bureau of Standards, consisting of a layer of semiconducting TiO_2 on a sheet of Ti, with a counter electrode of some other conducting material such as Ag. The most satisfactory oxide films are formed by heating Ti plates in steam at 600°C for about three hours. The counter electrodes are then applied by electroplating. The easy-flow direction is opposite to that for Cu_2O rectifiers. The TiO_2 rectifiers withstand reverse voltages of about 20 V per plate.

621.314.634.015.5 **3568**
Breakdown in Selenium Rectifiers.—R. Cooper. (*Proc. phys. Soc.*, 1st June 1952, Vol. 65, No. 390B, pp. 409–414.) Experiments show that breakdown may occur at higher reverse voltages as the ambient temperature is raised, and as the thermal-dissipation constant is lowered. At voltages near to and beyond the knee of the current/voltage characteristic the temperature coefficient of the rectifier is negative, i.e., rise in temperature causes the leakage current to decrease. Results do not support the thermal-instability theory of breakdown.

621.314.653 : 621.311.62 : 621.396.712 **3569**
Use of Thyratron Rectifiers in Broadcasting Transmitters.—C. Wait. (*Rev. tech. Comp. franç. Thomson-Houston*, July 1952, No. 17, pp. 33–40.) The characteristics and mode of operation of thyratron rectifiers are described, with illustrations of the waveforms of the cathode and anode voltages for various 3-phase arrangements. An outline scheme is shown for a complete rectifier unit for the medium and high voltages required for a broadcasting transmitter.

621.316.722 : 621.396.645.029.3 **3570**
Supply Problems at Low Frequency.—L. Chrétien. (*TSF et TV*, July/Aug. 1952, Vol. 28, Nos. 285/286, pp. 223–227.) Discussion of methods of stabilizing the anode voltage of an a.f. amplifier, with details of a practical circuit.

621.355.5 **3571**
Reversible Cell with Electrolyte a Thin Crystal Layer deposited by Evaporation.—A. Sator. (*C. R. Acad. Sci., Paris*, 4th June 1952, Vol. 234, No. 23, pp. 2283–2285.) Layers of Ag, $PbCl_2$ and Ag are deposited successively on a glass support. Repeated charging (at 0·5 μA) and discharging results in the reversible cell $+Ag/AgCl/PbCl_2/Pb/Ag$ with a terminal voltage of 0·44 V, which only drops to 0·41 V after 90 min discharge at about 1 μA.

TELEVISION AND PHOTOTELEGRAPHY

621.397.24/.26 **3572**
Paris-London Television.—T. H. Bridgewater. (*Electronic Engng*, Sept. 1952, Vol. 24, No. 295, pp. 410–412.) Discussion of problems encountered by the B.B.C. in connection with the cross-channel relay of July 1952. See also 2902 of October.

621.397.3 **3573**
Build-Up Curve and Bandwidth Utilization in Television.—E. Schwartz. (*Frequenz*, May/June 1952, Vol. 6, Nos. 5/6, pp. 138–141.) The relations between the steepness of the build-up curve, overshoot, Kell factor [3942 of 1940 (Kell et al.) and 2639 of 1950], and width of scanning aperture are discussed. Curves given show that the build-up curve is steepest for unity Kell factor, and that overshoot is greatest for a factor of 0·5 and practically vanishes for a factor of 2·0. Optimum bandwidth represents a compromise between the effects of the various factors involved. The method described by Goldmark & Hollywood (828 of March) for increasing the steepness of the build-up curve by a factor of 2 is noted.

621.397.5 : 621.39.001.11 **3574**
Quantized Signals in Communications Technique.—Schröter. (See 3545.)

621.397.5(485) **3575**
Television in Sweden.—F. Bernard. (*Télévis. franç.*, July/Aug. 1952, Nos. 84/85, p. 36.) Note of transmission equipment operating experimentally in Stockholm. A public service is to start in 1953.

621.397.61 **3576**
C.S.F. Television Transmitters.—J. Polonsky, L. Amster & G. Melchior. (*Ann. Radioélect.*, April 1952, Vol. 7, No. 28, pp. 151–165.) The units described are designed for service in France or abroad. Their frequency ranges are 41–85 Mc/s and 174–216 Mc/s. Powers of 5 and 20 kW are obtained by adding extra units to the 3-bay 500-W transmitter. The h.f. amplifier chain and synchronization system are described. The aerial coupling circuits include a band-suppression filter, a dummy aerial in the form of a lossy coaxial line, and diplexing equipment for feeding both vision and sound signals to one aerial. The functions of a maintenance

bay are illustrated by diagrams of the signal-generator output waveforms suitable for checking and monitoring the transmitter performance.

621.397.62 + 621.396.62] : 061.4 **3577**

19th National Radio Exhibition [London, 1952]: **State of Development in Television and Sound Receivers.**— (*Wireless Engr*, Oct. 1952, Vol. 29, No. 349, pp. 275–279.)

621.397.62 : 535.514 **3578**

Surfaces with Multiple Planes of Polarization. Application to Television.—P. Toulon. (*C. R. Acad. Sci., Paris*, 30th June 1952, Vol. 234, No. 27, pp. 2591–2592.) A study has been made of synthetically produced rectangular plates of optically polarizing material in which the plane of polarization varies as a periodic function of distance parallel to one edge of the plate. The distance between successive lines corresponding to the same plane of polarization is a characteristic parameter, termed the pitch. Various optical effects can be obtained by combinations of such plates. They have been applied successfully in the manufacture of variable-colour screens for colour television reception.

621.397.62 : 621.396.677.1 **3579**

The Detection of Television Receivers.—W. J. Bray. (*P.O. elect. Engrs' J.*, July 1952, Vol. 45, Part 2, pp. 49–51.) Description of equipment fitted in a van and suitable for detecting and locating television receivers that are being operated. Three horizontal loop aerials mounted on the roof of the van pick up energy radiated from the line-scanning coils of a receiver, and switching arrangements for intercomparison of the signal strengths from the three loops enable the receiver to be located, the discrimination being sufficient to distinguish between receivers in adjacent houses on the same side of a road.

621.397.621.2 **3580**

Line-Scan Circuit with Economy Transformer.—R. Andrieu. (*Telefunken Ztg*, June 1952, Vol. 25, No. 95, pp. 107–114.) Simplifying assumptions enable the relations between the most important parameters of this circuit to be determined and design data to be derived.

621.397.621.2 **3581**

Low-Power Deflection for Wide-Angle C.R. Tubes.—C. V. Bocciarelli. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 109–111.) The use of a narrow-neck tube with a specially shaped deflection yoke enables tubes to be produced with deflection angles up to 90° and with a considerable increase of the ratio of face diameter to tube length.

621.397.645.37 **3582**

New Amplifier Techniques.—V. J. Cooper. (*J. Brit. Instn Radio Engrs*, July 1952, Vol. 12, No. 7, pp. 371–391.) Three types of television amplifier are discussed, viz., the cathode repeater (2168 of 1950), the shunt-regulated amplifier (2562 of 1951) and the feedback amplifier with desired frequency response characteristics (642 of March). Practical circuits and experimental results are given in each case.

621.397.8 **3583**

Various Factors affecting the Quality of Television Pictures.—R. Monnot. (*Radio franç.*, June 1952, No. 6, pp. 1–15.) Discussion of factors affecting picture detail, contrast, distortion, stability, etc., including scanning methods, number of lines, camera optics, transmission bandwidth, transient response of video amplifier, c.r. tube deflection system, projection methods, ambient light, and the characteristics of the different elements of the television chain. The interconnection between technical and economic aspects of television is indicated.

621.397.812 **3584**

The Effect of Atmospheric Variations on Picture Quality.—P. Lemeunier. (*Télévis. franç.*, July/Aug. 1952, Nos. 84/85, p. 31.) A diagram based on 3 years' observations correlates in general terms the quality of television reception with local weather conditions.

621.397.828 **3585**

Noise Limiters for Television Sound.—R. T. Lovelock. (*Wireless World*, Sept. 1952, Vol. 58, No. 9, pp. 339–342.) In the series peak limiter for suppression of pulsed r.f. interference, shunt capacitance must be low to obtain good frequency discrimination. For the shunt limiter, a very low forward impedance is essential. A combination of these circuits is described which uses Ge diodes Type GEX34 and GEX03 in the series and shunt circuits respectively; the harmonic distortion introduced is negligible.

TRANSMISSION

621.396.61 : 621.317.35 **3586**

A Method to Estimate Attenuation of Spurious Emission of Very-High Frequency Transmitter.—H. Uchida. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser.B*, Sept. 1951, Vol. 3, No. 1, pp. 87–94.)

621.396.61 : 621.396.712 **3587**

The Latest C.F.T.H. Developments in Broadcasting Transmitters.—M. Guérineau. (*Rev. tech. Comp. franç. Thomson-Houston*, July 1952, No. 17, pp. 9–26.) Illustrated descriptions, with diagrams showing circuit arrangements, of 100/150-kW and 5/10-kW medium-wave transmitters and a 50-kW s.w. transmitter.

621.396.61.029.53 **3588**

A New 150-kW Medium-Wave Broadcasting Transmitter.—H. Campet & S. Odartchenko. (*Ann. Radioélect.*, April 1952, Vol. 7, No. 28, pp. 139–150.) The first transmitter of a new type constructed by the Société Française Radioélectrique was put into service in Luxembourg in 1951. The circuit and lay-out of equipment are shown. Features described include the overall-feedback system, high-power triodes with a.c. filament heating for the modulation amplifier, and Hg-vapour rectifiers which are liquid-cathode tetrodes. Performance figures are given.

621.396.619.23 **3589**

Bases of Application and Calculation of Frequency-Modulation Pulse Trains.—D. Bünemann & H. Pethke. (*Fernmeldetech. Z.*, May 1952, Vol. 5, No. 5, pp. 226–231.) The principles and operation of the serrasoid modulator [342 of 1949 (Day)], and of a pulse-counting discriminator system being developed for f.m. monitoring, are described. A formula is derived for direct calculation of the l.f. and h.f. spectra of a series of f.m. pulses. See also 3267 of November (Gundlach).

621.396.645.371 : 621.396.61 : 621.396.712 **3590**

C.F.T.H. Applications of Negative Feedback.—A. Warnier. (*Rev. tech. Comp. franç. Thomson-Houston*, July 1952, No. 17, pp. 53–60.) Brief discussion of the use of negative feedback for reducing distortion and background noise, and description of a two-path negative-feedback system which has been applied in broadcasting transmitters with excellent results.

VALVES AND THERMIONICS

537.525.92 **3591**

Some Considerations on the Space-Charge Equation.—M. Matsudaira, M. Wada & T. Koda. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, March 1952, Vol. 3, No. 2, pp. 215–231.) The limit of application of the three-halves power law is considered and a solution of the space-charge equation is obtained which expresses the characteristics of a valve with an oxide cathode and close electrode spacing.

621.314.632 : 621.396.822 **3592**

The Theory of Noise in the Crystal Rectifier.—Y. Watanabe & N. Honda. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser.B*, Sept. 1951, Vol. 3, No. 1, pp. 39–46.) The noise-producing effect of impurities in Si and Ge rectifiers is considered. Fluctuations in the concentration of surface-state electrons affect the height of the potential barrier and produce noise. Calculations based on Richardson's diffusion model (1391 of 1950) give results in good agreement with those obtained experimentally by Miller (2567 of 1947). See also 870 of March.

621.383.2 : 621.396.822 **3593**

Measurement of Fluctuations in a Photomultiplier.—F. Lenouvel. (*C. R. Acad. Sci., Paris*, 30th June 1952, Vol. 234, No. 27, pp. 2594–2596.) The output current of a 19-stage multiplier is measured directly by means of a galvanometer. An optical system comprising lamp, galvanometer mirror and photocell detector in conjunction with appropriately masked lenses is used to record either the mean value of the multiplier output current or the mean square of the fluctuations. Results are tabulated together with values calculated from theory.

621.383.27 **3594**

Photoelectric Characteristic in the Ultraviolet down to 1 500 Å of an Electron Multiplier using a Copper/Beryllium Alloy.—V. Schwetzoff, S. Robin & B. Vodar. (*J. Phys. Radium*, June 1952, Vol. 13, No. 6, pp. 369–370.) Measurements on a 12-stage multiplier sealed into a pyrex tube with a quartz window are reported. The photoelectric threshold is at about 4 eV (3 000 Å), and the photoelectric efficiency is 6 to 8 times less than that of Ag-O-Cs electrodes over the range 1 608–2 000 Å. The advantage of this alloy is its stability on exposure to the atmosphere.

621.383.4 : 546.817.221 **3595**

Impedance Measurements on PbS Photoconductive Cells.—E. S. Rittner & F. Grace. (*Phys. Rev.*, 15th June 1952, Vol. 86, No. 6, pp. 955–958.) Analysis of existing and new impedance measurements indicates that the observed decrease in parallel resistance with frequency is attributable to a known effect of distributed capacitance.

621.383.4 : 546.817.221 **3596**

Industrial Applications of Semiconductors: Part 4—Lead Sulphide Photocells.—C. J. Milner & B. N. Watts. (*Research, Lond.*, June 1952, Vol. 5, No. 6, pp. 267–273.) Discussion of the mechanism of photoconductivity, the production and properties of PbS photocells, and their various applications.

621.385.029.6 : 621.396.822 **3597**

Calculation of the Noise Figure of the Travelling-Wave Valve: Part 2.—W. Kleen. (*Arch. elekt. Übertragung*, July 1952, Vol. 6, No. 7, pp. 299–303.) Methods of investigation similar to those described in part 1 (3276 of November) are applied to valves in which the electron beam is subjected to potential jumps at points between field-free sections. With suitable choice of the lengths of these sections, an improvement of the noise figure can be obtained compared with that for the beam system considered in part 1. The effect of various parameters on the noise figure of the travelling-wave valve with helical delay line and different beam-generator systems is discussed.

621.385.029.64 : 168.2 **3598**

A Symbolism for Microwave-Valve Classification.—G. M. Clarke. (*Proc. Instn elect. Engrs*, Part IV, April 1952, Vol. 99, No. 2, pp. 24–28.) Full paper. See 2658 of September.

621.385.032.216 **3599**

Characteristic Shifts in Oxide-Cathode Tubes.—W. P. Bartley & J. E. White. (*Elect. Engng, N.Y.*, June 1952, Vol. 71, No. 6, p. 496.) Summary of A.I.E.E. Winter General Meeting paper, January 1952. Investigations have shown that an oxide-cathode valve operating in the space-charge-limited condition may have its transconductance changed with time as a result of change of one or more of the following factors: interface impedance, contact p.d., coating resistance, and peak emission. In the Type-6SN7GT valves studied, the only significant effects over a considerable period were resistive and contact-p.d. shifts, the most important component of resistance, in active base-metal cathodes, being the interface compound between the oxide coating and the base metal. Such interface resistances did not develop in passive-cathode valves in 3 000 hours under normal operating conditions, but the resistance of the coating itself changed enough to affect the transconductance.

621.385.032.216 **3600**

Thermionic Emitters under Pulsed Operation.—R. Loosjes, H. J. Vink & C. G. J. Jansen. (*Philips tech. Rev.*, June 1952, Vol. 13, No. 12, pp. 337–345.) See 2380 of August (Loosjes & Jansen) and back references.

621.385.032.216.2 : 539.16 **3601**

The Use of Radioactive Isotopes in a Study of Evaporation from Thermionic Cathodes.—W. F. Leverton & W. G. Shepherd. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 787–793.) Radioactive Ba$_{140}$, Sr$_{89}$ and Ca$_{45}$ were incorporated in the coatings of mixed-carbonate cathodes on Ni bases. The cathodes were mounted in diodes having a removable electrode between cathode and anode to permit separate measurement of material evaporated during processing and during operation. The rates of transfer found for all three elements can be expressed as a function of absolute temperature by a single formula with appropriate constants. The effect on the rate of transfer of bombarding the anode by electrons was investigated.

621.385.15 **3602**

Research on Electron Multiplication and its Applications: Part 2.—D. Charles. (*Ann. Radioélect.*, April 1952, Vol. 7, No. 28, pp. 115–138.) The construction of a simple form of cylindrical-diode multiplier and techniques for forming secondary-emission layers of Cs, K and Ba are described. Emission characteristics of different layers at various voltages and frequencies are shown graphically. Theory developed is supported by experimental results. Part 1: 2368 of August.

621.385.15 **3603**

Secondary-Emission Valves.—M. Hirashima. (*Wireless Engr*, Sept. 1952, Vol. 29, No. 348, pp. 246–252.) The response of valves using MgO-coated secondary emitters is investigated. Potentials of 10–100 V are built up on the surface of these emitters; as a result, single pulses or pulses at low repetition rate are distorted much more than pulses at a high repetition rate. The general trend of the waveform distortion is illustrated graphically by means of semiquantitative analysis of the experimental data obtained by Kawamura (*Proc. phys. math. Soc. Japan*, 1942, Vol. 24, p. 211).

621.385.2 : 546.289 : 538.63 **3604**

Germanium Phenomenon.—A. B. Kaufman. (*Radio & Televis. News, Radio-Electronic Engng Section*, July 1952, Vol. 48, No. 1, pp. 10, 29.) Experiments indicate that the forward resistance of a Ge diode increases appreciably when the diode is subjected to a strong magnetic field; an increase of about 0·5% was noted for a field strength of 2 800 gauss. Si diodes did not show this effect.

621.385.2.011.21 **3605**

The Admittance of a Diode with a Retarding Field.—J. J. Freeman. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 743–745.) The contribution of space charge to the diode admittance is found by evaluating the current induced in an external circuit. The susceptance is capacitive at low frequencies and inductive at high frequencies. The expression for the conductance is the same as that derived by Begovich (2959 of 1949).

621.385.2/.3 : 621.396.615.141.2 **3606**

Magnetron Effect in High-Power Valves.—A. M. Hardie. (*Wireless Engr*, Sept. 1952, Vol. 29, No. 348, pp. 232–245.) The resultant magnetic field in the neighbourhood of a squirrel-cage filament structure is calculated and the results are used to investigate theoretically the magnetron effect in valves with this type of filament. The theoretical treatment is restricted to the condition when anode and grid are strapped, since the problem becomes intractable for the case of a triode with anode and grid at different potentials. Experiments on two diode-connected valves gave results supporting the approximate theory. A valve with normal triode connections was also investigated experimentally, using a pulse method; a qualitative explanation is given of the observed results.

621.385.3 **3607**

The Amplification Factor of a Triode: Part 2—A Cylindrical Triode having a Cage Grid with Arbitrary Electrode Dimensions.—M. Wada. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser.B*, Sept. 1951, Vol. 3, No. 1, pp. 19–38.) The analysis developed in part 1 (552 of February) for u.h.f. planar triodes is extended to cover cylindrical arrangements of the type described by Rose et al. (501 of 1950). Results are compared with formulae derived by other workers.

621.385.3 : 621.318.572 **3608**

The Initial Conduction Interval in High Speed Thyratrons.—J. B. Woodford, Jr, & E. M. Williams. (*J. appl. Phys.*, July 1952, Vol. 23, No. 7, pp. 722–724.)

621.385.3.012 **3609**

Calculations of Families of Characteristics for a Planar Triode with Negatively Biased Control Grid of Parallel Round Wires of Finite Thickness and Spacing.—W. Dahlke. (*Telefunken Ztg*, June 1952, Vol. 25, No. 95, pp. 83–92.) The known distribution function for the cathode-current density of a planar triode is applied to the evaluation of various valve parameters as dependent on operating voltages and physical dimensions. Results are shown graphically.

621.385.3.026.445 **3610**

A Coaxial Power Triode for 50-kW Output up to 110 Mc/s.—R. H. Rhéaume. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1033–1037.) Description of the construction and special features of the Type-ML5681 valve, which has a thoriated cathode, a re-entrant anode with integral water-cooling jacket, and coaxial ring-seal terminals. The bandwidth is suitable for television broadcasting.

621.385.4 **3611**

Study on the Characteristics of a Beam Power Output Tube: Part 1—The Volt/Ampere Characteristics.—M. Wada. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser.B*, March 1952, Vol. 3, No. 2, pp. 135–150.) Analysis for the case of plane parallel electrodes. The formulae derived give results in good agreement with measurements on Type-807 valves.

621.385.4 **3612**

Effect of Electron Transit-Time on the Efficiency of Transmitting Tetrodes.—H. Rothe & E. Gundert. (*Telefunken Ztg*, June 1952, Vol. 25, No. 95, pp. 75–82.) The h.f. output of both triodes and tetrodes decreases with increasing frequency. This decrease is partly due to the finite transit time of the electrons between cathode and control grid, and between control grid and anode in triodes or between screen grid and anode in tetrodes. A quantitative analysis of transit-time effects in the space adjacent to the anode is presented and their contribution to power decrease is discussed. Under different operating conditions the calculated efficiency of tetrodes decreases almost linearly to about zero for a screen-grid/anode transit-time angle of 360°, but in practice the zero value is reached for much smaller angles, about 52° for Type-RS682 valves and about 60° for Type-4X150A valves. Effects of large and of small signal amplitudes on the efficiency are discussed.

621.385.832 **3613**

Ion Burn in Cathode-Ray Tubes: Metallized Screens and Ion Traps.—R. Roulaud. (*Rev. gén. Élect.*, June 1952, Vol. 61, No. 6, pp. 263–270.) The causes of ion burn are discussed and various methods adopted for eliminating this troublesome effect are described.

621.385.832 : 621.318.572 **3614**

A Decade Counter Valve for High Counting Rates.—J. L. H. Jonker, A. J. W. M. van Overbeek & P. H. de Beurs. (*Philips Res. Rep.*, April 1952, Vol. 7, No. 2, pp. 81–111.) A valve is described of the type having a ribbon beam deflected in one dimension to pass through a slotted screen over a target, ten discrete fixed positions of the beam being provided by means of feedback from the target to the deflection electrode. In each fixed position a part of the beam impinges on a fluorescent region of the wall, giving a visible numerical indication of its position. The beam is moved on by application of pulses to the deflection electrode. A detailed analysis is made of the flyback process. Time intervals $<0\cdot2\ \mu s$ can be resolved by use of appropriate valves in circuit with the counter valve.

621.396.615.14 **3615**

Properties of Lines with Periodic Structure.—P. Guénard, O. Doehler & R. Warnecke. (*C. R. Acad. Sci., Paris*, 7th July 1952, Vol. 235, No. 1, pp. 32–34.) The frequency dependence of the wave-transmission properties is studied. The expression for the field is written in a form corresponding to the superposition of progressive waves whose phase velocities form a series; these waves are designated as forward or backward according as the phase velocity has or has not the same sense as the energy velocity. For investigating the interaction between the wave field and an electron beam, it is convenient to consider the variation of the 'retardation factor' (ratio of free-space velocity to phase velocity along line) with wavelength; this function is plotted and discussed in relation to the dispersion of the forward and backward waves.

621.396.615.14 **3616**

New U.H.F. Oscillator Valves with Wide Electronic Tuning Band.—P. Guénard, O. Doehler, B. Epsztein &

R. Warnecke. (*C. R. Acad. Sci., Paris*, 21st July 1952, Vol. 235, No. 3, pp. 236–238.) An account of the basic principles of valves depending on the interaction between an electron beam and a transmission line consisting of elements with periodic spatial distribution (3615 above). When the beam velocity is equal to the phase velocity of a forward wave along the line, additive effects are obtained in the direction of the beam and the arrangement can be used as an amplifier. When, however, the beam velocity is equal to the phase velocity of a backward wave, the additive effect is obtained in the backward direction and the amplitude of the field transported by the line increases towards the origin of the beam, so that oscillations can be produced, the frequency being dependent on the velocity of the beam and the dispersion curve of the line.

621.396.615.14 **3617**

Reflex Resnatron shows Promise for U.H.F. TV.—G. E. Sheppard, M. Garbuny & J. R. Hansen. (*Electronics*, Sept. 1952, Vol. 25, No. 9, pp. 116–119.) In the reflex resnatron the negative repeller electrode reflects the electron beam back through the output cavity to the accelerator electrode. Wide-band modulation is effected with low power by varying the repeller voltage. Some details are given of the construction of an experimental valve capable of an output of 2·5 kW at 560 Mc/s, with a bandwidth of 8 Mc/s, power gain of $\sim$ 5, and overall efficiency of 38%, the repeller voltage being 6·5 kV negative with respect to the accelerator voltage of 8 kV.

621.396.615.14 **3618**

Some Limitations on the Maximum Frequency of Coherent Oscillations.—R. S. Elliott. (*J. appl. Phys.*, Aug. 1952, Vol. 23, No. 8, pp. 812–818.) Electron-beam oscillator valves are classified in two groups depending on whether or not they use resonant energy extractors; for those which do, it is proved that a natural upper frequency limit exists. The limit is determined chiefly by the a.c. beam current density and the noise level in the resonant structure. For practical values of these parameters the limit is below the frequency of light.

621.396.615.141.2 **3619**

Study of the Magnetron in the Cut-Off Condition: Part 1.—P. Fechner. (*Ann. Radioélect.*, April 1952, Vol. 7, No. 28, pp. 83–105.) Various theories of space charge are discussed. The static distribution of the charge density is then calculated. In the case of electrons emitted with velocities obeying a statistical law, the electron density has a maximum value at a certain distance from the cathode, this distance depending on the anode voltage. The space charge takes the form of an extremely thin ring of very high density rotating round the cathode and including almost all the electrons circulating in the interelectrode space. An electron in the ring is in stable equilibrium and can oscillate with large amplitude if a resonance condition is established. Conditions of resonance in a multicavity magnetron are to be considered in part 2. See also 2678, 2680 and 2946 of 1950.

621.396.615.141.2 **3620**

The Magnetron in the Static Cut-Off State. Experimental Study.—J. L. Delcroix. (*C. R. Acad. Sci., Paris*, 9th June 1952, Vol. 234, No. 24, pp. 2347–2349.) Investigations were carried out on carefully constructed magnetrons for which the ratio of anode to cathode diameter ranged from 1·25 to 7·5. Langmuir's law and the law governing the cut-off voltage (V_{co}) were verified for each valve. Magnetic fields (H) of 50–150 gauss and anode voltages (V) of 50–500 V were used. A residual current was observed in the cut-off region; it is probably due to spontaneous space-charge oscillations and is of an order of magnitude 1 000 times smaller than the thermionic currents which produce the space charge. It affords a means for studying the steady state and exhibits discontinuities for certain values of the applied voltage, the positions of the discontinuities only depending on the parameter m ($= V/V_{co}$) when H is varied. The residual current intensity depends on both H and m and increases with H when m is constant. The discontinuities fall into two classes, one class corresponding to transitions with small hysteresis of the order of 1–5 V, the other to transitions exhibiting very much greater hysteresis effects. Three distinct states have been distinguished, these being the Brillouin state and the first two 'bidromic' states. See also 3185 of 1951.

621.396.615.141.2 **3621**

Inverted Magnetron.—J. F. Hull. (*Proc. Inst. Radio Engrs*, Sept. 1952, Vol. 40, No. 9, pp. 1038–1041.) Description of the construction and performance of a new type of magnetron in which the positions of the cathode and the segmented anode are the reverse of those in a normal magnetron. Tests on experimental valves show that overall efficiencies of 25–55% can be achieved. Since a relatively low anode voltage and high anode current are required, it may be possible to operate such valves from a gas-filled modulator valve without a pulse transformer.

MISCELLANEOUS

001.891/.892 : 621.39 **3622**

Army Communications.—(*Wireless World*, Sept. 1952, Vol. 58, No. 9, pp. 353–354.) General account of the work of the Signals Research and Development Establishment at Highcliffe, near Christchurch.

621.38 : 061.4 **3623**

Electronic Instruments and Equipment. Exhibition in Manchester.—C. A. Taylor. (*Nature, Lond.*, 6th Sept. 1952, Vol. 170, No. 4323, pp. 407–408.) Short descriptions of some of the exhibits at the seventh annual exhibition of the North-Western Branch of the Institution of Electronics, July 1952.

ABSTRACTS AND REFERENCES INDEX

The Index to the Abstracts and References published throughout 1952 is in course of preparation and will, it is hoped, be available in February, price 3s. 9d. (including postage). As supplies are limited our Publishers ask us to stress the need for early application for copies. Included with the Index is a selected list of journals scanned for abstracting, with publishers' addresses.

INDEX

Vol. 29 **Wireless Engineer** 1952

INDEX TO AUTHORS

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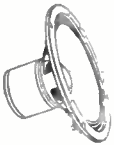

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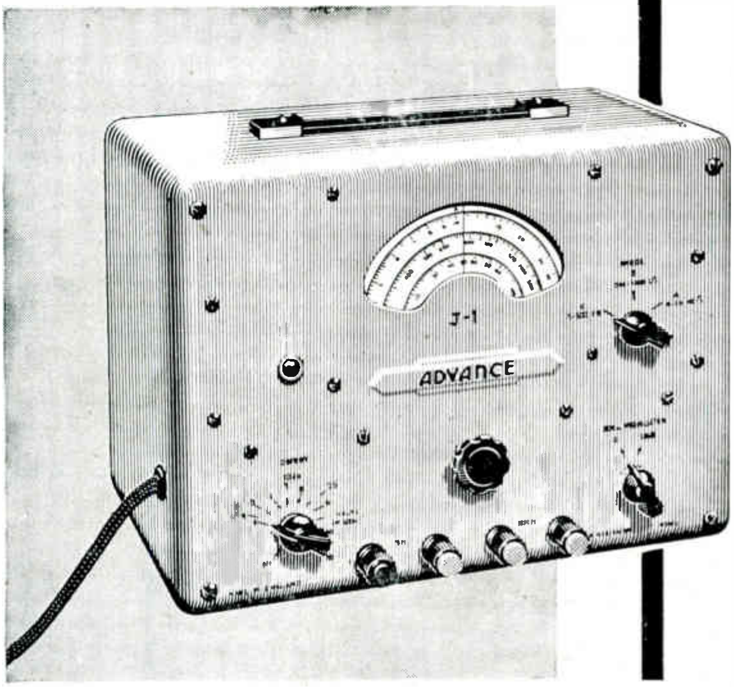

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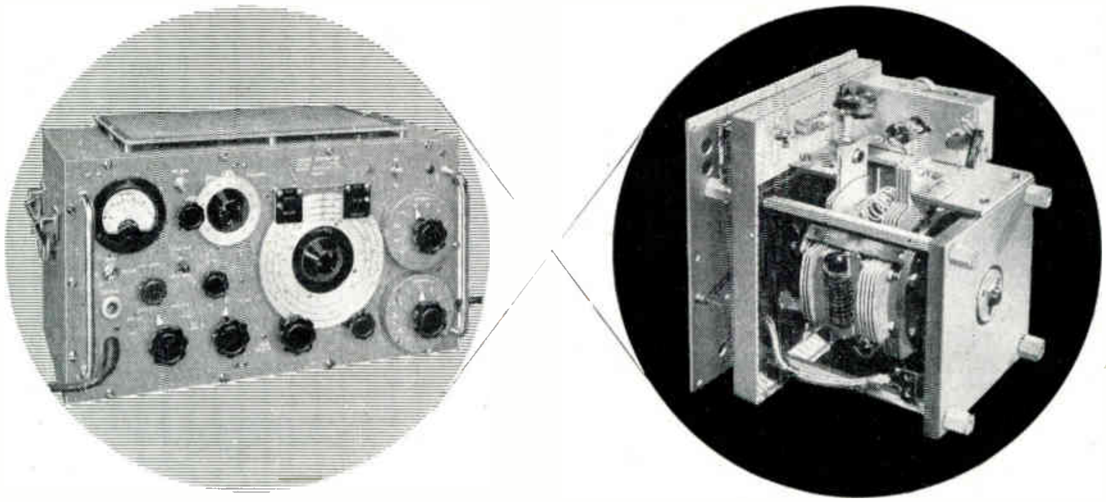

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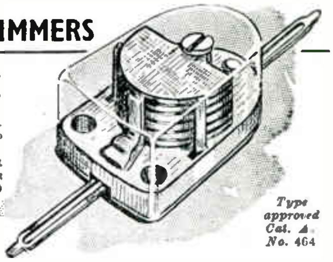

APPOINTMENTS—The engagement of persons answering these advertisements must be made through the local office of the Ministry of Labour and National Service, etc., if the applicant is a man aged 18-64 or a woman 18-59 inclusive, unless he or she or the employer is excepted from the provisions of The Notification of Vacancies Order, 1952.

Vacancies exist at the Stanmore Laboratories of The General Electric Company, Limited, as under. Applicants should write to the Staff Manager, The Grove, Stanmore Common, Stanmore, Middlesex, quoting the reference against the vacancy and stating age, qualifications and experience.

i. Graduate Mechanical Engineer is required for work on light engineering mechanisms of a reciprocating type. Three to five years' experience or more is required. (Ref. SS/WW.1).

ii. Engineer with Higher National Certificate in Mechanical Engineering is required with practical experience of small mechanisms. (Ref. SS/WW.2).

iii. Senior engineer or physicist with Honours degree is required for design of system test equipment required in connection with airborne radar. Previous experience in the field is essential. Applicants should be between 30 and 35 years of age. (Ref. SS/RA.1).

iv. Senior assistant is required for flight trials and assessment of airborne radar equipment. Experience of radar and similar work in the laboratory and in the air under operational conditions is essential. Candidates must be prepared to travel and work away from the Laboratories. (Ref. SS/LK.1)

v. Physicists and engineers with Higher National Certificate or degree are required for electronic circuitry and servo mechanisms and smaller electro mechanical devices. (Ref. SS/JM.1).

vi. Physicists and engineers are required for the microwave field to work on aerials and components. (Rev. SS/AH.1).

vii. Physicists and engineers with degrees and Higher National Certificates are required for a field trials team and for assessment work in connection with the trials. Candidates must be prepared to travel and work away from the Laboratories. (Ref. SS/JP.1).

viii. Engineers and physicists with Higher National Certificate are required for the design of small quantities of transformers for experimental apparatus. (Ref. SS/NB.2).

ix. Engineers and physicists with experience on magnetic amplifiers or small power electric motors are also required. (Ref. SS/NB.3).

x. There is a vacancy for an engineer or physicist for work on transistors and cold cathode valve circuitry. (Ref. SS/NB.4).

xi. Senior physicist or engineer is required for vibration test laboratory and to lead a small team engaged in the development of test techniques, vibration equipment and vibration instrumentation. (Ref. SS/CL.1).

xii. Senior physicist or engineer is required for a team engaged on the development and application of experimental stress analysis as an aid to the design of mechanisms. The work covers the fields of resistance strain gauge techniques, brittle lacquers and photo elasticity. (Ref. SS/CL.2).

xiii. A metrologist is required for work involving advice on workshop inspection techniques and undertaking accurate measurements required in the Establishment. (Ref. SS/CL.3).

E. K. COLE, LTD. (Malmesbury Division), invite applications from Electronic Engineers for permanent posts in Development Laboratories engaged on long-term projects involving the following techniques:—

1. Pulse Generation and Transmission.
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6. Electronics as applied to Atomic Physics.

There are vacancies in the Senior Engineer, Engineers and Junior Grades. Candidates should have had at least 3 years' industrial experience in the above types of work, together with educational qualifications equivalent to A.M.I.E.E. examination standard. Commencing salary and status will be commensurate with qualifications and experience. Excellent opportunities for advancement are offered with entry into a Pension Scheme after a period of service. Forms of application may be obtained from Personnel Manager, EKCO Works, Malmesbury, Wilts.

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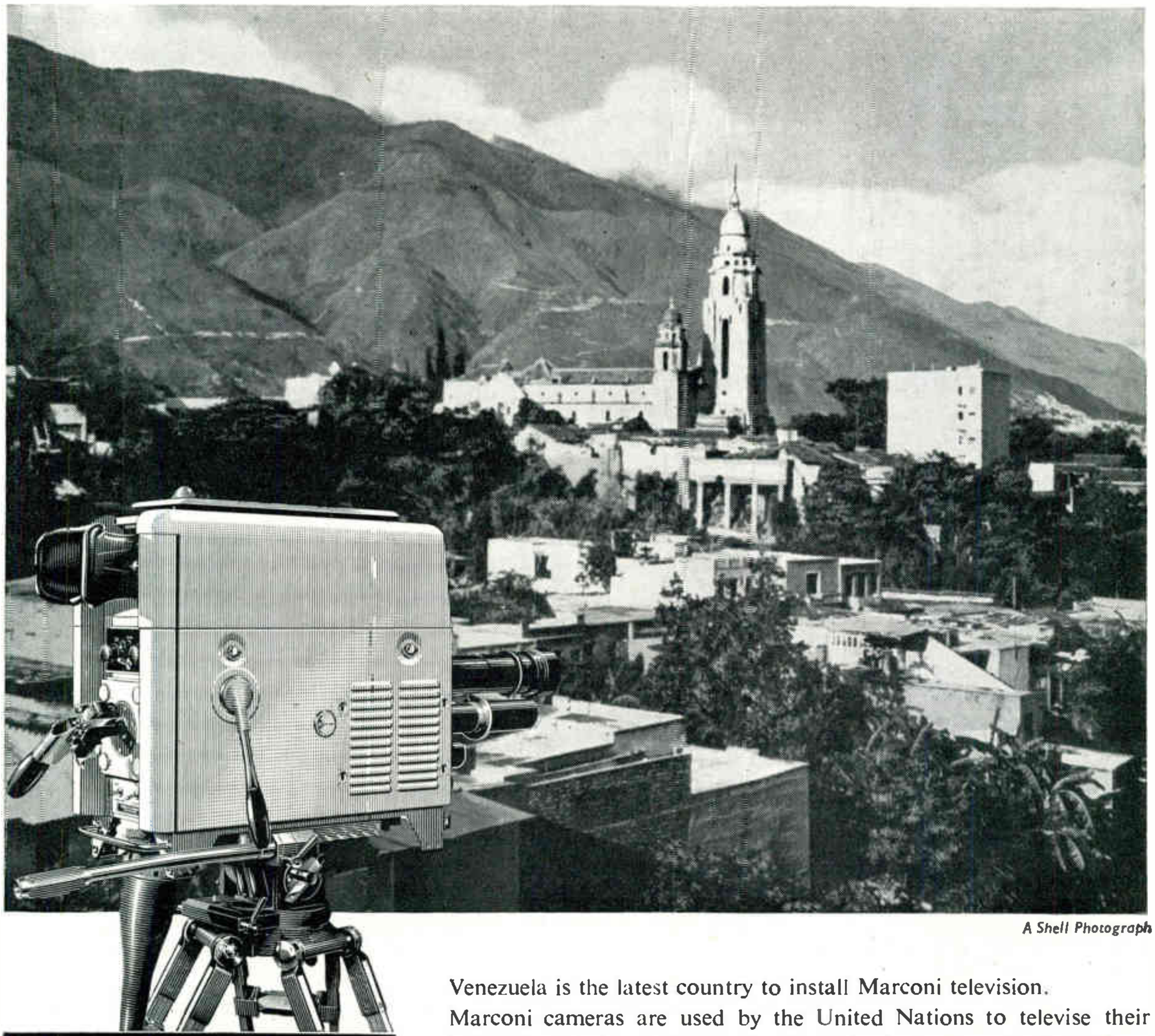
Wireless Station Superintendent (Temporary) required by the Gold Coast Government Posts and Telegraphs Department for two tours of 18 to 24 months in the first instance. Commencing salary, according to qualifications and experience in the consolidated scale £955 rising to £1,180 a year, with gratuity of £25 or £37 10s. 0d. according to salary, for each completed period of three months' service. Outfit allowance £60. Liberal leave on full salary. Free passages. Candidates must possess a Higher National Certificate in Electrical Engineering or equivalent, and have had practical experience in two or more of the following fields:—V.H.F. link systems, H.F. communication network; Frequency shift keying and teleprinter maintenance; V.H.F. and H.F. Direction finding systems; Aeronautical navigation aids (ground); Manufacture of light engineering equipment. Apply at once by letter, stating age, full names in block letters, and full particulars of qualifications and experience and mentioning this paper to the Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting on letter M.29100.B. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration.

THE CROWN AGENTS FOR THE COLONIES

Wireless Operator Mechanic required for the Falkland Islands Dependencies Survey for one tour of 18 or 30 months in the first instance. Salary according to qualifications and age in scale £250 rising to £415 a year. Duty allowance £40 a year. Quarters, subsistence, clothing and liberal routine canteen stores are provided free of charge while serving in Dependencies; it is possible for officers to save almost all emoluments. Liberal leave on full salary. Candidates must be able to transmit and receive Morse at 25 words a minute (plain language or code) and be capable of elementary maintenance of wireless transmitting and receiving equipment. Apply at once by letter, stating age, full names in block letters, and full particulars of qualifications and experience and mentioning this paper to the Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting on letter M.29387.B. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration.



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Senior Electronic Development Engineer required to take charge of Engineering associated with Guided Weapons and like projects.

Electronic Development Engineers also required for the same projects.

Reply stating age, qualifications and experience to Staff Manager (Ref. R.G.), G.E.C., Stanmore Laboratories, The Grove, Stanmore Common, Middlesex.

Senior Mechanical Design Draughtsmen required with experience of electronic layouts for work on Guided Weapons and like projects. Reply stating age, qualifications and experience to Staff Manager (Ref. R.G.), G.E.C., Stanmore Laboratories, The Grove, Stanmore Common, Stanmore, Middlesex.

The Research Laboratories of the General Electric Company, Ltd., propose to set up an organisation near Adelaide, South Australia, for trials and further development of guided weapon equipment which is at present under development in this country.

Applications are invited from men with qualifications suitable to fill the following vacancies:—

(*a*) An engineer to take charge of trials teams.

(*b*) An engineer or physicist to take charge of a laboratory engaged on the development and use of special test equipment.

(*c*) A physicist or mathematician to take charge of a small group on the analysis and assessment of trials results.

Candidates should have an honours degree or equivalent qualification. For post (*a*) and (*b*) they should have had experience of modern radar or similar equipment and of supervising the work of a small number of experimental staff. For post (*c*) experience or interest in statistics or the interpretation of experimental results is desirable together with ability to write clear concise reports and supervise the work of a small number of assistants.

The successful applicants will commence employment in this country on the work they will ultimately be doing in Australia, and will be transferred to that country in due course.

Details of conditions of employment, housing, passages to Australia, etc., will be given to candidates who are selected for interview.

Reply quoting reference KTH/AUST. to the Staff Manager, G.E.C. Stanmore Laboratories, The Grove, Stanmore Common, Stanmore, Middlesex, stating age, qualifications and experience.

The English Electric Valve Co., Ltd., Chelmsford, Essex, has several attractive vacancies, junior and senior, for Physics and Engineering Graduates to undertake research and development work on vacuum tubes. Applications from graduates who have recently qualified as well as those with industrial and research experience will be considered. Please write, giving full details and quoting ref. 419F to Central Personnel Services, English Electric Co., Ltd., 336 Strand, W.C.2.

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Senior physicist or engineer, with wide experience of radio communications and radar, is required to direct a research team in these fields at the Stanmore Laboratories of The General Electric Company, Limited. Familiarity with centimetric techniques, circuitry and propagation is essential together with a real knowledge of the fundamental aspects of such work. This is an appointment for a first-class research man and carries an attractive salary commensurate with experience. Applications should be sent to the Staff Manager (Ref. SS/NB.1), The Grove, Stanmore Common, Stanmore, Middlesex, giving full details of age, qualifications and experience.

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1. Radio and Television Development Engineers, able to work with minimum of supervision and carry through a project up to production stage.
2. Draughtsmen, both senior and junior, experience of Radio and Television preferable, but not essential.

Write giving full details to Radio Gramophone Development Co., Ltd., 3 Hampton Court Parade, East Molesey.

World Radio History

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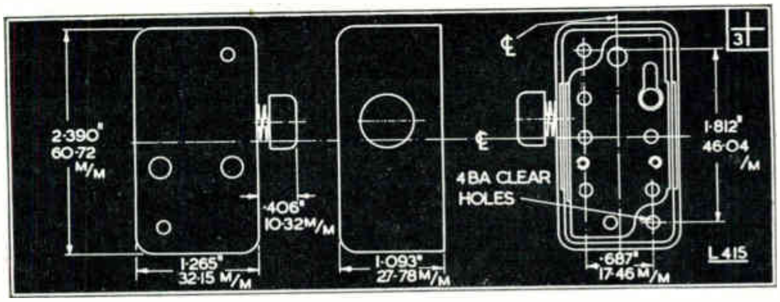

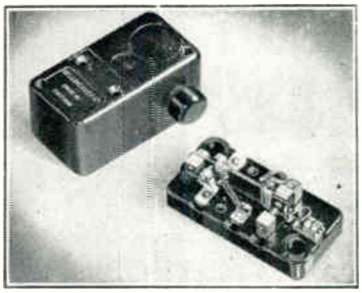

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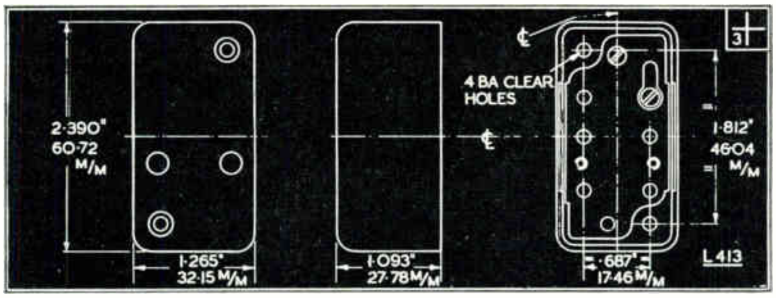

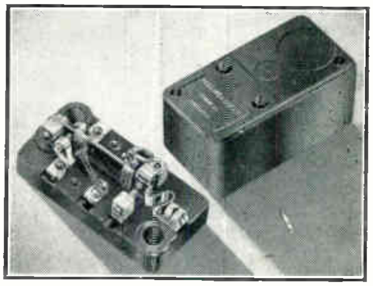

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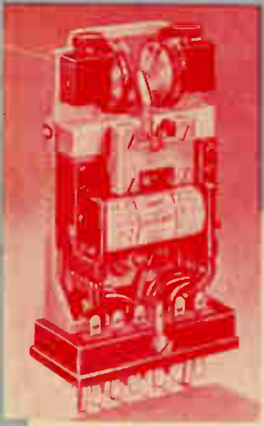

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